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## 3 Climate variability and drought

### Key points

- Droughts are a recurrent and frequent feature of Australia's climate.
  - Severe droughts bring sharp reductions in agricultural output and farm incomes.
  - Drought tends to exacerbate social problems.
- There have been three particularly severe and prolonged dry periods in Australia since 1900, including the period 2002 to 2007 (through to 2008 in some regions).
- Although the period 2002 to 2007 is regarded by many as one long drought, it includes three of the four highest ever years for Australia's overall agricultural output.
- Expert projections for Australia's climate make it clear that farmers and other Australians should be prepared for a hotter future. The outlook for rainfall is for continued variability, and for some regions, more frequent periods of extremely low rainfall. There is, however, large uncertainty surrounding the rainfall projections.
- Inflows to the Murray-Darling Basin in recent years have been the lowest on record, contributing to dramatic declines in annual allocations to irrigators.
  - In future there is likely to be substantially less water available for irrigation and its supply may become more variable. The consequences for irrigators, however, depend not only on the climate but, to a large extent, on water policy.

### 3.1 Drought and climate variability in Australia

This chapter discusses Australia's experience of climate variability and drought from meteorological, economic, social and environmental perspectives. In doing so it draws on the reports by the Bureau of Meteorology–CSIRO and the Expert Social Panel that form part of the review of drought policy.

#### Australia's climate

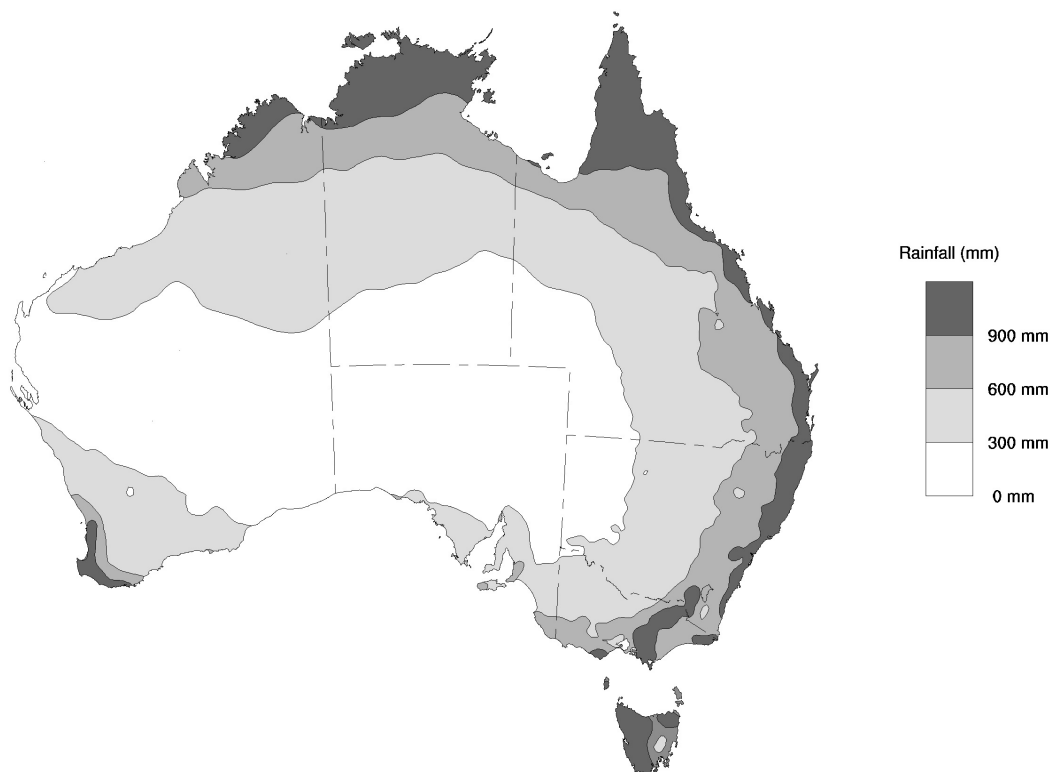
Average annual rainfall is relatively high along the eastern coastal fringe (from northern Queensland to Victoria and western Tasmania), parts of northern Australia and a small part of the southwest of Western Australia. Large areas of Australia's

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interior have an average annual rainfall of less than 300 mm (figure 3.1). There is a general gradient from warmer conditions in the tropical north to cooler conditions in the south, although topography also influences temperature.

**Figure 3.1 Average annual rainfall<sup>a</sup>**

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<sup>a</sup> Averaged over the period 1900 to 2007.

Source: BoM (2008 unpublished).

There is some degree of seasonality of rainfall almost everywhere in Australia (Lindesay 2005). There is a bias towards summer rainfall in northern Australia. This is most extreme in tropical areas that experience monsoonal rain. There is generally a winter bias in rainfall for more southerly latitudes.

Climate, including rainfall, varies from year to year. Indeed, Australia has one of the most variable climates in the world (Hennessy et al. 2008). Various factors, such as the El Niño–Southern Oscillation (ENSO) and the Indian Ocean Dipole, drive this variability on a range of timescales. These relate to interannual fluctuations in the ocean–atmosphere system. For example, during the El Niño extreme of ENSO, tropical convection and moist easterly onshore airflow diminishes over Australia, and parts of eastern Australia become generally sunnier, drier and warmer. El Niño events recur on average every three to six years, but this varies. The other extreme, La Niña, typically brings wetter than average conditions in eastern Australia.

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## Defining drought

Drought is a part of Australia's climate variability. Drawing on international meteorological literature, Hennessy et al. (2008) refer to four types of drought.

- *Meteorological drought*: a period of months to years when atmospheric conditions result in low rainfall. This can be exacerbated by high temperatures and high evaporation, low humidity and desiccating winds.
- *Agricultural drought*: short-term dryness in the surface soil layers (root-zone) at a critical time in the growing season. The start and end may lag that of a meteorological drought, depending on the preceding soil moisture status.
- *Hydrological drought*: prolonged moisture deficits that affect surface or subsurface water supply, thereby reducing streamflow, groundwater, dam and lake levels. This may persist long after a meteorological drought has ended.
- *Socioeconomic drought*: the effect of elements of the above droughts on supply and demand of economic goods and human wellbeing.

Meteorological drought and agricultural drought are of primary importance to dryland agriculture. Hydrological drought is of particular relevance to irrigated agriculture. In relation to 'socioeconomic drought', it should be understood that neighbouring wheat farms that receive the same low rainfall have experienced the same severity of drought, even if the socioeconomic effects of this are much more pronounced on one farm than the other due to factors such as relative management skills or capital bases. As argued by the Australian Land Management Group, there is a need to 'distinguish between cause (a meteorological event) and effect (stress of various forms)' (sub. 24, p. 3).

For simplicity, this report uses the term 'drought' to refer to the first three types above. When hydrological drought is being specifically discussed, reference is made to its:

- primary cause — low inflows to water bodies
- main consequence for agriculture — low water allocations to irrigators.

## History of major droughts

Droughts are a natural, recurrent and frequent feature of Australia's climate. Droughts vary in their intensity, duration, geographic extent and proximity to the preceding drought. Box 3.1 briefly describes the major periods of drought since the mid 1800s.

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**Box 3.1 Major periods of drought and their effects**

1864-66	All states affected except Tasmania.
1880-86	Southern and eastern states affected.
1895-1903	The Federation Drought. Several years of generally below-average rainfall were followed immediately by one or two years of exceptionally low rainfall. Sheep numbers halved and more than 40 per cent of cattle were lost. Most devastating drought in terms of stock losses.
1911-16	Loss of 19 million sheep and 2 million cattle. The national wheat crop failed completely in 1914.
1918-20	Only parts of Western Australia free from drought.
1939-45	The Forties Drought. Loss of nearly 30 million sheep between 1942 and 1945. 1940 was one of the driest years on record across southern Australia.
1963-68	Widespread drought, the last two years of which saw a 40 per cent drop in wheat harvest, a loss of 20 million sheep, and a decrease in farm income of \$300-500 million.
1972-73	Mainly in eastern Australia.
1982-83	One of the most intense and widespread droughts on record. Total loss estimated in excess of \$3 billion.
1991-95	Particularly dry in parts of Queensland, northern New South Wales and parts of central Australia. Average production by rural industries fell about 10 per cent, resulting in possible \$5 billion cost to the Australian economy. There was particularly low rainfall across large parts of Australia in 1994.
2002-07	Winter crop production declined sharply in 2002-03 and, after recovering, declined again in 2006-07. Inflows to the Murray-Darling Basin were the lowest on record, severely impacting irrigated agriculture.

*Sources:* BoM (nd); Lindesay (2005).

Many participants regard the period from 2002 to at least 2007 as being one long drought (Macquarie River Food and Fibre, sub. 36; Queensland Farmers' Federation, sub. 82; NSW Farmers' Association, sub. 98). The National Farmers' Federation stated:

The last seven years have been a challenging period for Australian farmers with widespread and prolonged drought leading to a severe reduction in farm production ... (sub. DR176, p. 17)

The final section of this chapter places this recent period in the context of the historic record and likely future climate.

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## 3.2 Effects on agricultural systems

Drought is but one of the climatic risks farmers face. Too much rain, very heavy rain, or rain at the wrong time of year, can damage crops and hamper harvesting. Floods can kill livestock and cause damage to farm infrastructure. Frosts, hail and extreme winds can also affect farm production and income.

Drought, however, differs from these other climate risks in at least two important ways. First, drought can affect a much greater proportion of farms at any one time. Second, drought usually has a slow onset, can last for several years, and its end can be highly uncertain. Other climate risks are usually discrete events.

The effects of drought on different types of agricultural systems are outlined below. These effects can be reduced or ameliorated through farm management practices, as discussed later.

### *Broadacre grazing*

Drought generally reduces pasture growth, which translates to lower meat or wool production. In addition, the carrying capacity of the land decreases and so either some livestock must be sold, feed bought in, or animals agisted where feed is available. If livestock are sold early due to drought, the farmer's income will be reduced and brought forward. Providing supplementary feed drives up costs, and so reduces farm profit, but can assist in retaining core breeding stock. Drought can also make it more difficult and expensive to provide water for livestock.

### *Dryland cropping*

Dryland cropping yields are highly dependent on the quantity and timing of rain prior to and during the growing season. Much of Australia's cropping is on land that receives insufficient rain to yield a profitable crop fairly frequently, with some crops failing altogether. There are, however, some higher rainfall areas, particularly in Western Australia, that tend to produce higher wheat yields in relatively dry years (Land and Water Australia 2006).

Meteorological conditions are often judged in terms of the number of good seasons experienced over a five or ten year period. The likelihood of poor seasons occurring influences land prices and this can mean that some land is profitable for opportunistic cropping even if very good seasons only occur once or twice in five years.

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### *Irrigated cropping*

The availability and price of water to an irrigated property depends on water policy and water markets, as well as on the inflows to rivers and groundwater sources. Irrigators generally experience relatively little disruption during a short drought. However, when inflows have been low for an extended period, holders of water entitlements may only receive a small proportion of their usual annual allocation and sometimes zero allocations occur. Farmers can maintain production by buying water on the temporary market, but prices tend to increase substantially during dry periods. When water prices are high, some irrigators choose not to plant and so have no crop to sell at the end of the season (although they may have some income from selling that year's water allocation). Others temporarily switch to dryland forms of agriculture, while the remainder buy water to grow an irrigated crop. For those who do put in an irrigated crop, the quantity of rainfall on the property can also be important as this influences how much water needs to be purchased.

### *Horticulture*

Horticulture in Australia is intensive and generally irrigated. In many cases, horticulture involves perennial plantings such as fruit trees and grape vines. Trees and vines generally require some irrigation water to survive and even more if they are to produce a good harvest. During periods with low inflows, when water allocations are low and water prices high, the choice can be between allowing plantings to die (which can lead to expensive reestablishment followed by a period of several years before full production is restored) or facing a water bill that is so high as to make the farm unprofitable in that year. Severe pruning to minimise water use is another strategy that is sometimes adopted and this can also be costly.

### *Dairy farming*

About half of Australian dairy farms are irrigated to some degree (Australian Dairy Industry Council, sub. 58), which largely explains why 'pasture for grazing' is the single largest use of irrigation water in Australia (table 2.6). These farms can experience problems associated with the low water allocations and high water prices described above. Often, irrigated and dryland dairy farms buy in feed during droughts. As explained by the Australian Dairy Industry Council:

... income production from milking cows is tied to fixed infrastructure (the milking shed), meaning feed has to be brought to a milking herd. Buying, transporting and feeding out large quantities of high quality feed is an expensive operation. To be agisted elsewhere, milking cows would have to be dried off and consequently do not produce income. (sub. 58, p. 2)

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### *Intensive livestock*

Intensive livestock production, such as that undertaken by pork, chicken and some beef producers, relies on purchasing feed all of the time, not just during drought. The main impact of drought on these producers is that it tends to increase their delivered feed costs. Australian Pork Ltd reported:

... in general feed cost amounts to almost 60 per cent of cost of production for a pig, and approximately 80 per cent of total feed costs are related to the costs of grains. (sub. 95, p. 13)

While drought in Australian grain growing areas tends to push up feed costs, other factors, such as international grain prices, can also be important.

## **3.3 Market impacts**

Drought has varying effects on the agricultural sector, regional economies, and the national economy.

### **Impacts on agriculture**

#### *Agricultural output*

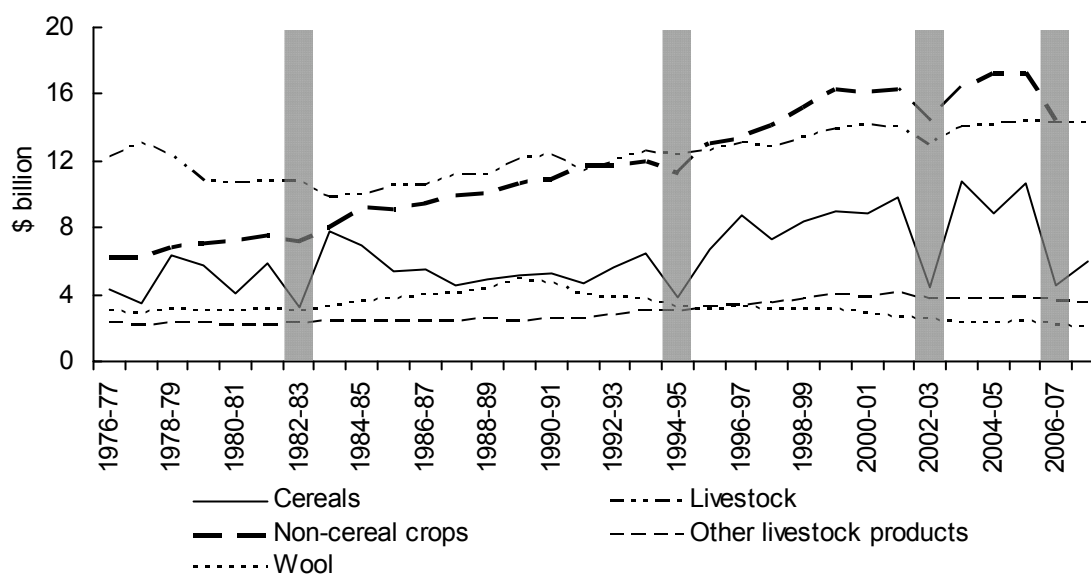
As noted in chapter 2 (figure 2.1), the four most recent widespread drought years (1982-83, 1994-95, 2002-03 and 2006-07) have all been associated with a sharp reduction in agricultural output. For example, agricultural output decreased by approximately 19 per cent between 2005-06 and 2006-07. Despite recurring droughts, agricultural output has continued to increase over the longer-term. Indeed, three of the four highest output years in Australia's history occurred in the three years between 2002-03 and 2006-07.

Drought has different effects on the various types of agricultural operations (figure 3.2). The output of cereal and non-cereal crops declines sharply in drought years, but tends to rebound strongly in the following year.<sup>1</sup> Drought generally causes a reduction in livestock production and this impact may be spread over a number of years.

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<sup>1</sup> It is common for above average rainfall years to follow drought years and this often contributes to the increases in crop production.

**Figure 3.2 Agricultural output by industry, 1976-77 to 2007-08<sup>a</sup>**  
Chain volume (2005-06 prices)



<sup>a</sup> Other livestock products includes milk, eggs and honey.

Data sources: ABS Australian National Accounts; Agricultural Production (2008 unpublished).

### Farm incomes

Drought generally decreases farm incomes because it reduces output and can increase costs. However, as discussed in the previous section, drought has differing effects on various types of agricultural activities.

Other economic variables, and decisions that farmers make in response to them, also affect farm incomes. For example, in recent years many dairy farmers have purchased fodder to maintain production during drought and this has increased their costs. However, the prices received by farmers for milk increased between 2002-03 and 2007-08, with a large increase of approximately 50 per cent between 2006-07 and 2007-08 (ABARE 2008c, p. 744). Although the farm cash income and farm business profit of dairy farms was adversely affected by 2006-07 drought, its impact was at least partially offset by higher milk prices. More recently, world milk prices have declined, and consequently Australian farm-gate milk prices were forecast (in December 2008) to fall by approximately 5 per cent in 2008-09 compared to 2007-08 levels (ABARE 2008c).



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The drought preparedness strategies undertaken by farmers will also influence the extent to which a drought event affects their output and incomes. For example, a livestock producer who has stored substantial quantities of fodder to feed stock is likely to suffer a less severe drought-induced decline in output and income than one who has taken fewer such measures.

The data presented in chapter 2 generally show that each of the major droughts that have occurred in the past 25 years has been associated with a reduction in the cash incomes of broadacre and dairy farms. Incomes for both have recovered after droughts, although the magnitude of recovery differs with each drought episode.

In contrast with the volume of agricultural output, which as noted, continues to increase despite periodic droughts, farm incomes do not display a similar upward trend. This is because of the confluence of factors affecting farm incomes, most notably the long-term decline in the farm terms of trade.

### *Asset values*

Land is the main asset for most farm businesses<sup>2</sup>. A major influence on the value of farm land is the future return expected from owning it. Often this relates to future agricultural production, but may also relate to the conversion of the land to other uses, such as residential use. The occurrence of drought in a particular year does not generally lower expectations about returns for future seasons and so would not be expected to have a major influence on the value of farming land. An exception to this might occur if the drought resulted in a sharp increase in the number of properties coming on to the market in a region where there are few potential buyers.

The evidence is consistent with this hypothesis. Rates of return to farming have been relatively high (see chapter 2), including during the 2002 to 2007 period, in large part due to continued increases in farm land values (figure 3.3). ABARE (2008e) stated that the phenomenon of continually increasing farm land values reflected factors such as changes in population growth, urban and peri-urban development and economic growth in regions strongly influenced by mining. Further reasons for the continued increase in farm land values may include:

- the positive attitude of banks towards agriculture
- new and more intensive farming systems
- competition for limited land with neighbours and new managed investment schemes (O’Callaghan 2006).

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<sup>2</sup> Extensive pastoral leases across northern Australia are a significant exception.

The Australian Bankers' Association argued that increases in land values reflected expectations that future commodity prices would be strong:

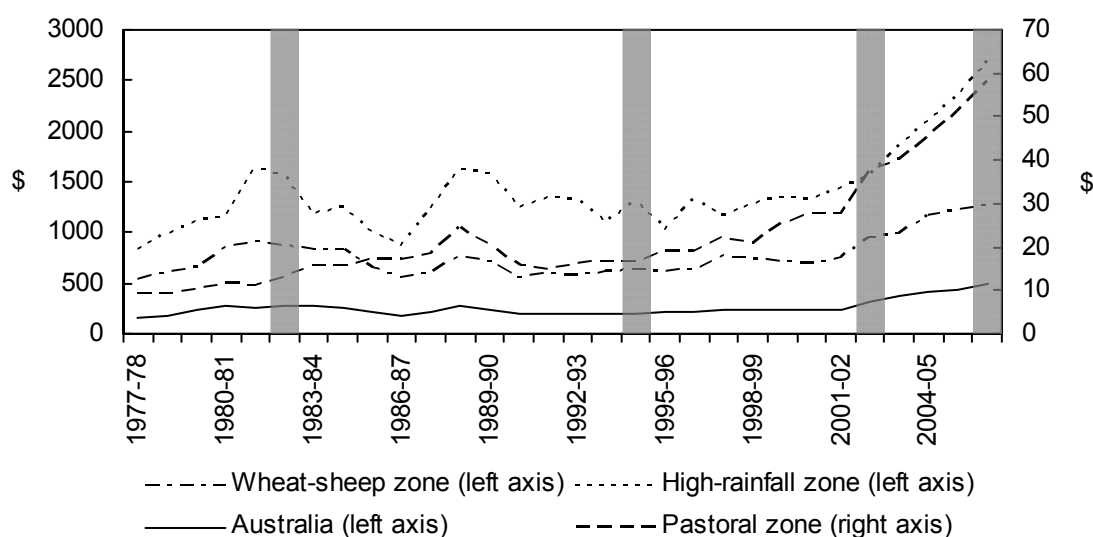
That phenomenon of increasing land prices during this drought has been an extraordinary event ... prices are reflecting the expected demand for soft commodities, going forward ... those prices are now looking a little bit high, but over the long-term, the expectations are there that there will be pressure on commodity prices that are expected to enable those property prices to be sustained. (trans., pp. 470-1)

Another possible reason why farm land values have increased in recent years is due to investment interests from abroad. Compared to other countries (especially those where land is much more expensive and those with weaker systems of property rights and institutional structures) investment in agricultural land in Australia seems to represent a quite attractive investment opportunity.

It is also possible that the provision of government drought support, particularly interest rate subsidies, has been capitalised into farm land values, making land prices higher than they would otherwise be. The National Farmers' Federation submitted:

It is important to note that farm land value has been intrinsically tied to drought policy in the recent decade. Interest-rate subsidies, EC support, and other assistance measures have buffeted and placed a 'floor' under land value. (sub. DR176, p. 21)

**Figure 3.3 Broadacre land values per hectare, 1977-78 to 2006-07**  
Average per farm (2007-08 dollars)



Data source: ABARE (2008 unpublished).

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There appears to be little evidence of a clear relationship between land values and drought for various types of broadacre land. Indeed, over the period 2002-03 to 2006-07, (real) average land values per hectare for broadacre farms in exceptional circumstances (EC) declared areas (as of 30 June 2007) increased at a faster rate than those for non-EC declared areas (ABARE 2008 unpublished).

Investment in other farm assets, such as machinery and equipment, may be affected by drought. Constrained cash flows caused by drought can reduce the ability of farmers to invest in new assets and undertake the maintenance of existing assets, reducing their productive value. Figure 2.16 shows that gross fixed capital formation decreased during the 2002-03 and 2006-07 droughts. After the 2002-03 drought, gross fixed capital formation recovered, suggesting that drought may postpone investment decisions taken by farmers rather than prevent new investment altogether.

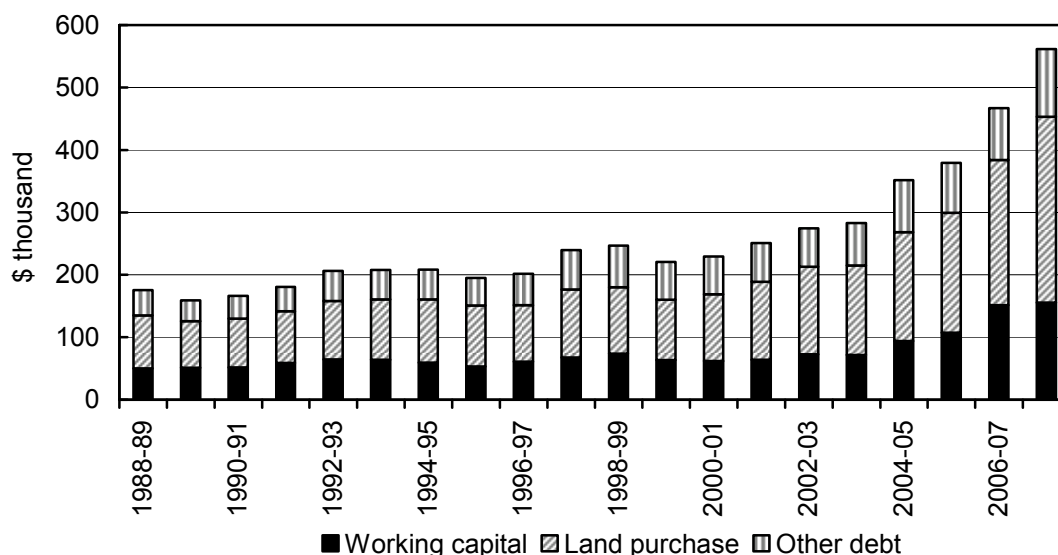
### *Farm debt*

During the late 1990s and early 2000s, average (broadacre and dairy) farm debt increased (figure 3.4), primarily as a result of the financing of new investments associated with a rising proportion of farms purchasing additional farm land (ABARE 2008e). Since the 2002-03 drought however, there has been an increase in farm working capital debt. High land prices have allowed many farmers to maintain high equity positions despite increases in their debt. As noted by the Australian Bureau of Agricultural and Resource Economics (ABARE), farmers with low equity tend to have greater difficulty accessing working capital debt facilities, and therefore need to rely more heavily on surplus cash flows generated by their farm businesses to provide funds for working capital and drought recovery (ABARE 2008e, p. 12).

### *Agricultural adjustment*

Drought can exacerbate existing adjustment pressures facing farmers. The combination of factors such as declining farm terms of trade, technological change, and the trend towards larger farm sizes are all long-term adjustment issues in agriculture, and are more likely to induce changes in farm numbers than the recurrent phenomenon of drought. Nevertheless, the occurrence of drought may induce some farmers facing adjustment pressures to leave the industry, though often not until after the drought has ended. However, young farmers who have bought their properties, or farmers who have made large investments (such as buying more land to become more viable), just before drought may suffer particularly adverse financial effects due to unfortunate timing.

**Figure 3.4 Broadacre and dairy farm business debt, 1988-89 to 2007-08**  
Average per farm (2007-08 dollars)



Data source: ABARE (2008 unpublished).

## Regional impacts

The direct decline in agricultural activity that arises from drought can also have effects on agriculture-dependent businesses, such as farm machinery and equipment suppliers, fertiliser and seed suppliers and harvesting contractors. During drought, farmers are less likely to require the goods and services of such firms, leading to a decline in their production levels. The decrease in output of agriculture and agriculture-dependent business also reduces the output of other regional industries due to reduced final expenditures on the goods and services they produce.

With lower levels of production, primary producers and agriculture-dependent businesses often reduce the number of hours worked by existing workers and/or reduce the number of workers they employ. This also applies to other regional industries affected by reduced expenditure on the goods and services they produce. The financial and employment effects of drought on a particular region are dependent on a range of factors. This includes the severity and duration of drought, the types of agricultural output produced in the region and their linkages with downstream industries, and the relative importance of agriculture to the region (Stayner 1996).

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As an example of how drought severity may differ between regions, Adams et al. (2002) observed that, during the 2002-03 drought, some grain growers around Adelaide, south east South Australia and south-western Victoria realised near average harvests. However, other areas, such as the eastern Eyre Peninsula (in South Australia), north-western Victoria and northern New South Wales, suffered extreme or total crop failure. On a state basis, New South Wales suffered the largest decline in agricultural output in 2002-03 (32 per cent), while large falls also occurred in Western Australia (28 per cent), South Australia (26 per cent) and Victoria (21 per cent) (ABS 2008d).

The extent to which a region is affected by drought is in part dependent on the types of agriculture practised. Regions with a high proportion of broadacre cropping may be more vulnerable to a rainfall drought than a region that has a high proportion of irrigated dairy farming. In broadacre livestock areas affected by drought, farmers can agist stock, which can increase activity in regional transport industries, or reduce stock numbers, potentially increasing activity in local abattoirs and associated industries.

The effects of drought on a given region may also be ameliorated if there is a significant increase in the proportion of farm household members who obtain off-farm income, especially if it is not agriculture related or weather-dependent. Expenditure of such income in the region can partially offset drought-related reductions in final expenditures, regional output and employment. There may, however, be some changes in the composition of regional output, as income obtained is likely to be spent on maintaining consumption levels, rather than on-farm inputs. Furthermore, nonfarm businesses can reduce the flow-on effects of drought they experience by reducing their inventories, and depending on their degree of mobility, seeking productive opportunities in other localities (Stayner 1996).

As discussed in chapter 2, the relative significance of agriculture has declined over time, and a number of factors have favoured the growth of larger regional centres over smaller rural towns. For example, Stayner observed:

Farmers now have more reasons for visiting town, and it is efficient to tend to them all in the same place. Because it is now necessary to go to town to do the banking, buy chemicals, and pick up a replacement part, and since the increasing complexity of these inputs makes it desirable to shop around for price, service and information, there are 'agglomeration' economies which favour the larger places offering such services and choice. (Stayner 1996, p. 4)

Moreover, with better and cheaper transport, the relative costs of going further, to a larger town, have declined while the benefits have increased.

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Levantis (2001) found that, although the economies of many small towns (defined as those with less than 1000 people) were highly dependent on (broadacre) farm expenditure, most farm expenditure took place in larger towns. However, in larger towns, farm household expenditure per town resident (used as an indication of the relative importance of agriculture to the local economy) was lower than in small towns. Therefore, although small towns are still highly dependent upon expenditure from agriculture, larger towns are less so. Indeed, chapter 2 (box 2.2) showed that agriculture accounts for only a relatively small share of inner regional employment. Agriculture is more important to employment in outer regional, remote and very remote areas. However, private services are more important than agriculture in all of these areas, and other industries, such as health and education, and infrastructure, also account for a large share of total employment (BITRE 2008).

The growth of regional centres and declining significance of agriculture in these centres also means that alternative employment opportunities available to individuals outside agriculture are changing. Given the industrial diversification of regional centres, they typically provide a fairly wide range of employment options. However, as activity has moved away from smaller rural towns, the employment options they offer have generally reduced. Nevertheless, the wider the range of alternative employment choices available to individuals, the less severe the impacts of drought on employment are likely to be. For example, in its submission to this inquiry, the Rangelands Drought Taskforce South Australia stated:

The mining boom and high demand for employment in the region has masked many of the negative impacts of the drought (sub. 60, p. 2).

In summary, while droughts have negative effects on economic activity and employment at the regional level, the growth of regional centres and the declining significance of agriculture in these centres means that these effects have gradually become less pronounced than in the past.

## **National impacts**

Although agriculture now accounts for only a small share of Australia's national economic output, drought can still have a significant influence on measured gross domestic product (GDP). For example, the ABS estimated that the 2002-03 drought reduced farm GDP by around 28.5 per cent, which subtracted around 1 percentage point from Australia's aggregate GDP growth (ABS 2004). The latter estimate reflects only the direct effects of drought (that is, those that result only from the direct decline in farm GDP).

Droughts also have flow-on effects, which occur due to reductions in the output of agriculture-dependent industries and decreased final expenditures in other

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industries. These effects are more difficult to quantify than the direct effects of drought, but one way to do so is to use a Computable General Equilibrium model. Horridge et al. (2005) used such a model to analyse the effects of the 2002-03 drought on a range of economic variables. They estimated that the 2002-03 drought led to a reduction in Australia's GDP growth of 1.6 percentage points. Of this, 1 percentage point reflected the direct decline in agricultural production, and the remaining 0.6 of a percentage point reflected negative flow-on effects. More recently, the Reserve Bank of Australia (RBA) forecast that the fall in farm output in 2006-07 would reduce GDP growth by around one half of a percentage point (RBA 2006).

In Australia, droughts have reduced GDP growth in the years in which they occur, but have not slowed growth in the long run. When the agricultural sector recovers from drought, farm GDP increases, and this causes aggregate GDP to rise. For example, the RBA estimated that:

- the 1982-83 drought reduced Australia's GDP growth by around 1-1.5 percentage points, but the subsequent recovery added approximately the same amount to GDP growth
- the 1991-95 drought period also subtracted around 1-1.5 percentage points from GDP growth, while the recovery added approximately 0.75 percentage points to GDP growth (RBA 2002).

The effect of drought on the GDP growth rate is essentially transitory because in the long-run, GDP growth depends on the growth rates of labour and capital accumulation and total factor productivity growth (that is, increases in output that occur for a given quantity of inputs), not temporary movements in the level of farm GDP.

Although drought can have significant ramifications for farm and other regional employment, it does not necessarily have the same effect on aggregate (nationwide) employment:

Whilst the [2002–03] drought had a devastating impact on agricultural employment, the strength of the broader domestic economy saw above trend growth in total employment. ... at an aggregate level, employment declines related to drought were offset by the strong growth in other sectors. (Lu and Hedley 2004, p. 34)

Despite the decline in agricultural employment arising from the 2002–03 drought (see figure 2.5), total economywide employment increased in that year. Therefore, although drought may result in a decline in employment in rural areas, it does not necessarily mean that aggregate levels of employment will decline. Growth in non-agriculture industries provides individuals with the opportunity to find alternative sources of employment, although not always in the same region.

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The effect of droughts on inflation are generally relatively small, although there can be significant price effects on certain food items in the short term. For example, the prices of foods that rely on wheat as an input typically rise after the onset of drought, whereas meat prices initially fall as slaughter rates increase. The RBA (2008) made the observation that, during the droughts which occurred in 1982-83, 1994-95 and 2002-03, average food prices increased at approximately the same rate as the overall Consumer Price Index. The RBA stated that the reasons for the historically muted effects of drought on consumer prices are because:

- the contribution of commodity prices to final retail food prices is often small
- the contribution of drought-affected food prices to the Consumer Price Index is relatively small
- the increase in cereal prices is partially offset by lower meat prices
- many food items can be imported if shortfalls in domestic production occur
- some food manufacturers who use drought-affected inputs have some scope to use substitute ingredients.

In contrast to previous droughts, the 2006-07 drought did result in food prices increasing at a faster rate than the overall Consumer Price Index. The reason for this, according to the RBA, was because a broader range of food items were affected than in previous droughts. In particular, the RBA noted that because the decline in stored water levels led to reductions in dairy and vegetable production, the prices of these items rose more markedly than in previous droughts (RBA 2008, p. 11).

### **3.4 Social impacts**

As stated by the Tasmanian Farmers and Graziers Association:

Drought is ... not just about the mechanics and business of farming, but about people, about health and wellbeing, about education, community welfare, social cohesion, rural living, and about all the aspects of life that humans are involved in. (sub. 69, p. 7).

The Expert Social Panel's report on the social dimensions of drought was presented to the Commonwealth Government at the end of September 2008. The Commission is in broad agreement with the panel on many of their conclusions on the social impacts of drought. For example, the following quote from the panel's report is consistent with the Commission's assessment:

At times the Panel found it difficult to separate the social impacts of dryness from the longer term socio-demographic trends contributing to a decline of some rural populations. However, it was clear from the Panel's assessment that drought has an



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impact on the wellbeing of farm families, rural businesses and communities. (Kenny et al. 2008, p. 1)

The intention here is not to cover in detail all of the social impacts discussed in the Expert Social Panel's report, but rather to outline the Commission's understanding of some of the main issues. This understanding informs the policy recommendations made later in this report. This section also makes use of the results of the Australian Institute of Family Studies' Rural and Regional Families Survey, as this appears to be the largest and most comprehensive survey of the impacts of drought on people living in regional and rural Australia (box 3.2).

**Box 3.2      Australian Institute of Family Studies' Rural and Regional Families Survey — methodology**

The Rural and Regional Families Survey is a population-based study of 8000 people living in areas of Australia in which at least 10 per cent of the population were employed in agriculture or a related service industry. The interviews were conducted over September to December 2007 with people living in over 400 postcodes. Four groups of 2000 people were interviewed. The groups (based on rainfall deficits in the area in the last three years compared to the last 100 years) were:

- severe drought (0 to 5th percentile)
- drought (6 to 10th percentile)
- below-average rainfall (11 to 49th percentile)
- above-average rainfall (50 to 100th percentile).

Data on respondents' perceptions of drought were also obtained. The categories derived according to this social definition of drought were:

- currently in drought
- in drought in the last year but not currently in drought
- in drought in the last 3 years but not in the last year
- not in drought in the last 3 years.

The effects of drought were estimated using multivariate statistical modelling (regression analysis), which allows for the effects of drought after taking into account other differences between families and geographic areas.

*Source:* AIFS (sub. 92).

### *Financial hardship*

Often the market impacts of drought, discussed in the previous section, have social consequences. For example, reduced farm incomes can lead to financial hardship

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for households that are unable to adequately supplement their income through off-farm employment, or through drawing down savings, extending their borrowing, or accessing drought assistance or other government income support payments. An applicant for drought assistance in Tasmania reported:

We have had to sell three-quarters of our stock and also hand feeding grain to the rest so there is no money left for living expenses which puts a lot of strain on the family. (cited in Country Women's Association in Tasmania, sub. 17, p. 3).

Financial hardship affects people in a range of ways. Some farmers told the Commission and the Expert Social Panel that difficulty in finding money to meet the educational needs of their children because of drought was something they felt particularly keenly. The Expert Social Panel reported hearing that 'some children and young adults are being denied educational ... opportunities because of household financial limitations' (Kenny et al. 2008, p. 7). However, this could be said of any household facing financial difficulties anywhere in Australia — it is not a problem unique to drought-affected farmers.

The Australian Institute of Family Studies (AIFS) survey quantified the reduction in income arising from drought. It found that (using a rainfall definition of drought) farmers in severely drought-affected areas had, on average, annual household incomes of around \$34 600 compared to \$38 600 for their counterparts in above average rainfall areas (sub. 92). This is a surprisingly small differential — the average income for those with above average rainfall was only 12 per cent higher than that of farmers in severely drought-affected areas.

The survey provides additional data on financial hardship. As explained by the AIFS:

Respondents were asked, 'In the last 12 months, did any of the following happen to your family because of a shortage of money? Could not pay electricity or the telephone bills on time; could not pay the mortgage or rent on time; pawned or sold something; went without meals; asked for financial help from friends or family; asked for help from welfare/community organisations'. The experience of one or more of these events was considered to be indicative of financial hardship. (sub. 92, p. 13)

Table 3.1 shows that the proportion of farmers experiencing financial hardship was high relative to farm workers and other people employed in rural areas. This may be related to the risks, capital exposure and infrequency of income faced by farmers. The table also shows that 35 per cent of farmers in areas with above average rainfall experienced financial hardship and this rose to 45 per cent in areas affected by drought. This suggests that in a drought-affected area, the drought results in a further one in ten farmers experiencing financial hardship. In other words, most cases of financial hardship suffered by farmers were due to factors other than drought.

The increase in financial hardship in drought-affected areas was more pronounced for farm workers than for farmers, and there was a marked difference, for those workers, between drought and severe drought. For people living in rural areas and employed outside agriculture, the prevalence of financial hardship was essentially the same irrespective of drought status (table 3.1).

**Table 3.1 Experience of financial hardship, by drought status (rainfall definition) and type of employment <sup>a</sup>**

Per cent of each employment group

Employment group	<i>Drought status</i>			
	Severe drought	Drought	Below average rainfall	Above average rainfall
Farmer	45	45	41	35
Farm worker	36	25	28	23
Employed but not in agriculture	23	24	22	22

<sup>a</sup> Estimates derived from logistic regression.

Source: AIFS (sub. 92, p. 15).

The AIFS also presented data based on a social definition of drought. These data show a larger increase in financial hardship for those in drought compared to those not in drought, relative to the data based on the rainfall definition (although the drought status categories are somewhat different) (AIFS, sub. 92). Asking people about the drought status of their area would seem to be less reliable than using rainfall records to make this assessment and so this report focuses on the results based on the rainfall definition.

### *Family relationships*

Financial difficulties, concerns over the future of the farm, and other concerns caused or exacerbated by drought can put a strain on family relationships. The Expert Social Panel report on the impact of drought on families found:

... the present dryness has had an impact on the functioning of rural families, through enforced long-term separation of family members, psychological impacts on toddlers and school age children, an increased burden of responsibility on women and the divisive issue of succession planning in tightened economic circumstances.

The Panel formed the view that while many farmers will say they are coping, their coping mechanisms are creating greater pressure on their families. (Kenny et al. 2008, p. 34)

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The Expert Social Panel noted that its findings were contrary to that of the AIFS. From its survey the AIFS found:

... no evidence that drought had a negative impact upon family relationships, as measured by separation, quality of the couple relationship, family functioning and family conflict. (sub. 92, p. 5)

Whereas the AIFS survey did not find empirical evidence to support the relationship between drought and deteriorating family relationships, the Expert Social Panel drew on a wider range of qualitative evidence.

### *Mental health*

The Expert Social Panel reported:

It is clear to the Panel that extended dryness has a significant negative impact on the mental health of farm families and others within rural communities. In particular, the Panel heard repeatedly during the public forums and in written submissions that the pressures of drought were leading to an increase in the incidence of depression, anxiety and stress in rural and remote areas. (Kenny et al. 2008, p. 60)

The AIFS survey also found considerably higher rates of mental health problems among people who regarded their area as being in drought (sub. 92). The survey, however, showed very little difference in the prevalence of mental health problems between areas with different drought status, as defined by rainfall (table 3.2). The main exception to this was that a greater proportion of farm workers in severely drought-affected areas had a mental health problem compared to other farm workers, although the AIFS reported that this was not a statistically significant result.

**Table 3.2 Reports of mental health problems, by drought status (rainfall definition) and type of employment<sup>a</sup>**

Per cent of each employment group

Employment group	<i>Drought status</i>			
	Severe drought	Drought	Below average rainfall	Above average rainfall
Farmer	16	17	14	17
Farm worker	13	5	9	8
Employed but not in agriculture	9	9	7	10

<sup>a</sup> Estimates derived from logistic regression.

Source: AIFS (sub. 92, p. 25).

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A smaller study commissioned by the Birchip Cropping Group involving interviews with farm families in northwest Victoria during drought conditions found:

Serious depression is not common but is present and many reported a loss of enjoyment and confidence in farming. (Rickards 2007, p. 4)

The Expert Social Panel identified a link between suicide and drought:

Recent studies examining trends in Australian suicide rates have consistently demonstrated male rates are higher in rural and remote areas than in major cities. Further, there is evidence linking suicide to drought in New South Wales, with an 8 per cent rise in the long-term mean suicide rate being associated with a decrease in precipitation of about 300 millimetres. (Kenny et al. 2008, p. 59)

### *Community stability and cohesion*

As discussed in chapter 2, a range of factors has led to the long-term decline of many small towns in Australia as people and economic activity move to larger centres. Many people living in or close to these small towns are negatively affected by these changes, which can be exacerbated by drought, particularly where they result in a loss of local services or social interaction.

The Expert Social Panel found:

When family farms are struggling with events such as dryness, the communities in which people normally spend their money and participate also suffer. Dryness negatively impacts on the ability of members of a rural community to work together for the benefit of the whole community, eroding the capacity of people to engage in community projects or do the voluntary work that keeps rural communities alive. (Kenny et al. 2008, p. 3)

Based on survey results the AIFS concluded:

Drought was ... associated with a higher rate of closure of key services and more people reporting low levels of community social cohesion. However, drought was also associated with higher rates of membership of community organisations. ...

The effects of drought on residential mobility are quite hard to estimate. However, our analysis seems to indicate that households were adjusting to adverse circumstances in drought-affected areas, with some members of households probably moving (temporarily or otherwise) towards areas with greater economic opportunity. (sub. 92, p. 5)

The Birchip Cropping Group study found:

Besides accelerating rural decline, the drought has had positive and negative social effects on communities. (Rickards, 2007, p. 5)

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Overall, the evidence suggests that when it comes to matters such as financial hardship, mental health and community cohesion, drought is a factor but is not the dominant influence. The evidence also suggests that there is a higher prevalence of some social problems among farmers compared to the general population, regardless of drought status.

### **3.5 Environmental impacts**

The Department of the Environment, Water, Heritage and the Arts reported:

... the recent drought has impacted on environmental issues including impact on soil condition, damage to exclusion areas, protection of fragile areas such as remnant vegetation and erodible creek lines and irreparable damage to groundwater. (sub. 107, p. 4)

Some of the environmental impacts of drought, such as pasture and soil degradation, threaten the natural asset base of the farm. As a consequence, farmers have an incentive to ameliorate these impacts by changing management practices, such as adopting single or no-till cultivation systems or destocking to retain vegetation cover. Other on-farm impacts, such as damage to remnant native vegetation, can threaten environmental values that are important to the wider community as well as to the farmer.

The environmental consequences of drought are influenced by farm management practices. One inquiry participant argued:

Reducing bare ground will always reduce environmental damage during droughts, and the most crucial part of the recovery is when plant populations are attempting to re-establish themselves. (P. Morris, sub. 23, p. 4)

Wind erosion and dust storms tend to be more prevalent during droughts. Measurements of airborne dust indicate that there was a generally high level of dust storm activity during the 1960s, with peaks in the drier years (Australian State of the Environment Committee 2006). Since then dust storms have become generally less prevalent, with drought years, such as 1994, 2002 and 2003, being exceptions to this. The general lessening in dust storms since the 1960s may be at least partly due to improved farm management practices.

Drought can also lead to a greater spread of weeds from one farm to other farms or into public land. This can occur either because the bio-physical conditions resulting from drought allow weeds to spread more easily, or because drought-affected farmers do not have the time or resources to undertake normal weed control work. While regulations and collective interests among farmers exert pressure for weed and pest control activities to continue, these may be less effective during drought.

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A major environmental impact of hydrological drought is that it reduces flows in water courses, which can threaten the health of valley and river systems. The Department of the Environment, Water, Heritage and the Arts stated:

... a recent assessment of the ecosystem health of the 23 valley systems in the Murray-Darling Basin showed that 13 were in very poor condition, seven were in poor condition, two were assessed as moderate and just one was in good condition. (sub. 107, p. 4)

The Wentworth Group reported on the state of the Coorong, near the mouth of the Murray River:

Salinity levels in the southern Coorong now exceed the maximum levels tolerated by the plants and animals that underpin the international status of these wetlands, and acid sulphate soils lie ready to be exposed and release acid into the water if lake levels were to continue to fall. (Wentworth Group 2008, p. ii)

The ecosystem health of valley systems is influenced at least as much by water policy as it is by variations in climate, and in particular, decisions on how much of the available water is allocated to environmental flows. These allocation decisions can become particularly contentious during droughts because of the increased scarcity of water for irrigation, industry, domestic use and the environment.

Projections (discussed later in this chapter) for increased temperature and, for some areas more frequent periods of extremely low rainfall, have implications for future environmental impacts. The Australian Conservation Foundation stated:

Many Australian plant and animal communities are already substantially degraded as a result of habitat conversion, overallocation of water for human use, overgrazing, invasive species, salinisation and so on ... Increasing drought frequency, intensity and extent are likely to have dire consequences for Australia's biodiversity conservation efforts. While many Australian native species are adapted to high climate variability, the marked speed and depth of climate change underway is likely to cause a further contraction in the range of many plants and animals, and, ultimately, many extinctions, local and global. (sub. 106, p. 11)

As noted earlier, one of the objectives of the National Drought Policy (NDP) relates to maintaining and protecting Australia's environmental resource base (chapter 1). The Department of the Environment, Water, Heritage and the Arts reported that there are 'no measures within the current suite of drought support initiatives that explicitly address' this objective (sub. 107, p. 2). Indeed, the department was concerned that NDP measures may actually make environmental outcomes worse:

There is potential ... for the existing drought support policy to have unintended, or perverse, consequences that encourage land managers to manage terrestrial and aquatic resources unsustainably. (sub. 107, p. 2)

Later chapters and appendices analyse this issue further.

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## 3.6 Recent experience and future outlook

This section explores recent climate variability and droughts, and the future outlook, drawing heavily on projections made by the Bureau of Meteorology and CSIRO (Hennessy et al. 2008). Three periods are examined:

- 1993 to 2008, which equates roughly to the period that EC declarations have been made.
- 2002 to 2007, which is widely regarded as one long drought for large parts of Australia.
- 2010 to 2040, which is the period for which the projections were made.

There is no universally accepted way of comparing droughts, or climate more generally, for different periods. The main measures used here are the prevalence of exceptionally low rainfall, average rainfall over a given period, the prevalence of exceptionally low soil moisture and inflows to water bodies that supply water for irrigation (box 3.3). Data are presented for seven regions (figure 3.5).

### Box 3.3 Indicators of the severity of drought

The following indicators of drought severity are used in this report. The first three relate to meteorological and agricultural drought, the fourth relates to hydrological drought.

#### Exceptionally low rainfall

Hennessy et al. (2008) define exceptional events as occurring, on average, once every 20 years. The dataset they used for rainfall was for the period 1900 to 2007 and, for any one area, the six lowest rainfall years in this period were classified as having exceptionally low rainfall. They determined the percentage area of each region that had exceptionally low rainfall in each year and then averaged these percentages over various periods.

The prevalence of exceptionally low rainfall years is a useful, but not perfect, indicator of the severity of meteorological drought. Perhaps its main imperfection is that it can be misleading in comparing multi-year periods. For example, a five year period that included one exceptionally low rainfall year and four years of very much below average rainfall would probably be considered more severely drought affected than a five year period that included two exceptionally low rainfall years and three average years.

#### Average annual rainfall

Data on average annual rainfall is used to complement the data on exceptionally low rainfall. If, for a particular region, a period has both a higher prevalence of exceptionally low rainfall years and lower average annual rainfall than another period it can be said to be 'drier', and highly likely to be more severely drought affected.

(Continued on next page)



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**Box 3.3 (continued)**

Examination of the historic record also reveals the combination of exceptionally low rainfall years and average annual rainfall to be a good proxy for agricultural drought. For example, there is generally close concordance between these measures and the major drought periods identified in box 3.1.

**Exceptionally low soil moisture**

Hennessy et al. (2008) generated data on exceptionally low soil moisture in a similar way as for exceptionally low rainfall. The differences are that the soil moisture data was generated using a computer model (the model was driven by daily rainfall and potential evaporation data) and that only the period 1957 to 2006 could be covered due to data constraints.

Soil moisture is potentially a better indicator of drought than rainfall alone as it incorporates the influence of temperature and other factors on evaporation (and therefore on the moisture available for uptake by plants). Hennessy et al. (2008) used data on soil moisture in preference to other possible indicators, such as the Palmer Drought Severity Index. Exceptionally low soil moisture is, however, limited in its usefulness in making historical comparisons because data are only available from 1957.

None of the indicators used in this report fully capture the severity of agricultural drought as they are not sensitive to within year variations in rainfall such as at the time of seed germination or other crucial periods of the growing cycle.

**Inflows to water sources used for irrigation**

The annual volume of inflows to water sources used for irrigation is used as an indicator of the severity of hydrological drought in this report. As the Murray-Darling Basin supplies most of Australia's irrigation water, most attention is given to inflows to this system.

**How does recent rainfall and soil moisture compare to the historic record?**

Overall rainfall and incidence of exceptionally low rainfall varies considerably between decades:

In Australia, the twentieth century was characterised by frequent droughts around 1900 and again in the 1930s and 1940s, with wet conditions becoming widespread in the 1950s and 1970s. (Hennessy et al. 2008, p. 8)

Because of this variability, comparisons of recent periods to longer term averages can be sensitive to how far back the longer term averages go. This report compares more recent years to the period 1900 to 2008.

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Figure 3.5    **Regions used for climate comparisons**

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Source: Hennessy et al. (2008).

### *From 1993 to 2008*

For most regions, the last 16 years had either a fairly average or below average occurrence of severe drought. For Queensland, Northwest Australia and Southwest Australia exceptionally low rainfall years were less prevalent for the period 1993 to 2008 than for 1900 to 2008, and average rainfall was higher. For New South Wales and the Murray-Darling Basin exceptionally low rainfall years were also less prevalent for the period 1993 to 2008 than for 1900 to 2008, but average rainfall was slightly lower (by 2.1 and 1.9 per cent respectively) (tables 3.3 and 3.4).

For many people in these regions the idea that rainfall over the last 16 years was about average may conflict with their perceptions. There are at least three possible reasons for this. First, some people's perception of average rainfall may relate more closely to the last 40 years ('living memory' for many people) than the longer historic record that includes the Federation Drought and the Forties Drought. Second, the Bureau of Meteorology and CSIRO data cited above are averages for what are mostly very large geographic regions and trends for smaller areas within

them can be quite different. Data in the annex for this chapter shows that some districts in these regions had significantly below average rainfall over the last 16 years. Third, the most recent period, since the very dry year of 2002 may register most strongly in people's memory — this period is examined later.

In contrast to the above, the Victoria and Tasmania region and southwest Western Australia had more prevalent exceptionally low rainfall years for the period 1993 to 2008 than for 1900 to 2008, and average rainfall was lower (by 4.9 per cent and 7.9 per cent respectively) (tables 3.3 and 3.4). The extended dry period being experienced in these regions (and parts of South Australia) was commented on by the Bureau of Meteorology:

In the south-west of Western Australia, and in parts of south-eastern Australia (principally central and western Victoria and south-eastern South Australia, together with northern and eastern Tasmania), long-term rainfall deficits extend back beyond 2000. In both regions, the most recent year in which there was widespread above-average rain was 1996. At some locations, such as Melbourne, there have been eleven consecutive years with below-average rainfall from 1997 to 2007, with 2008 highly likely to become the twelfth. (BoM 2008, p. 2)

**Table 3.3      Average percentage area having exceptionally low rainfall, selected periods by region**

Per cent of total area in region

	<i>1900-2008</i>	<i>1993-2008</i>	<i>2002-2007</i>
Queensland	5.5	3.9	7.5
New South Wales	5.5	5.0	10.7
Victoria & Tasmania	5.5	7.0	14.1
Southwest Australia	5.5	3.4	5.4
Northwest Australia <sup>a</sup>	5.6	2.4	5.6
Murray-Darling Basin	5.5	4.8	11.4
Southwest WA	5.5	9.0	10.6
Australia	5.5	3.1	5.1

<sup>a</sup> Based on financial rather than calendar years, so as to capture the complete wet season.

Sources: Hennessy et al. (2008); BoM (2009 unpublished).

### *From 2002 to 2007*

The period 2002 to 2007 was chosen for analysis because, for large parts of Australia, it included two very low rainfall years and there was a general absence of wet years. For most parts of Victoria, Tasmania and South Australia, 2008 was also a low rainfall year, but the majority of Queensland, northern New South Wales and Western Australia's agricultural land received close to average or above average rainfall. This brought relief from rainfall drought, although the timing of rainfall adversely affected grain quality in some areas.

It can be seen from tables 3.3 and 3.4 that the period 2002 to 2007 had a higher prevalence of severe drought than the historic record for all regions except for Northwest Australia<sup>3</sup> and Southwest Australia. A relevant question to ask is: How exceptional is the dry period from 2002 to 2007 in the context of Australia's agricultural history?

**Table 3.4 Average annual rainfall, selected periods by region**  
Millimetres

	<i>1900-2008</i>	<i>1993-2008</i>	<i>2002-2007</i>
Queensland	615	618	552
New South Wales	523	512	452
Victoria & Tasmania	741	705	672
Southwest Australia	261	281	252
Northwest Australia	458	572	536
Murray-Darling Basin	476	467	406
Southwest WA	658	606	591
Australia	457	500	457

*Sources:* Hennessy et al. (2008); BoM (2009 unpublished).

Table 3.5 shows that there have been previous six year periods that have a higher prevalence of exceptionally low rainfall years and lower average rainfall than 2002 to 2007 for all regions except southwest Western Australia. For example, on average 19.2 per cent of New South Wales experienced exceptionally low rainfall each year during the period 1940 to 1945, compared to 10.7 per cent for 2002 to 2007. Also in this state, average annual rainfall was 417 mm for 1940 to 1945, compared to 451 mm for 2002 to 2007. While the period 2002 to 2007 was not the driest six year period since 1900 in Victoria and Tasmania, it was close to being so.

Data for soil moisture were only available for the period 1957 to 2006, meaning that it was not possible to make the same comparisons for this measure. However, the limited comparisons able to be made show a higher prevalence of exceptionally low soil moisture in earlier periods than for 2002 to 2006 for all regions except southwest Western Australia (table 3.5).

<sup>3</sup> The Bureau of Meteorology (2008, p. 1) report 'much of northern Australia continues to experience well above average rainfall, with record high rainfall widespread about the Top End, Kimberly and parts of Cape York Peninsula over the 3 to 10 year timeframe'.

**Table 3.5 Period 2002–2007 compared to driest six year period since 1900**

	<i>Exceptionally low rainfall</i>			<i>Average annual rainfall</i>			<i>Exceptionally low soil moisture</i>		
	<i>2002-2007</i>	<i>Highest since 1900</i>		<i>2002-2007</i>	<i>Lowest since 1900</i>		<i>2002-2006</i>	<i>Highest since 1957</i>	
	% area	Period	% area	mm	Period	mm	% area	Period	% area
Qld	7.5	1900-05	24.7	552	1900-05	483	9.0	1966-70	18.7
NSW	10.7	1940-45	19.2	452	1940-45	417	11.4	1966-70	15.7
Vic&Tas	14.1	1967-72	15.7	672	1940-45	643	6.2	1966-70	12.0
SW	5.4	1940-45	15.1	252	1935-40	213	6.6	1977-81	13.8
NW	5.6	1961-66	13.5	536	1933-38	372	1.6	1991-95	10.4
MDB	11.4	1940-45	16.5	406	1940-45	387	10.9	1966-70	16.1
SW WA	10.6	1967-72	25.8	591	2001-06	577	11.7	2002-06	11.7
Australia	5.1	1924-29	13.0	457	1935-40	396	na	na	na

na Not available.

Sources: Hennessy et al. (2008); BoM (2009 unpublished).

As mentioned above, the Bureau of Meteorology and CSIRO data cited above are averages for large regions and as such are likely to mask trends for smaller areas. The annex to this chapter shows that this is indeed the case. For example, there are rainfall districts in Queensland and elsewhere, that have experienced their driest six year period since 1900 within the last decade.

Another issue in comparing recent years with past drought periods is that in some areas drought is continuing:

In south-eastern Australia (especially Victoria and Tasmania) the situation has worsened during 2008, with three-year rainfalls now at record low levels in numerous locations, including many areas critical for inflows into the Murray-Darling system. (BoM 2008, p. 1)

Overall, the data presented in this report confirm that the period from 2002 to 2007 ranks with the Federation Drought and the Forties Drought as one of the three most severe, widespread and prolonged dry periods since 1900.

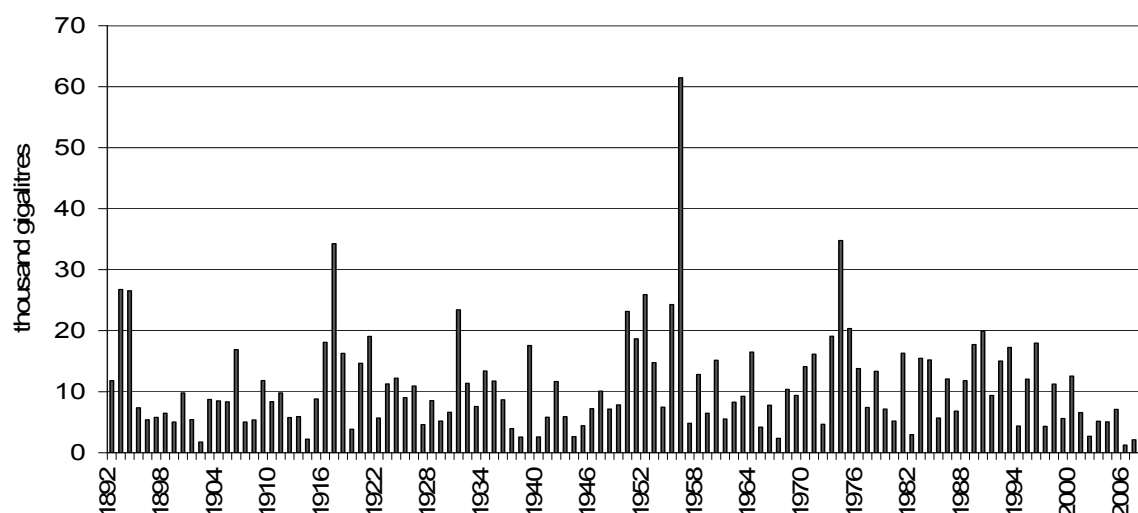
## How does the current hydrological drought compare to the past?

Rainfall over the Murray-Darling Basin from 2002 is close to the lowest on record:

Averaged over the Murray-Darling Basin as a whole, seven-year rainfalls [October 2001 to September 2008] are slightly higher than the driest seven year totals recorded during the 1937-46 period. When comparing rainfall deficits in the Murray-Darling Basin on timescales of five-to-ten years, the post-2001 period, the 1937-46 period and the 1895-1903 period (the 'Federation Drought') are essentially indistinguishable in broad terms. (BoM 2008, p. 2)

The run-off and inflows over this period are, however, easily the lowest on record. Inflows to the Murray system for the period 2002 to 2007 averaged 3986 gigalitres per year. The previous lowest six year average inflows were 5501 for 1940 to 1945 and 5707 for 1897 to 1902 (figure 3.6).

**Figure 3.6 Murray system inflows (including Darling), 1892 to 2008**



<sup>a</sup> Excludes any Snowy Scheme releases into the Murray. The data is generally modelled on current conditions, produced from tributary models running at the current level of development. The models are steady state (with no increased regulation or extraction through time). Where modelled data are unavailable (post 2000) observed data are used.

*Data source:* Murray Darling Basin Commission (2008 unpublished).

With respect to the last ten years, Manton states:

In the southern part of the Murray-Darling Basin, a mean rainfall reduction of 13 per cent over the last decade has led to a mean runoff reduction of 39 per cent. During the similar drought period of 1937-1946, a rainfall reduction of 14 per cent was associated with only a 22 per cent runoff reduction. (Manton 2008, p. 11)

It is normal for a given reduction in rainfall to cause a greater reduction in run-off and inflows into rivers, due to evaporation and retention of water in the soil. It is apparent, however, that the quantity of inflows resulting from a given amount of rainfall has been particularly low over the last ten years. Manton (2008) identifies changes in the seasonality of rainfall and increased temperatures as contributors to this change. Changes in land-use and agricultural practices may also have contributed to the very low inflows of recent years.

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While much of Australia's agricultural land received close to average or above average rainfall in 2008, the hydrological drought in the Murray-Darling Basin has become worse. Murray system inflows in the autumn of 2008 were not much higher than the record lows seen in 2007 (MDBC 2008).

For dryland cropping, farmers rely solely on rainfall. For irrigated agriculture, however, there is not such a direct relationship between inflows to water systems and water used. What matters most to irrigation farmers is the annual allocation they receive on their entitlement, together with the price of traded water (particularly when allocations are low).

Water entitlements vary in their degree of security — irrigators most commonly hold either 'general security' or 'high security' entitlements. The NSW Irrigators Council reported:

In current circumstances, irrigators on the NSW Murray River with General Security entitlement are facing a third consecutive year of zero allocations. (sub. 62, p. 4)

Table 3.6 shows that allocations for high security entitlements have also declined dramatically in recent years for irrigators serviced by Goulburn-Murray Water in Victoria.

Table 3.7 shows a different pattern for major irrigation schemes in Queensland (many of which are not in the Murray-Darling Basin), with less severe shortfalls in the availability of irrigation water in the last two years, but a somewhat greater prevalence of shortfalls in the earlier years of this decade. It should be noted that irrigators in Queensland do not generally hold high security entitlements.

Horticulture Australia Council stated:

In the past one/two seasons, significant numbers of growers have been struggling — for the first time ever — with insufficient water to produce a crop. (sub. 66, p. 1)

This and other evidence demonstrates the unprecedented severity of the hydrological drought in the Murray-Darling Basin in recent years and that this has translated to record low allocations to irrigators. This outcome for irrigators is a result of both low rainfall and inflows, and deficiencies in water policy, as discussed in chapter 10.

**Table 3.6 Goulburn-Murray Water, Victoria: announced allocations by river system, 1992-93 to 2007-08**

Per cent of entitlements<sup>a</sup>

	<i>Murray</i>	<i>Broken</i>	<i>Goulburn</i>	<i>Campaspe</i>	<i>Loddon</i>	<i>Bullarook Creek</i>
1992-93	200+	—	200+	200+	—	—
1993-94	200+	—	200+	200+	—	—
1994-95	220	—	200	180	—	—
1995-96	200	—	150	200	—	—
1996-97	200	—	200	220	—	—
1997-98	130	170	120	190	—	190
1998-99	200	170	100	100	—	190
1999-00	190	170	100	100	—	190
2000-01	200	170	100	220	—	190
2001-02	200	170	100	180	—	190
2002-03	129	100	57	100	—	170
2003-04	100	170	100	100	67	177
2004-05	100	170	100	39	100	190
2005-06	144	170	100	31	100	190
2006-07	95	77	29	0	0	36
2007-08	43	71	57	18	5	0

<sup>a</sup> Percentage of water right until 2006-07, then percentage of high-reliability water shares.

Source: Goulburn-Murray Water (2008).

**Table 3.7 SunWater, Queensland: announced allocations by scheme, 2000-01 to 2007-08<sup>ab</sup>**

Per cent of irrigation customer allocations<sup>c</sup>

	<i>Burdekin-Haughton</i>	<i>Bundaberg<sup>d</sup></i>	<i>Nogoa-Mackenzie</i>	<i>Mareeba-Dimbulah</i>	<i>St George</i>	<i>Dawson Valley<sup>e</sup> Upper</i>	<i>Lower</i>
2000-01	98	76	100	100	114	80	80
2001-02	100	37	100	100	100	100	100
2002-03	100	100	100	100	100	100	100
2003-04	100	100	100	100	100	100	100
2004-05	100	100	100	100	80	88	100
2005-06	100	100	100	100	85	86	100
2006-07	100	46	80	100	89	48	49
2007-08	100	81	100	100	96	100	82

<sup>a</sup> The six largest SunWater schemes (based on customer allocations) are included and these are listed from largest to smallest. <sup>b</sup> The data for 2000-01 and 2001-02 are as reported in SunWater annual reports. The data for later years are the highest announced allocations for each year, as reported on SunWater's website. <sup>c</sup> The term 'customer allocation' as used in Queensland is equivalent to the term 'entitlement' as used in Victoria.

<sup>d</sup> Excludes 'Burnett Water'. <sup>e</sup> Separate data for the Upper and Lower sub-schemes were not available for 2000-01 and 2001-02 and so the overall scheme allocation percentages have been used for these years.

Sources: SunWater (2001, 2002 and 2009).

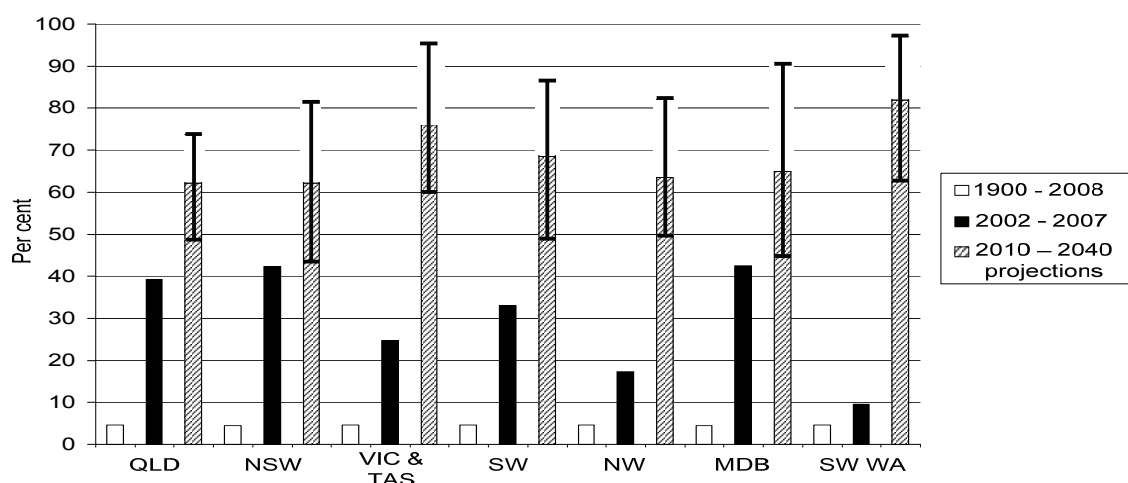


## What is projected for the future?

Hennessy et al. (2008) used climate models that incorporate the influence of emissions of greenhouse gases to project likely changes in exceptional climatic events through to 2040. Figure 3.7 shows that even their ‘low’ projections would see exceptionally hot years occurring far more frequently over the period 2010 to 2040, than has been experienced in the past. They concluded:

... the analysis clearly shows that the areal extent and frequency of exceptionally hot years have been increasing rapidly over recent decades and this trend is expected to continue in future. (Hennessy et al. 2008, p. 13)

**Figure 3.7 Simulated percentage area having exceptionally hot years<sup>a</sup>**

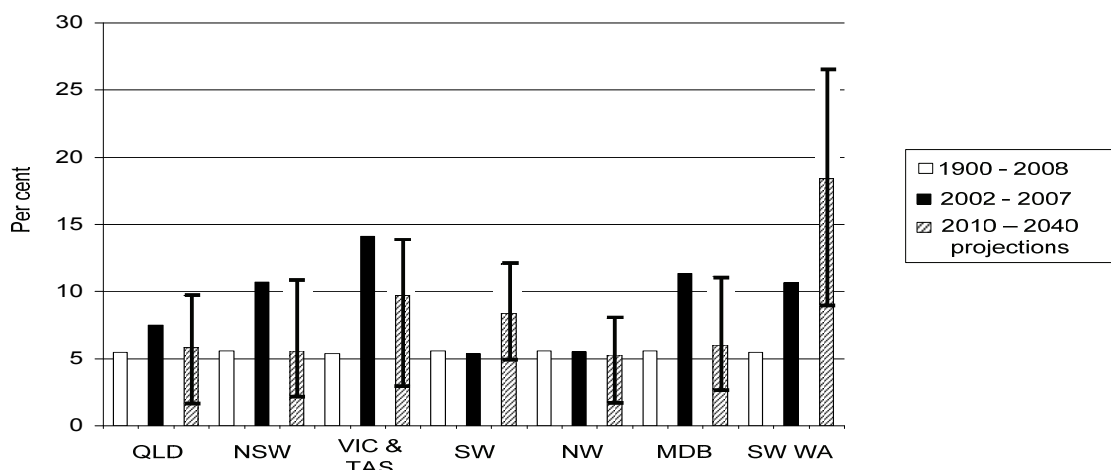


<sup>a</sup> The tops and bottoms of the error bars shown for the 2010–40 projections represent the highest and lowest ten per cent of the model results respectively.

Data sources: Hennessy et al. (2008); BoM (2009 unpublished).

The projections for exceptionally low rainfall show a much less clear difference between what has been experienced in the past and what can be expected in the future (figure 3.8). The mean projections are for exceptionally low rainfall years to occur with roughly the same frequency for 2010–40 as for 1900–2008 in Queensland, New South Wales, Northwest Australia and the Murray-Darling Basin but with substantially greater frequency in Victoria and Tasmania, Southwest Australia and the southwest of Western Australia. The difference between the ‘high’ and ‘low’ projections are, however, very large. For most regions the available science leaves open the possibility that severe drought over the next thirty years could either be more prevalent or less prevalent than in the past.

**Figure 3.8 Simulated percentage area having exceptionally low annual rainfall<sup>a</sup>**



<sup>a</sup> The tops and bottoms of the error bars shown for the 2010–40 projections represent the highest and lowest ten per cent of the model results respectively.

*Data sources:* Hennessy et al. (2008); BoM (2009 unpublished).

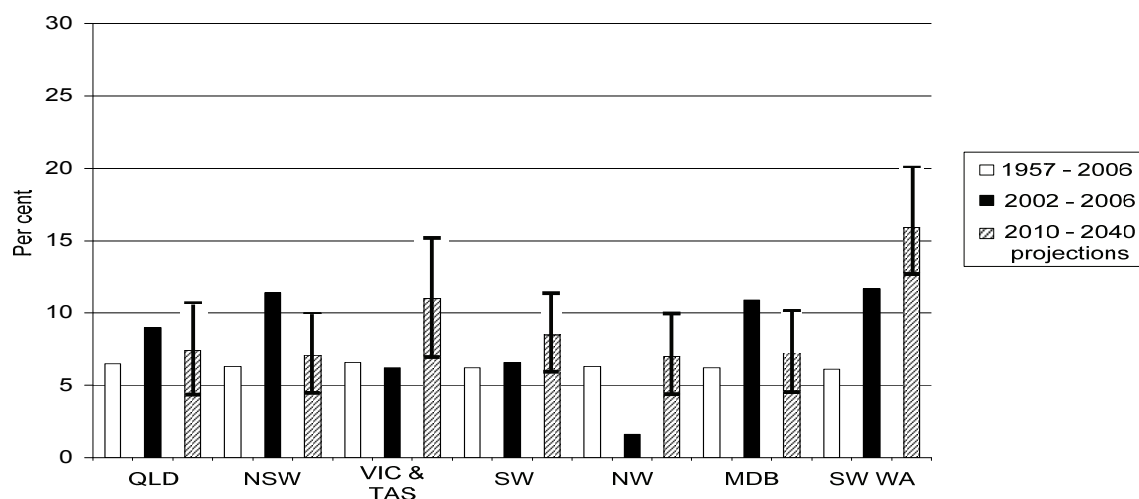
The projections for exceptionally low soil moisture are fairly similar to those for exceptionally low rainfall, except that on the soil moisture measure the chance that the future will be drier than the past is generally somewhat higher (figure 3.9). The reason for this is that both rainfall and evaporation influence soil moisture and projected temperature increases are expected to increase evaporation.

The projections for Australia’s climate through to 2040 make it clear that farmers and other Australians should be prepared for a hotter future. The outlook for rainfall is less certain, but for some areas there is a likelihood of lower rainfall. Accordingly, whether a dryland farm business is prepared for, and able to be self-reliant through the droughts that have occurred in Australia’s past remains a relevant minimum benchmark. As discussed in chapter 8, resources should be (and are being) devoted to climate science and modelling to try to give greater clarity to the outlook for regional climate futures.

The outlook for inflows to the Murray-Darling system, and other water systems used for irrigation, is more negative than the outlook for rainfall. This is because of a range of factors that may lead to a continuation of the trend toward lower proportions of rainfall ending up as inflows. These factors include:

- higher temperatures due to climate change leading to increased evaporation
- increased use of farm dams that intercept water that would otherwise have become inflows

**Figure 3.9 Percentage area having exceptionally low annual average soil moisture, historic and simulated future<sup>a</sup>**



<sup>a</sup> The tops and bottoms of the error bars shown for the 2010–40 projections represent the highest and lowest ten per cent of the model results respectively.

*Data sources:* Hennessy et al. (2008); BoM (2009 unpublished).

- conversion of grazing land to plantation forests that generally use more water
- increasing water use by native forests that regenerated following recent bushfires<sup>4</sup>
- increasing on-farm physical water-use efficiency, which reduces the volume of water that leaves the farm in the form of surface flows or groundwater recharge (van Dijk et al. 2006; PC 2006).

In addition, community expectations and government policy support an increase in the proportion of water resources allocated to environmental flows, further reducing the amount of water for irrigation.

The outlook for the future, therefore, is that there is likely to be substantially less water available for irrigation and its supply may become more variable. The consequences for irrigators depends in large part on water policy, as discussed in chapter 10.

The expected impacts of climate change on agriculture extend beyond changes in the severity and frequency of drought. These other impacts are in some cases likely to increase agricultural output (for example, higher atmospheric carbon dioxide concentrations). A paper commissioned for the Garnaut Climate Review estimated

<sup>4</sup> Very young forests use relatively little water, but as they grow, water use increases substantially. Water use declines somewhat as forests reach maturity.

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that wheat yields in many parts of Australia were likely to increase as a result of climate change through to 2030, despite some of the regions concerned being expected to have reduced rainfall (box 3.4).

#### **Box 3.4      Impacts of climate change on agriculture**

A considerable amount of research is being conducted in Australia on the likely impacts of climate change on agriculture. The following examples illustrate that changes in the frequency and severity of droughts is only one of a number of expected changes to the climate that may impact on agriculture over the next few decades.

##### **Wheat yields**

The Garnaut Climate Change Review presented estimates of changes to wheat yields resulting from human-induced climate change for ten sites across Australia's wheat growing areas (Garnaut 2008). The estimates, which draw on Crimp et al. (2008), take into account likely changes in temperature, rainfall and carbon dioxide concentrations. It is assumed that farmers will adapt to the changing climate, for example, by changing planting times and wheat cultivars to make use of longer growing seasons.

The estimates suggest that climate change up to the year 2030 is likely to be a net positive for wheat yields for at least nine of the ten sites examined, regardless of whether global mitigation action is taken to reduce greenhouse gas emissions. The estimates are for increases ranging from 1.6 per cent to 20.6 per cent, relative to 1990 yields. For the tenth site, Minnipa in South Australia, the estimates are for a 0.8 per cent increase with no mitigation and a decrease of up to 7.4 per cent with mitigation.

##### **Value of irrigated agricultural production**

The Garnaut Review also presented estimates of changes in the value of irrigated agricultural production in the Murray-Darling Basin resulting from human-induced climate change, based on Quiggin et al. (2008). The estimates take into account likely changes in river system inflows, but not yield responses to increases in temperature or carbon dioxide concentrations. It is assumed that farmers optimally adapt to changing conditions but that existing institutional arrangements are retained.

It is estimated that the value of irrigated agricultural production in the Murray-Darling Basin will decline relative to a world with no human-induced climate change. In 2030 declines of between 3 and 12 per cent are estimated, depending on the strength of global mitigation. With no mitigation the value of agricultural production declines sharply after 2030.

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**Box 3.4** (continued)**Overall assessment**

ABARE has used general equilibrium models to analyse the impacts of climate change on Australian agriculture (Gunasekera et al. 2007 and 2008). Its approach takes into account both the impacts of climate change on the productivity of Australian agriculture and international impacts that influence demand for Australia's agricultural exports (such as the global impacts of climate change on agricultural production and economic activity). Assumptions include no mitigation and no planned adaptation to climate change.

ABARE's illustrative modelling results are that Australian agricultural output will be around 38 per cent higher in 2030 than in 2006, whereas it would be around 48 per cent higher in 2030 in a world without climate change. In other words, a decline of 6.8 per cent ( $((1.48-1.38)/1.48)*100 = 6.8$ ) relative to what would have occurred without climate change (rising to 11.5 per cent in 2050) (Gunasekera et al. 2008).

## Annex: Rainfall by district

Rainfall averages for large regions, such as those reported on in Hennessy et al. (2008) and in the body of this chapter, are likely to mask trends for smaller areas. To explore this, a range of rainfall statistics was compiled for 33 of the 110 Australian Rainfall Districts used by the Bureau of Meteorology (table 3.8). The selections were made such that each of ABARE's 33 regions are at least partially represented. ABARE's regions tend to be smaller in areas of Australia that are most important for agriculture and so selecting rainfall districts in this way gives greater representation to important agricultural areas.

Table 3.8 shows there are areas that have experienced trends in the severity of drought that are quite different to those for the larger region that they are part of. For example, while for Queensland as a whole rainfall for the period 2002 to 2007 was 14 per cent higher than for 1900 to 1905 (table 3.5), for the Central Highlands district, 2002 to 2007 had the lowest rainfall for any six year period since 1900.

**Table 3.8 Rainfall statistics for selected Australian Rainfall Districts<sup>a</sup>**

<i>Rainfall district (name and number)</i>	<i>Exceptionally low rainfall (% incidence)</i>			<i>Average annual rainfall (mm)</i>		
	<i>1900- 2008</i>	<i>1993- 2008</i>	<i>2002- 2007</i>	<i>1900- 2008</i>	<i>1993- 2008</i>	<i>2002- 2007</i>
<i>Queensland</i>						
North Peninsula (27)	5.5	–	–	1344	1465	1378
Upper Carpentaria (30)	5.5	–	–	634	640	597
Barron North Coast (31)	5.5	6.3	16.7	1455	1545	1399
Central Highlands (35) <sup>d</sup>	5.5	6.3	16.7	612	559	506
Central Lowlands (36)	5.5	6.3	16.7	480	465	406
Lower Western (37)	5.5	6.3	16.7	228	234	189
Moreton (40) <sup>d</sup>	5.5	6.3	16.7	957	856	788
East Darling Downs (41)	5.5	–	–	650	618	562
<i>New South Wales (including ACT)</i>						
Western (Far NW) (46) <sup>b</sup>	5.5	12.5	16.7	231	222	185
Central Western Plains (50)	5.5	6.3	16.7	480	469	401
Northwest Plains (E) (53)	5.5	6.3	16.7	609	641	578
Central Tablelands (S) (63)	5.5	6.3	16.7	805	749	694
Illawarra (68)	5.5	–	–	1077	930	918
Goulburn-Monaro (70)	5.5	6.3	16.7	702	640	594
Riverina (E) (74)	5.5	6.3	16.7	466	439	388

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Table 3.8 (continued)

Rainfall district (name and number)	Exceptionally low rainfall (% incidence)			Average annual rainfall (mm)		
	1900- 2008	1993- 2008	2002- 2007	1900- 2008	1993- 2008	2002- 2007
<i>Victoria</i>						
South Mallee (77) <sup>b</sup>	5.5	6.3	16.7	370	344	320
South Wimmera (79) <sup>c</sup>	5.5	6.3	16.7	548	488	463
Upper North (80) <sup>b</sup>	5.5	6.3	16.7	535	493	438
West Gippsland (85)	5.5	12.5	16.7	847	785	761
<i>Tasmania</i>						
Midlands (93) <sup>be</sup>	5.5	12.5	16.7	611	541	518
<i>South Australia</i>						
Western Agricultural (18)	5.5	6.3	–	278	276	269
Far North (17)	5.5	6.3	–	160	164	127
Lower Murray Valley (24B)	5.5	–	–	391	380	374
Lower Southeast (25B)	5.5	6.3	16.7	620	562	552
<i>Western Australia</i>						
East Kimberley (2)	5.5	–	–	575	759	708
Fortescue (5)	5.5	–	–	313	385	316
North Coast (8) <sup>c</sup>	5.5	6.3	16.7	379	356	304
South Coast (9A) <sup>d</sup>	5.5	12.5	16.7	774	725	710
South Central (10A)	6.4	12.5	16.7	425	400	384
<i>Northern Territory</i>						
Darwin-Daly (14GA)	5.5	–	–	1183	1386	1351
Victoria (14F)	5.5	–	–	571	726	702
Barkly (15A)	5.5	–	–	428	506	493
Alice Springs (15B)	6.4	6.3	–	278	315	275

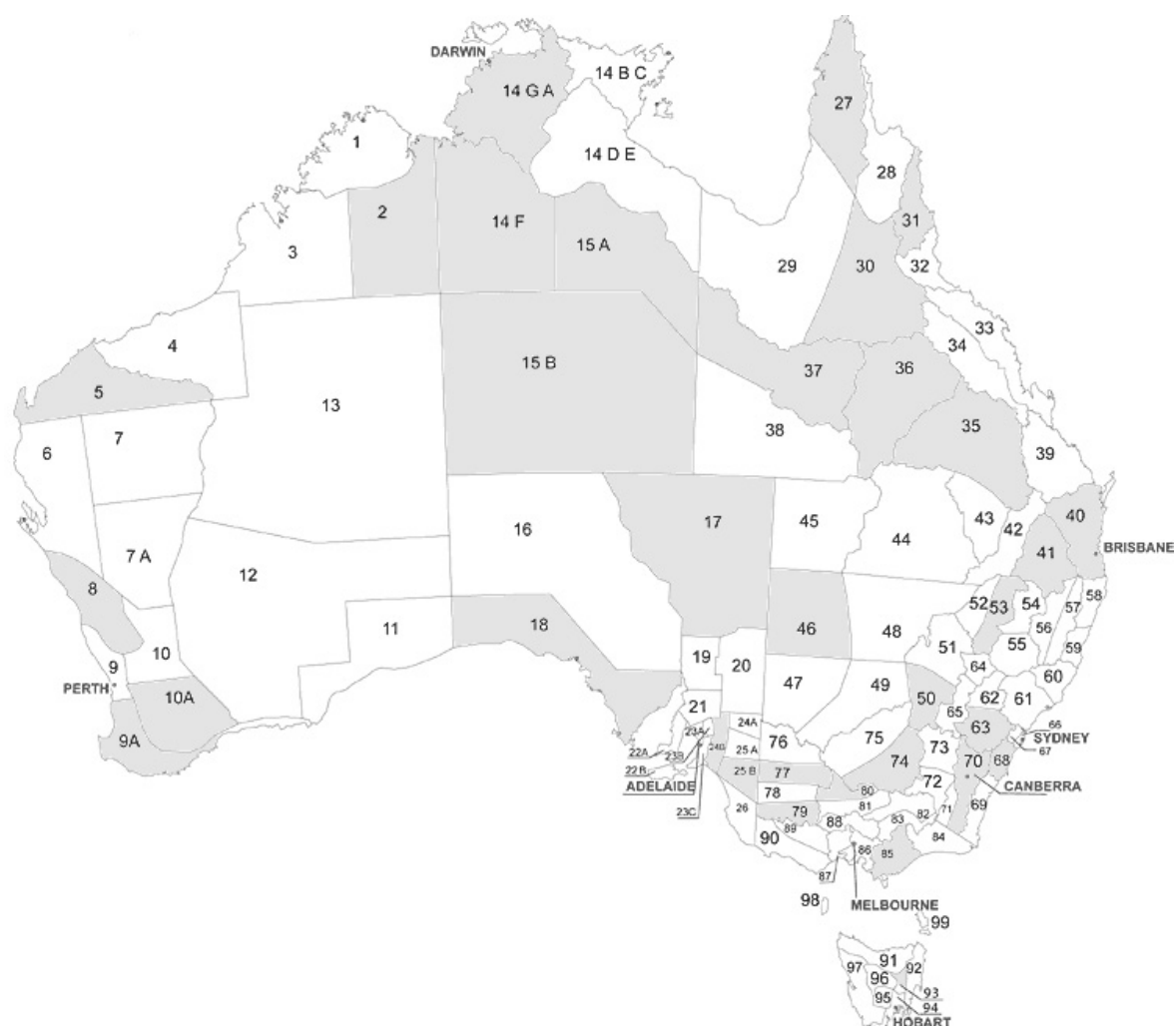
<sup>a</sup> Annual rainfall data averaged across each district was used for this table. Accordingly, each year either is, or is not, an exceptionally low rainfall year. Therefore, the incidence of exceptionally low rainfall (that is, the proportion of years within the period that fit this criteria) is reported, in contrast to the earlier tables, which report the areal extent of exceptionally low rainfall (the percentage of the region that fits this criteria each year, averaged over the period). <sup>b</sup> Incidence of exceptionally low rainfall for 2002-07 is matched but not exceeded by other six year periods since 1900. <sup>c</sup> Average annual rainfall for 2002-07 is the lowest for any six year period since 1900. <sup>d</sup> Average annual rainfall for 2001-06 is the lowest for any six year period since 1900. <sup>e</sup> Average annual rainfall for 2003-08 is the lowest for any six year period since 1900. – Nil or rounded to zero.

Data source: BoM (2009 unpublished).

Seven of the 33 districts (18 per cent) experienced the six year period with the lowest rainfall since 1900 sometime during the period 1998 to 2008. This is exceeded only by the period 1935 to 1945, during which nine of these districts experienced the six year period with the lowest rainfall.

The locations of the selected rainfall districts are shown in figure 3.10.

Figure 3.10 Australian rainfall districts<sup>a</sup>



<sup>a</sup> Shaded districts are those included in table 3.8.

Source: Bureau of Meteorology (2004).