Current water availability and use

Ian Prosser

Key messages

- Overall, Australia has sufficient water resources to support its current uses, consuming 6% of renewable water resources each year.
- Current use of rainfall and water resources in effect meet the needs of more than 60 million people, through Australia's exports of agricultural produce.
- A very uneven distribution of water resources across Australia and high year-to-year variability means that water resources in some regions are fully or over allocated, while others remain largely undeveloped.
- Australia's arid landscape and high potential evaporation pose challenges from the high demand for water by crops and cities, and large water losses from reservoirs and inland rivers.
- Some water resources are at risk from bushfires and unlicensed uses, which can reduce water availability to licensed users.

A summary of Australia's water resources and their use

A pervasive question is whether Australia has sufficient water resources to meet current and future uses. To answer that question fully, requires considerations of sustainability and likely changes to the resource as a consequence of climate change, but the key starting point is to compare Australia's water resources with the uses placed on them.

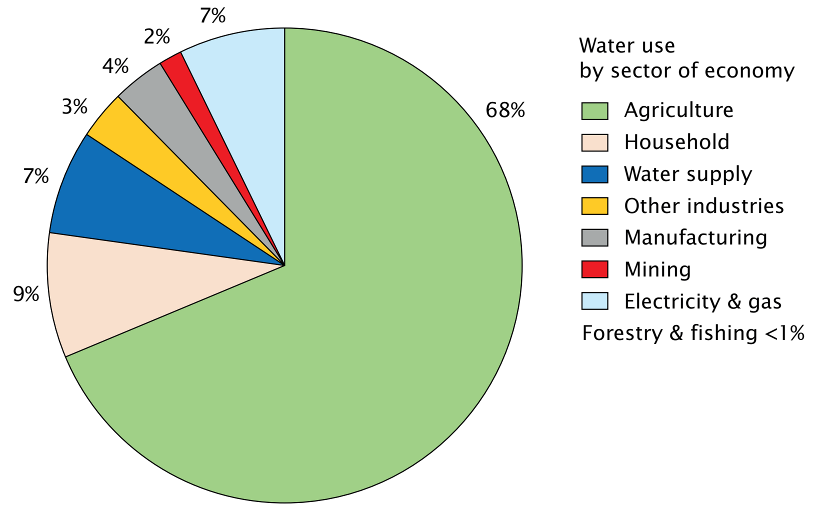
Australia receives an average of 417 mm of rainfall per year (Table 1.1),[1] which adds up to 3 700 000 GL of water per year (a gigalitre is 1×10^9 litres). Rainfall supports Australia's dryland (non-irrigated) agriculture and some domestic water supplies (via rainwater tanks), but is not itself considered a water resource for statutory water management. It is only when rainfall runs off into creeks, rivers, and lakes or recharges groundwater aquifers that it becomes a managed resource.

The sum of runoff and recharge is the total renewable water resource. It can be extracted, stored, managed, regulated, distributed, and used for a range of purposes. On average, only 9% of rainfall in Australia becomes runoff, and approximately 2% percolates through the soil to recharge groundwater (Table 1.1).[2] The rest evaporates back into the atmosphere, mainly through vegetation.

Table 1.1: Water use compared with average total renewable resource.[1, 2, 3]

	Average annual fluxes
Rainfall	3 700 000 GL (417 mm of rainfall)
Runoff	350 000 GL (9% of rainfall)
Groundwater recharge	64 000 GL (2% of rainfall)
Total renewable water resources	414 000 GL (11% of rainfall)
Evapotranspiration	3 286 000 GL (89% of rainfall)
	Average annual fluxes
Total extraction	72 431 GL (17% of renewable resource)
Total consumption	24 449 GL (6% of renewable resource)

Only a small proportion of Australia's renewable water resources is consumed each year. The Australian Bureau of Statistics produces reports on water use every 4 years. Levels of water use in 2008–09 and 2004–05 were reduced by drought across southern Australia so the statistics for 2000–01 are used here to better reflect unrestricted demand for water. In 2000–01, of the total 72 431 GL that was extracted for use, 47 982 GL was returned to rivers, mainly being used for hydroelectric power generation, and 24 449 GL was consumed by industry, households, and agriculture (Table 1.1). Of the water consumed, 68% was used in irrigated agriculture to produce food and fibre, 23% was consumed in various industries, and 9% was taken for household water use (Figure 1.1). It will be interesting to see the next set of statistics on water use because restrictions on use have eased and the population has increased, but people are now more conscious of water conservation.



▸ ***Figure 1.1**: Water consumption by different sectors of the economy for 2000–01. Consumption in the water supply industry is mainly the losses of water that occur in supplying water and providing sewerage services.[3]*

Australia is a generally arid continent but it uses only a low proportion of its water resources compared with other regions of the world (Table 1.2). It is the driest populated continent, and has the lowest proportion of rainfall converted to runoff,[4] giving it slightly less water per unit area than any other region of the world (Table 1.2). However, Australia has by far the lowest population density of any major region, so it has moderately plentiful water resources per person and consumes a smaller percentage of its water resources than other dry regions and the most densely populated regions of the world (Table 1.2).

Table 1.2: Global comparison of water resources and use.[5]

Region	Available water per area	Population density	Available water per capita	Water consumed	Consumption per resource
	ML/ha	People/km²	ML/person/year	10^3GL/year	%
Australia[(a)]	0.5	2.5	21.3	25	6.0
North America	2.8	20.7	13.4	603	9.9
Central America	11.2	115.7	9.6	23	2.9
Southern America	6.9	21.5	32.2	165	1.3
Western and Central Europe	4.3	107.1	4.0	265	12.6
Eastern Europe	2.5	11.5	21.4	110	2.5
Africa	1.3	32.7	4.0	215	5.5
Middle East	0.8	47.1	1.6	271	56.0
Central Asia	0.6	18.5	3.0	163	62.0
Southern and Eastern Asia	5.5	174.4	3.2	1991	17.1
Oceania and Pacific[(b)]	1.1	3.3	33.0	26	2.9
World	3.2	50.4	6.4	3832	8.9

(a) Data from Table 1.1
(b) Includes Australia

Inspecting rice near Yenda, New South Wales. Photo: Greg Heath, CSIRO.

Australia's water resources are in effect used to support more than our domestic population of 22 million people. Water is used in the production of almost all goods and services, and particularly in the production of food and fibre (e.g. cotton). For instance, it takes about 8000 L of water to produce a pair of leather shoes and about 5000 L of water to produce a kilogram of cheese.[6] This principle of water required for production can be applied on a global scale to show that some countries, such as Australia, use more water to produce their exports than is embodied in their imports. Countries with very high population densities and only small areas of arable land tend to be net importers of embodied water because they import much of their food and export manufactured goods that require less water.

Australia exports a majority of its agricultural produce and imports many manufactured goods, using far more water to support domestic consumption and exports than is used to produce the imports. Using the data of the Water Footprint Network,[7] Australia is effectively supporting a population of about 67 million people at our own high levels of consumption.

Much of the water used in agricultural produce is rainfall used in dryland agriculture, not water extracted from rivers and groundwater for irrigation. The two types of water should not be compared directly with each other when examining the water use efficiency of different crops. Irrigation consumes water resources from rivers and groundwater, the use of which competes with other uses, including for the environmental values that rivers, lakes, and estuaries support. By contrast, the rainfall that evaporates through dryland crops would also have evaporated through the natural vegetation cover on the land, or other vegetation covers. Only where dryland agriculture reduces the amount of water flowing into rivers and groundwater (perhaps by storing water in farm dams) does it impact on water resources and other water users.

Putting Australia in a global perspective shows that although it has enough water to meet its needs and to support trade, there have still been recent water shortages. The problems emerge in the very uneven distribution of the water and where it is used.

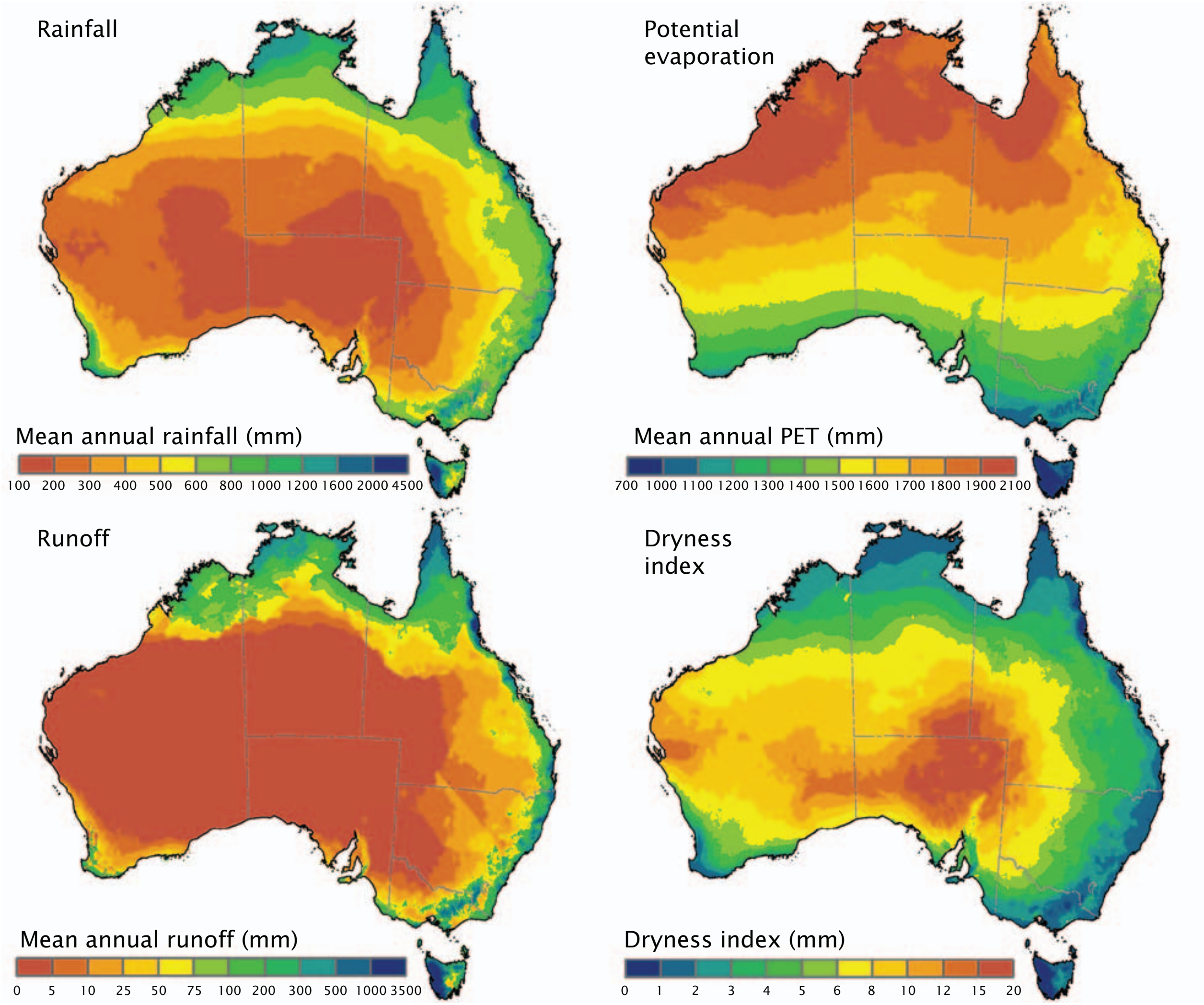
Water resource patterns across Australia

Australia has a thin wet margin and a dry interior. The north, east and south-west coasts and ranges receive moderate to high rainfall while the rest of the continent is dry. A better indicator of the aridity of the continent, though, is the dryness index, which is the ratio of potential evaporation to rainfall (Figure 1.2). Potential evaporation is the amount of evaporation that would occur if an endless supply of water were available, whereas actual evaporation is much lower, because a landscape may be dry for much of the time. If rainfall is insufficient to meet the demand of potential evaporation, the landscape is at least seasonally dry. Where rainfall is greater than potential evaporation, the dryness index is less than 1.0, there is excess water to keep soils moist, excess rainfall becomes runoff and plant growth is not limited by water availability. On a mean annual basis, only western Tasmania, the Australian Alps and the Wet Tropics have a dryness index less than 1.0.

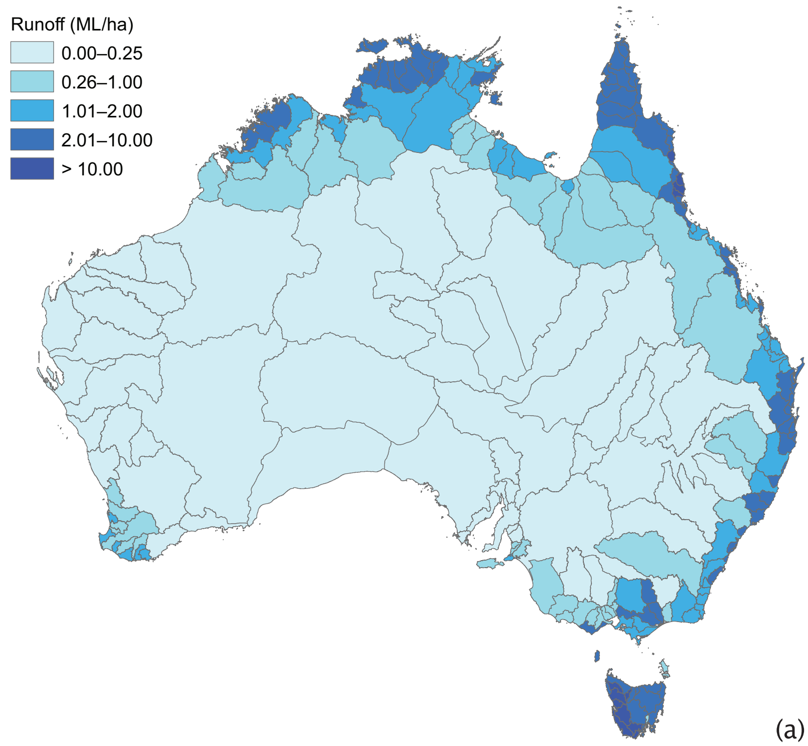
Where the dryness index is greater than 1.0, the landscape is water-limited for at least part of the year and plant growth is limited by water availability. The larger the dryness index, the greater the moisture deficit and the lower the amount of runoff. Most of Australia is water-limited, producing little runoff either seasonally or over the whole year. These annual averages mask strong variations between years, controlled by climate variability. Almost every year, some part of Australia experiences drought, where low rainfall and high potential evaporation cause more intense aridity than normal, and this can persist for several years.

Not only are Australia's water resources concentrated around the coastal rim, so too is its population and water use. Figure 1.3(a) shows how the pattern of runoff is distributed as surface water resources among the 224 river basins in Australia. Figure 1.3(b) shows what proportion of surface water resource is used. Water use is greater than 40% of the surface water available in and around capital cities and across the Murray–Darling Basin. Small coastal rivers tend to have higher rates of use than the larger rivers, showing that intense use is local, close to the coast and does not fully utilise the resources of the larger basins.

The Murray–Darling Basin is Australia's most developed rural water resource, where 48% of surface water is consumed on average each year, mainly in the southern part of the Basin.[8] This water resource is considered to be over allocated[9,10] in the sense that the high levels of water use have degraded the rivers and wetlands that rely on them (see Chapter 9). Coastal cities largely rely upon small river basins that are fully developed, so water is transferred from neighbouring river basins (e.g. piping water from the Thompson River in Victoria to supply Melbourne or from the Shoalhaven River to supply Sydney). Water use in other coastal areas of Victoria, New South Wales, Queensland, northern Australia, and much of Tasmania is below 10% of runoff. These are areas with potential for further development, although factors other than water availability need to be considered.



▲ ***Figure 1.2***: *Rainfall, potential evaporation (PET), runoff, and dryness index across Australia. The dryness index is the ratio of potential evaporation to rainfall. Where the dryness index is less than 1.0, there is on average more rainfall than can be evaporated giving large volumes of runoff. Where dryness index values are greater than 1.0, there is a deficit between rainfall and evaporation potential leaving a dry landscape, with little runoff and the need for irrigation to support vibrant plant growth. Rainfall and potential evaporation data were obtained from Bureau of Meteorology databases and runoff is a CSIRO compilation of modelling and measurements.*



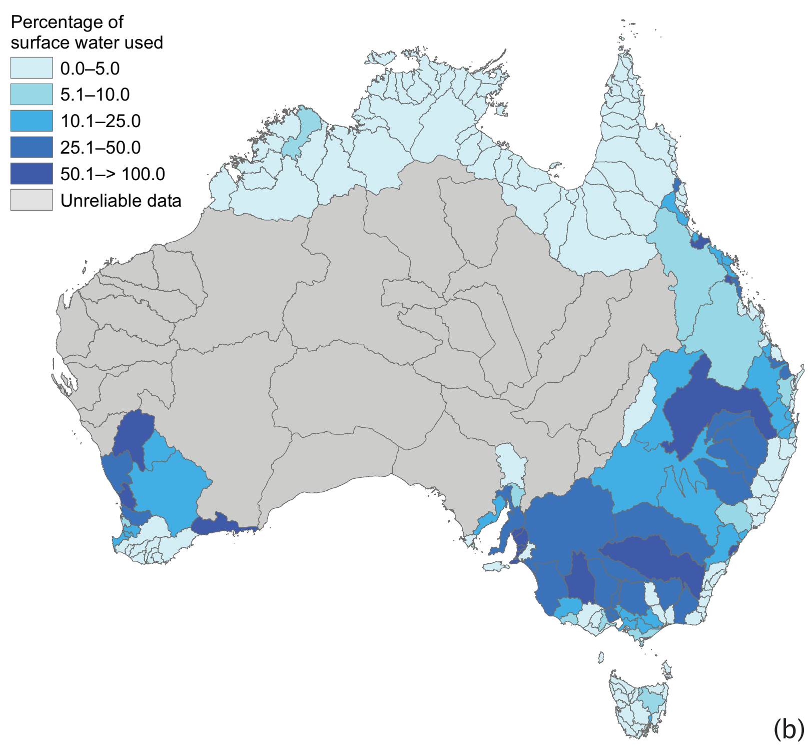


Figure 1.3: *(a) Availability of surface water shown as average annual volume of surface water (ML) per hectare of land for each Australian river basin; (b) Percentage of surface water used for each Australian river basin.*[8,11,12] *Arid areas rely mainly upon groundwater and have unreliable data for surface water use.*

Constraints on water use

Even in the fully developed river basins, only about half of the available surface water is consumed over time. This reflects some physical constraints on water resource development and use as well as limits imposed to protect rivers and wetland environments from degradation. Some of these constraints are more extreme in Australia than elsewhere.

As well as very uneven spatial distribution of water resources, the regions with temperate climate (outside of tropical and desert climates) have the highest year-to-year variability of runoff in the world.[13] For example, in the Murray River a dry year produces approximately one-tenth the river flow of a wet year. Typically, the difference in runoff between wet and dry years in Australian temperate climates is twice that of the northern hemisphere temperate regions. This is partly due to a higher rainfall variability in Australia that is amplified in the amount of runoff, and is linked to the strong influence of El Niño and La Niña seasonal weather patterns and the high potential evaporation of Australia.

The high variability of runoff from year to year puts a constraint on the amount of water that can be reliably supplied even with large storages. In the Murray–Darling Basin in the drier years, which have low flow, more than 60% of all water available is used and in nearly one-third of years more than 70% is used (Figure 1.4). After accounting for the need to leave sufficient water in the river to keep supplying users downstream, no further water could be used. In wetter years, large flows coincide with low demand for water because of the good rainfall, so only a small proportion of water is used. When yearly supply is balanced against demand, only about half of the water is used.

Australia's high potential evaporation and variable runoff mean that very large dams are needed to provide a reliable supply of water to cities. More than 23 000 GL/year is lost to evaporation from Australia's major dams, similar to the volume that is used.[14,15] Wivenhoe Dam stores 10 years of supply for Brisbane when it is full, yet the high evaporation and drought up to 2009 meant it

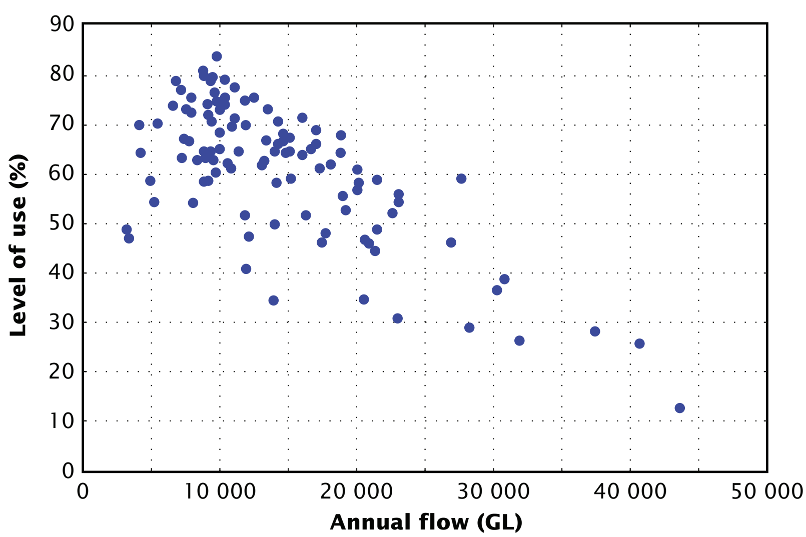


Figure 1.4: *Water used in the Murray–Darling Basin as a percentage of the annual flow at Wentworth. Wentworth is the point of maximum flow in the Basin.[8] In dry years, almost all water is used, while wet years have low levels of use because of both higher supply and lower demand.*

came close to emptying, before rapidly refilling when above average rainfall returned. In large river systems there are also significant losses of river flow as water moves downstream. Across the Murray–Darling Basin there is 28 900 GL/year of runoff on average, but by the junction of the Murray and the Darling Rivers half of this has evaporated or seeped into groundwater.[8] When the sources of water are very distant from the points of use, only a fraction of runoff is usable.

A dry climate means that water use per capita is high. Use in Australian houses is comparable with other cities of the world with similar standards of living, but more water is used outdoors because of the high irrigation demands of gardens and parklands. Domestic water use has decreased in recent years as a result of conservation measures. For example, in cities with hot or dry summers such as Brisbane, Adelaide, and Perth, over 100 kL was consumed per person per year prior to water restrictions and a new focus on water conservation.[16] In European cities with high housing density and low garden watering, use is of the order of 50 kL per person per year. During water restrictions, Brisbane achieved a use of 53 kL per person per year.[16]

A similar situation of high water demand occurs in irrigated agriculture in Australia. The larger the gap between rainfall and potential evapotranspiration, the greater the amount of irrigation water needed to support highly productive agriculture. Some Australian irrigation areas have evaporative demands that are three to eight times greater than the rainfall (Table 1.3).

Table 1.3: Rainfall (P), potential evaporation (Epot), rainfall deficit (Epot-P), and aridity index Epot/P for selected city and irrigation locations.

Location	P[a] (mm/year)	Epot[a] (mm/year)	Epot-P	Epot/P
Brisbane	1046	1821	775	1.7
Sydney	1156	1624	468	1.4
Melbourne	598	1525	927	3.1
Adelaide	500	1751	1251	3.4
Perth	766	1884	1118	2.4
Ord irrigation	870	2535	1665	2.9
Burdekin	569	2229	1660	3.8
Griffith	401	1808	1407	4.5
Narrabri	635	2023	1388	3.2
Renmark	239	1878	1639	7.7

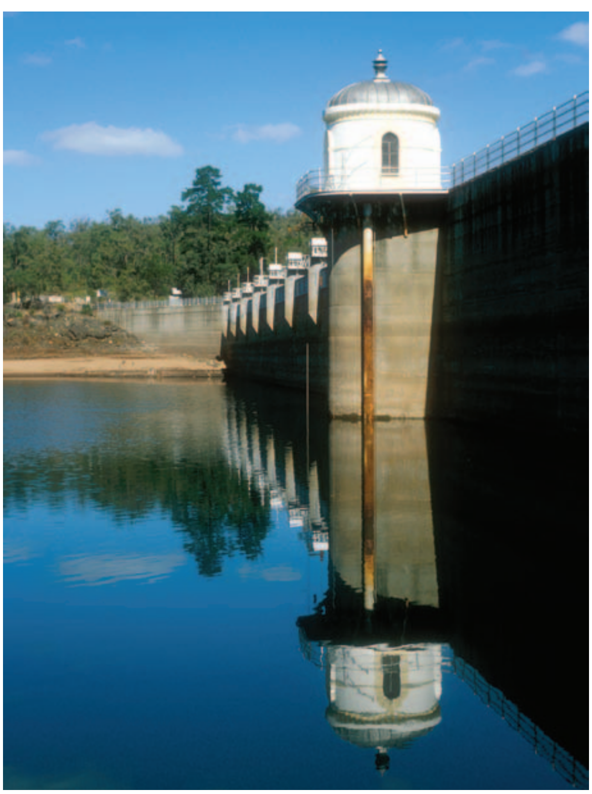
[a] *Obtained from Bureau of Meteorology databases*

Australia is similar to other subtropical and arid continental regions such as India, central and east Asia, and western United States of America in requiring irrigation to support the most productive agriculture. In temperate Europe and America and the Wet Tropics, most agricultural production is supported directly by rainfall.[17]

Opportunities for development of water resources

The contrast of high levels of water use in some basins with low levels of use elsewhere raises the prospect of increasing use by transferring water between river basins. The Snowy Mountains scheme transfers 1000 GL/year from the Snowy River into the Murray–Darling Basin.[18] Several smaller transfers take water from the Murray–Darling Basin to augment supplies for Adelaide and Melbourne. More ambitious schemes such as piping water from northern Australia to the Murray–Darling Basin, the Bradfield Scheme[4] or the proposal to augment Perth's dwindling surface water supplies with a canal from the Fitzroy River in the Kimberley region have all been suggested.

The more ambitious schemes have high financial and environmental costs. For example, the cost of building a canal from the Kimberley in northern Australia to augment Perth's supply was at least $20/kL.[19] Shipping using super-tankers would reduce the cost to $7/kL,[19] and the Perth desalination plant supplies water at $1.16/kL.[20] For irrigation water, the lower price and the larger quantities of water required make these schemes even less financially attractive. For example, a typical supply price for irrigation water is around $33/ML (3 cents/kL), more than 30 times lower than the price for urban water. A proposal to transfer water from the Clarence River into the Murray–Darling Basin, would supply 755 GL/year (7% of water use in the Basin) at a capital cost of



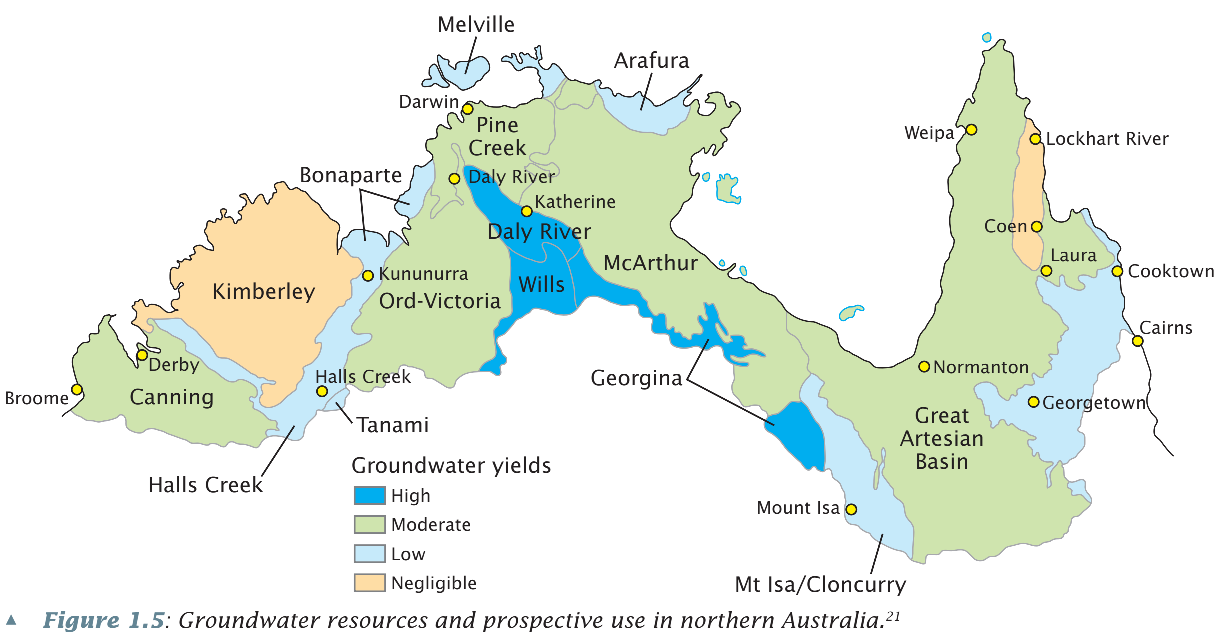
Mundaring Weir, east of Perth, Western Australia.
Photo: Bill van Aken, CSIRO.

$656 million and an operating cost of $130/ML (13 cents/kL).[4] More cost-effective solutions have been used to augment urban water supplies, and irrigated agriculture is being developed where there is more water available, such as in northern Tasmania.

There is renewed interest in developing water resources for irrigation in northern Australia to alleviate the pressure on the Murray–Darling Basin. Runoff from the two drainage divisions in the north is nearly eight times that of the Murray–Darling Basin. Although opportunities for water resource development exist in the north, they are not as straightforward as is suggested by the high runoff because some of the limiting factors of Australia's water resources described above are magnified in the north.

Northern Australia has a hot climate, with most rain falling from November to April. Water is in deficit with rainfall less than potential evaporation for 10 months of the year. The annual rainfall deficit is over 1500 mm/year for much of the region, and crop water demands are very high, as is evaporation from storages (Table 1.3). The ratio of dam storage to supply of water would need to be higher than for southern Australia. Much of the runoff occurs as major floods, which can be a hazard rather than a resource, causing extensive inundation of the lowland regions for weeks to months at a time. Northern Australia has fewer locations for large dams because of its open valleys and, aside from the most easterly ranges, the headwater regions are the driest and hottest parts of the catchments.[21]

Groundwater presents the most attractive opportunities for irrigation, with approximately 600 GL/year of groundwater available (Figure 1.5). The Daly, Wiso, and Georgina groundwater provinces in the Northern Territory and north-western Queensland have the greatest potential, although the Daly province is almost fully allocated. The Canning (east of Broome), Ord-Victoria



▲ ***Figure 1.5**: Groundwater resources and prospective use in northern Australia.[21]*


Maroondah Reservoir, near Healesville, Victoria. Photo: Nick Pitsas, CSIRO Publishing.

(east of Kununurra), Pine Creek (south-east of Darwin), McArthur and Great Artesian provinces could each be expected to deliver 10 to 100 GL of groundwater a year.

Water availability is just one factor contributing to irrigation development and is probably not the limiting factor in northern Australia at present. Other factors that need to be considered include suitable land and crops, and access to infrastructure, workforce, and markets.

Risks to water availability and use

The amount of water that is available to licensed users in the future is at risk from external impacts on the resource such as climate change and bushfires, and internal risks created by the way water use is licensed and managed. The main risks that have been identified are:

- climate change (see Chapter 3)
- bushfires
- plantations and other revegetation
- farm dams
- floodplain harvesting
- unlicensed groundwater bores (see Chapter 4)
- double accounting of surface and groundwater (see Chapter 4)
- mining water use (see Chapter 10)
- reduced return flows from irrigation (see Chapter 8).

Bushfires pose a risk to water availability when regenerating forests use more water than the mature forest they are replacing. This effect is most pronounced in the ash forests of south-eastern NSW and Victoria where the trees usually do not survive fire. The density of regrowth can reduce runoff for several decades. The major bushfires in Victoria in 2003 and 2006–07 burnt over a million hectares of forest. Their combined impact on the Murray River (at the confluence with the Ovens River) is expected to be 255 GL/year reduction or approximately 3% of the average annual flow.[22]

Forest plantations and farm dams use significantly larger volumes of water than the agricultural practices that they replace, so their expansion can reduce the amount of runoff in rivers. It is where plantations replace pastures, rather than existing forests, that water use increases significantly.

Floodplain harvesting, unregulated groundwater bores, and mining are direct uses of water that may not have water access entitlements and can impact on users with entitlements to the resource. These activities, together with plantations and farm dams, are termed 'intercepting activities' because they intercept (or use) water that would otherwise have contributed to the formal water resource. Their use is hard to measure, but a national assessment (Table 1.4) indicates that significant volumes of water are involved. Intercepting uses that have been in place for decades are not of concern because their use of water would have been included in assessing how much water was available and distributing that across entitlements. It is the future expansion of intercepting land activities that poses the larger risk because it reduces the amount of water available to those with entitlements. Although the projected future volumes in Table 1.4 are small on a national scale, development is usually focussed in particular valleys, where impacts can be locally significant.[23] Where there are significant impacts from intercepting land uses, a possible solution is to bring the uses into the system of entitlements.

Table 1.4: National assessment of intercepting activities.[23]

Activity	Current water use (GL/year)	Potential additional water use to 2030 (GL/year)
Plantations	2000	62
Farm dams	1600	300
Floodplain harvesting	890 [(a)]	0 [(b)]
Stock and domestic groundwater bores	1100	286

[(a)] 880 GL of this use occurs in the northern Murray–Darling Basin.
[(b)] Moratoriums on construction of storages are in place.

Better water information for Australia

With increasing demands on Australia's finite water resources, and concerns about risks to the resources, it is imperative that there is accurate information on availability and use of water. Water is a significant business, community, and ecological asset that deserves the same level of accountability as any other asset. There were few reliable and current sources for water information covering the whole of Australia available for compilation in this book. Statistics were highly variable depending on the period reported or the methods used, adding to uncertainty over the scarcity of water across Australia.

To overcome these problems at a national scale, the Bureau of Meteorology has been mandated to compile, analyse, forecast, and report on water across the country.[10] It estimates that water information is collected by some 200 agencies across Australia, and some of it is hard to access and compile to build a national picture. CSIRO is working with the Bureau of Meteorology to develop technologies for automatic accession, processing, analysis, and reporting of this information. Traditional field measurements of rainfall, river flow, and groundwater level, are being complemented with new satellite remote sensing of hard-to-measure water attributes such as the amount of water evaporating through vegetation or seeping from unlined irrigation canals.

The best opportunities come from combining on-ground measurements and remote sensing in computer models to map and forecast the state of water resources across the country. For example, remote sensing from satellites is being used to estimate rainfall between gauges that are widely spread across the landscape, to measure flows on floodplains, or to measure use of water by crops (Figure 1.6). An example of new seasonal forecasts of river flow is given in Chapter 3.

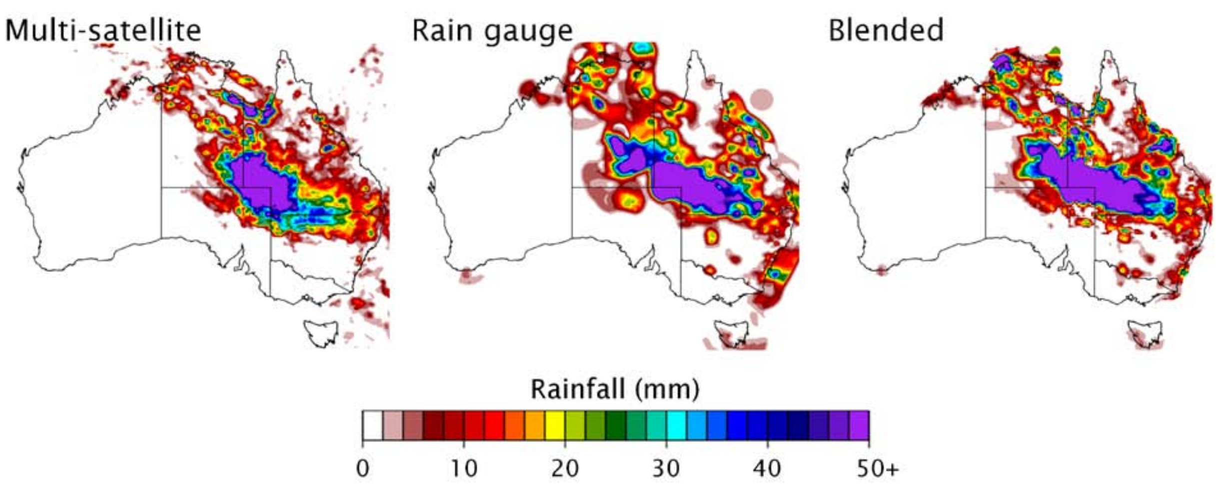
Farm dam near Wallacia, New South Wales. Photo: Greg Heath, CSIRO.

Conclusions

Australia is only partly a dry continent. It is a continent with a thin wet margin, where most of the population lives, but it is also sparsely populated and uses only a small proportion of its water resources. Australia exports much of its agricultural produce and its use of rainfall and water resources is enough to support, in effect, more than 60 million people. There is more than enough water overall to meet the country's needs yet the perception of aridity is real.

Australia's rainfall is notoriously unreliable, and in temperate regions its river flows are the most variable in the world. On top of that, high rates of potential evaporation place large demands on water for the irrigation of crops and household gardens, and results in much water being lost from rivers and dams. Australia has to store very large quantities of water to ensure reliable supplies, and even then some large dams used to supply cities have come close to running dry. The use of water resources is highly concentrated around the large capital cities and in the southern Murray–Darling Basin, which is considered to be over allocated. Future water supplies are at risk from climate change, bushfires, and the way water is licensed for use.

There are opportunities to develop new water resources but these are often, not coincidentally, in places with highly valued aquatic ecosystems, or where there are other factors that limit water use, such as lack of economic opportunity. Questions about the values or benefits obtained from water should be examined before considering whether and how water could be used more effectively.



▲ ***Figure 1.6***: *Rainfall estimates for 1 March 2010. From left to right: from a NASA multi-satellite rainfall product; from analysis of rain gauges; and from combining the gauge and satellite rainfall estimates. The rain front shown led to widespread flooding in southern Queensland and northern New South Wales.*

Further reading

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