A review of CGE modelling of irrigation developments and policies in Australia

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Abstract

Australia is the driest inhabited continent on earth. Its most important irrigation development is in the Murray-Darling Basin, which is relatively adjacent to the majority of Australia's population. CGE modelling using TERM-H2O has demonstrated that attempts to restore the balance between water for economic purposes and water for the environment in the basin will have little impact on regional economies. However, substantial public spending has been on inefficient water infrastructure upgrades to appease concerns about regional economic damage.

Modelling of the Flinders-Gilbert irrigation scheme proposed in far northern Queensland indicates that it is unlikely to yield net economic benefits. Although in theory there is abundant water that irrigators could use, extreme isolation is among the reasons that the scheme is unlikely to be viable. The Ord River scheme, completed in tropical Western Australia in the early 1970s, has created few jobs relative to construction costs.

Research is currently under way on variants of the "Bradfield" scheme. Projects under this scheme aim to use water in remote Queensland for economic purposes.

Introduction

The following sketches CGE modelling that has been undertaken on water allocation issues in Australia. The discussion refers to issues and irrigation schemes in the Murray-Darling Basin, the Flinders-Gilbert basins in far north Queensland, the Ord River scheme in tropical Western Australia and some comments on the "Bradfield" scheme in Queensland. The accompanying presentation will review past CGE modelling studies of irrigation development and issues in Australia.

A recurring theme is that Australia is the world's driest inhabited continent. Water availability and climate have resulted in a large share of the population living in coastal regions, particularly in the south eastern corner. 45% of Australia's land mass is north of the Tropic of Capricorn, yet only 5% of the population lives there, implying a population density of 0.4 people per square kilometre in the north. A sense of under-population and under-development has contributed to the push for irrigation schemes in the north.

Historically, agricultural development in the north has been motivated by multiple objectives. For example, invasions in World War II contributed to propositions over ensuring decades that such development would show the rest of the world that Australia occupied its remote regions. In the present day, growing recognition of the historical affinity of First Nation's people with the land dims such arguments. Development of the Ord River scheme in the far north of Western Australia proceeded over several stages from the early 1960s, when 14,000 hectares of irrigation land were developed. It would appear that the Ord scheme has yielded poor returns from public investment.

Different versions of the multi-regional CGE model TERM have been used to analyse CGE various irrigation projects and water issues.

The Murray-Darling Basin

The Murray-Darling Basin is regarded by analysts as having some of the best legislation concerning water management in the world. The virtues of current arrangements include separation of water rights from land ownership and, mainly in the southern basin, the opportunity for temporary or permanent water trades. Unfortunately, political interference in response to the 2007 Water Act has eroded attempts at environmental improvements.

The basin dominates Australia's irrigation schemes, accounting for two-thirds of Australia's irrigation activities, and producing about 14% of Australia's total agricultural output. Around 26% of Australia's agricultural output is produced by dry-land farming in the basin (ABS 2019).

In 2017-18, agriculture accounted for 2.2% of Australia's GDP. This suggests that irrigated agriculture in the Murray Darling Basin accounts for 0.3% of Australia's GDP (value-added of around $5 billion). We need to keep this figure in mind when recalling that the Australian government has committed $13 billion under the Murray Darling Basin plan. Wittwer and Young (2020) reported that for every $4 spend on infrastructure upgrades in the basin, even with optimistic assumptions (arguably unrealistic) concerning the impact on water availability, there would be a welfare loss of $1.

The Murray-Darling Basin is the most important of Australia's irrigation scheme quite simply because it is close to where most Australians live. Five mainland capitals are either in the basin (Canberra) or within 150 kilometres (Adelaide, Brisbane, Melbourne and Sydney). 57% of Australia's population lives in these cities and another 4.5%, excluding Canberra, live within the basin.

TERM-H2O, originally depicting statistical sub-division regions within the basin, including a number of modifications to depict characteristics of production within the basin. A number of agricultural commodities are produced using either irrigated or dryland technologies within the model. Some factors are highly mobile between different activities. Irrigable land could be used for either irrigated or dryland production, with water requirements (irrigated plus rain) per hectare being fixed for particular crops. In the southern basin, irrigation water is tradable between sectors and regions, with less tradability in the northern basin. The model allows water to move from annuals to perennials during years of water scarcity.

TERM-H2O modelling indicated that water buybacks were the most efficient way of meeting the environmental objectives of the 2007 Water Act. Indeed, voluntary buybacks at market prices, by improving farmers' terms of trade, may raise aggregate consumption in the basin relative to no buybacks (Dixon et al., 2011).

Figure 1: Map of Murray-Darling Basin

How much water flows through the MDB and what happens if water is removed from irrigated activities?

The 140th largest river system in the world, in terms of volumetric flow, discharges around 60,000 GL per annum.[1] The average of the Murray is around 24,000 GL per annum, varying from 5,000 GL in 1902 to 57,000 GL in 1956.[2] The nearest river to the home of GTAP, the Wabash, discharges around 32,000 GL per annum.

[1] https://en.wikipedia.org/wiki/List_of_rivers_by_discharge
[2] https://en.wikipedia.org/wiki/Murray%E2%80%93Darling_basin

The river closest to the Murray in terms of discharge and geographic importance might be the Nile, the longest river in the world. It discharges around 88,000 GL per annum at Aswan, and 44,000 GL per annum in Cairo.

In a live audience, I would undertake a straw poll on what volume of water taken from the Murray Darling Basin should be set aside for the environment. In 2001-02, irrigation water extracted from the basin exceeded 10,000 GL.

In estimating the regional economic impacts of removing water from irrigation activities, we need to remember that only 2% of farmland across the basin is irrigated, and accounts for no more than 35% of output. Dry-land production is much lower per hectare, but accounts for around 65% of farm output in a typical year. Given the impact that drought has on dry-land productivity, potentially reducing output by around 80% in extremely dry years, it follows that dry-land losses have a much greater impact on the basin economy than reducing water allocated to irrigated activities.

CGE modelling can provide insights into major projects even before the model is run, starting with regional data underlying the CGE model. For example, the $13 billion scheme in the Murray-Darling Basin appears excessive when irrigation value-added in the basin is around $5 billion per annum. Scientific analysis indicates that between around 3900 GL and 7500 GL of water rights need to be set aside for the environment if sites of ecological importance within the basin were to have a reasonable chance of surviving in the long term. While the price of permanent water (i.e, an ongoing right) varies according to seasonal conditions, rising in drought, $13 billion may have been a much larger sum than necessary to purchase 7500 GL of water rights. At present, around 2000 GL have been purchased, with billions already spent on infrastructure upgrades with sub-economic returns and dubious environmental benefit.

It would have been much better value for public money to spend a couple of billion dollars more on purchasing a couple thousand more gigalitres for the environment and then undertaking additional spending on essential services in the basin. Every dollar spent on essential services in the basin creates four times as many jobs as comparable spending on water infrastructure upgrades (Wittwer and Dixon, 2013).

CGE models may help identify false attribution. For example, Wittwer and Griffith (2011) estimated that prolonged drought reduced jobs in the southern MDB by around 6000 in the period 2006 to 2008. Irrigators' councils and others blamed water buybacks for the woes of drought.

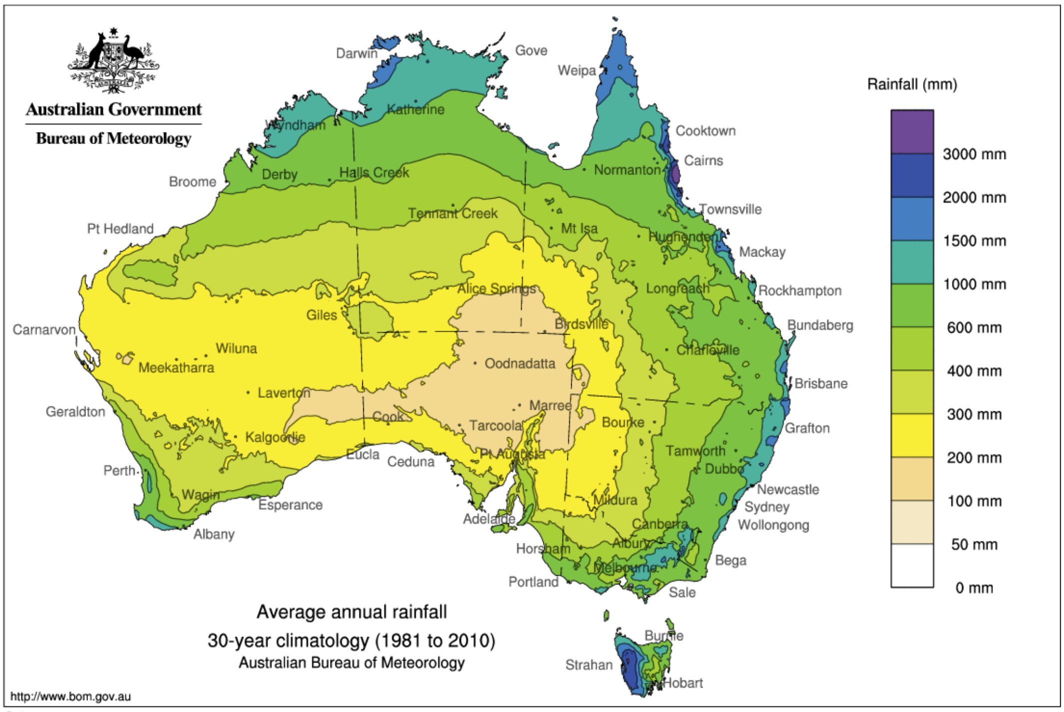
One of the many disturbing aspects of water use in the basin in the past decade is that in response to recurrent droughts in California, which grows 80% of the world's almonds, plantings have accelerated the southern Murray Darling Basin. The problem with this is that with climate change, irrigated water supply will diminish if headwater runoff fails. This happened from 2006 to 2008 and will happen again. Water trading in the southern basin ought to be an efficient way of moving water from annual to perennial crops when it is scarce. The larger the water requirements of perennials are in the basin, the more vulnerable the system is to collapse. That is, the next major failure of headwater runoff in the southern basin will result in substantial areas of perennial plantings dying due to lack of water.

What about other irrigation schemes?

Ord River scheme

The Ord River Scheme in the far north of Western Australia opened in 1972. In figure 3, the scheme is located to the north of Halls Creek, in a region receiving average rainfall of over 700 mm per annum. Of that, the average in the three summer months is around 450 mm. In the coolest month of the year, July, the average maximum temperatures falls to just under 30C. Annual evaporation is around 3000 mm.[3] In some circumstances, the summer rainfall would make the region favourable for irrigation. Hindsight suggests otherwise. Over the life of the scheme, the Australia Institute estimates that is has cost more than $2 billion in today's dollars. The Australia Institute estimates that a recent $330 million investment to expand the scheme created 61 new jobs (Wright 2017).

Figure 2: Average annual rainfall



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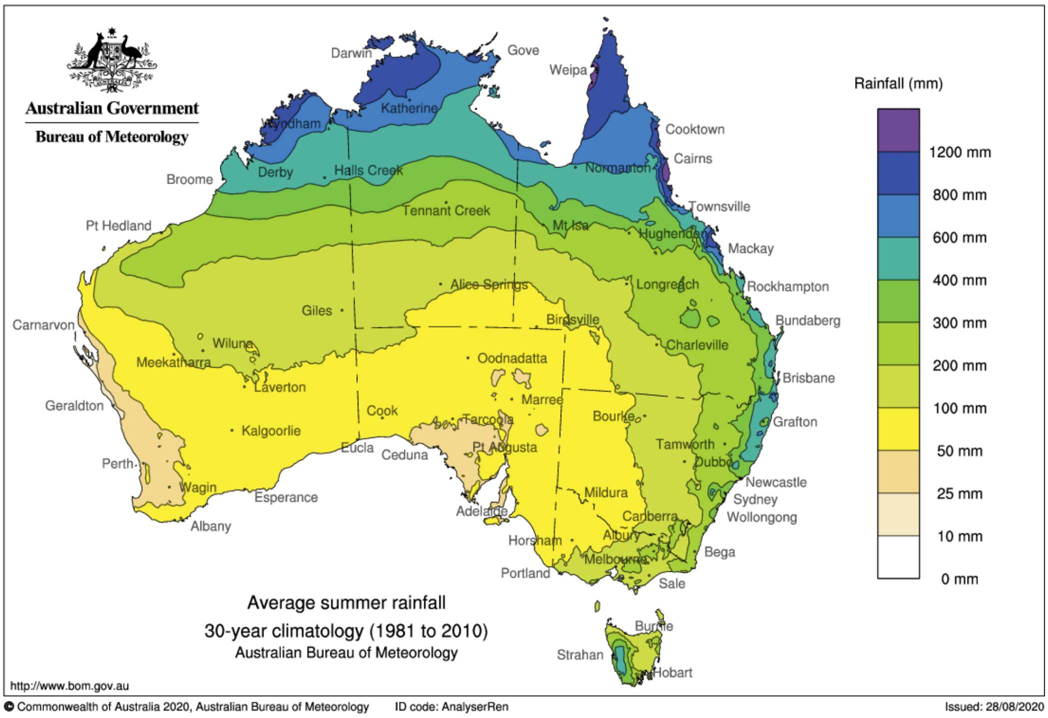
[3] From https://www.eldersweather.com.au/climate-history/wa/ord-river

Figure 3: Average summer rainfall



The Kimberley SA3 region has a population of around 36,000. The 2016 census revealed total jobs of around 12,000. Around 500 of these jobs are in agriculture, and of those 270 jobs are in beef cattle production, which is a rangeland activity. That leaves around 230 jobs at most for the Ord irrigation scheme. The institute estimated that there were around 200 irrigation jobs – a reasonable estimate. In the census, Kununurra SA2, where the Ord is located, had fewer than 160 agricultural workers, although seasonal labour may increase the number.

Figure 4: Average annual evaporation

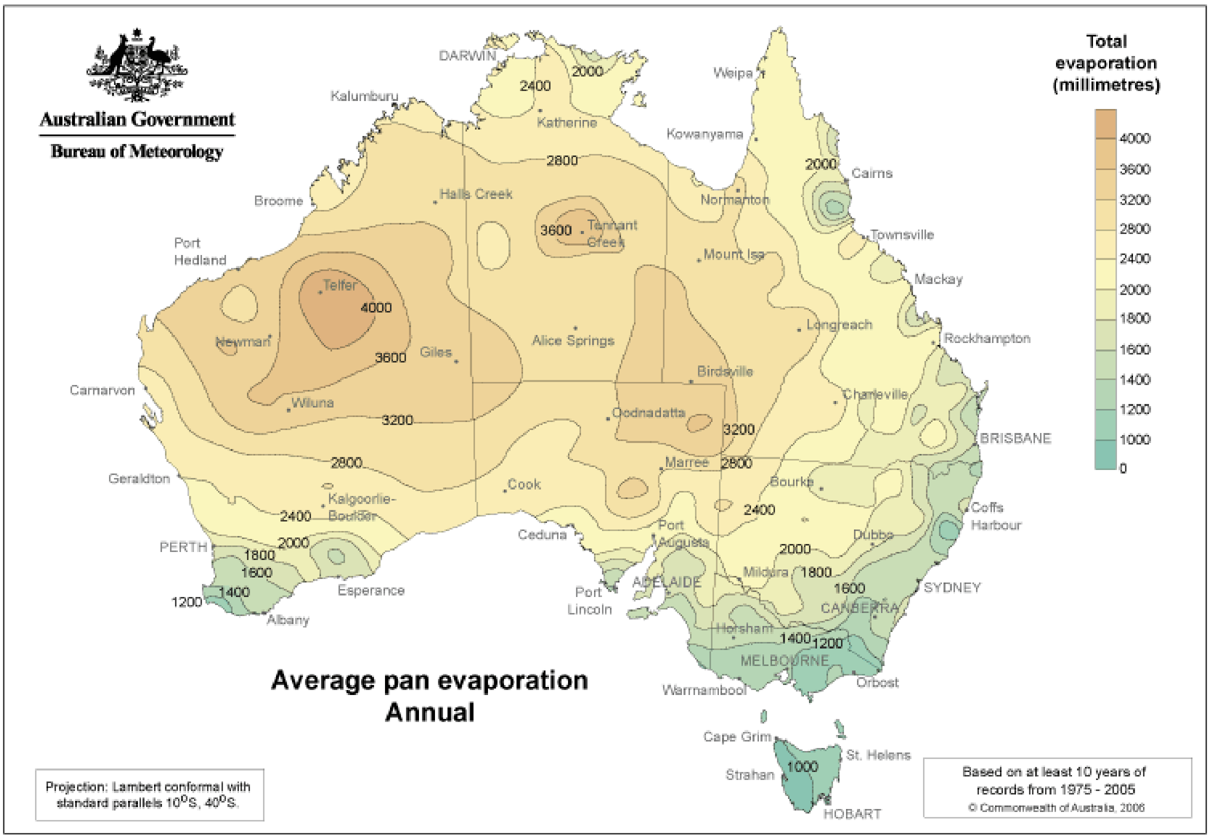
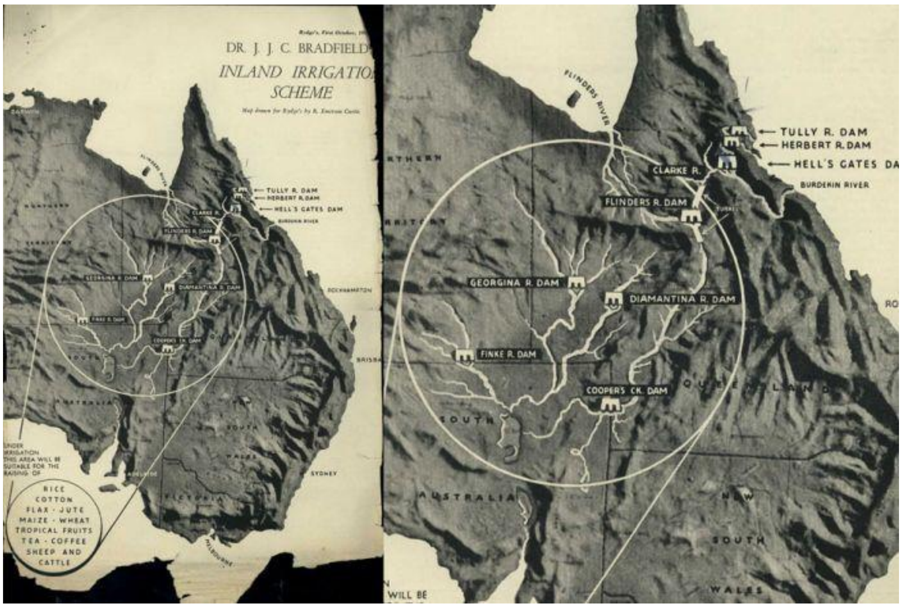


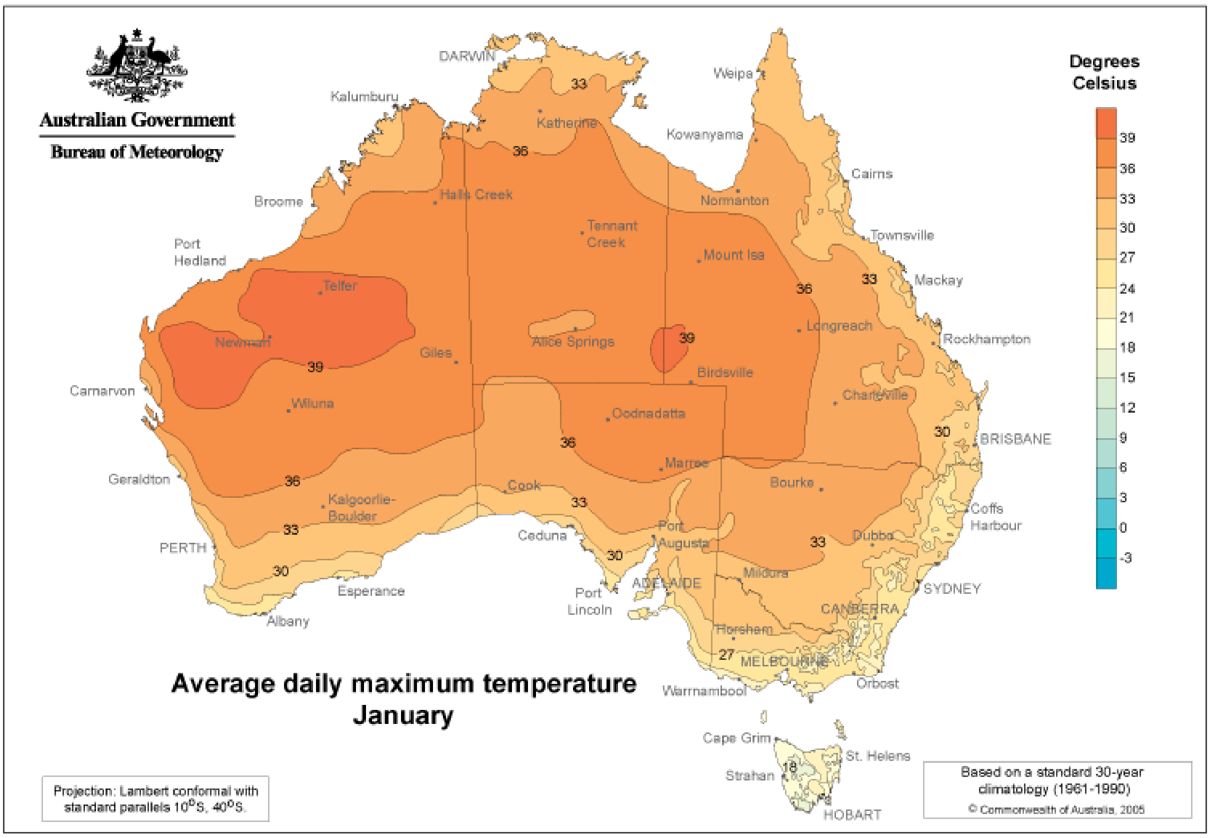
Figure 5: The 1938 Bradfield scheme



The Bradfield idea

The original Bradfield scheme to move water to inland Australia was proposed in 1938, abandoned in 1947 and now it's back. This time, different project options are being examined which include pumped hydro to extend the effective capacity of renewable electricity generation.

Figure 6: Average maximum temperatures, January



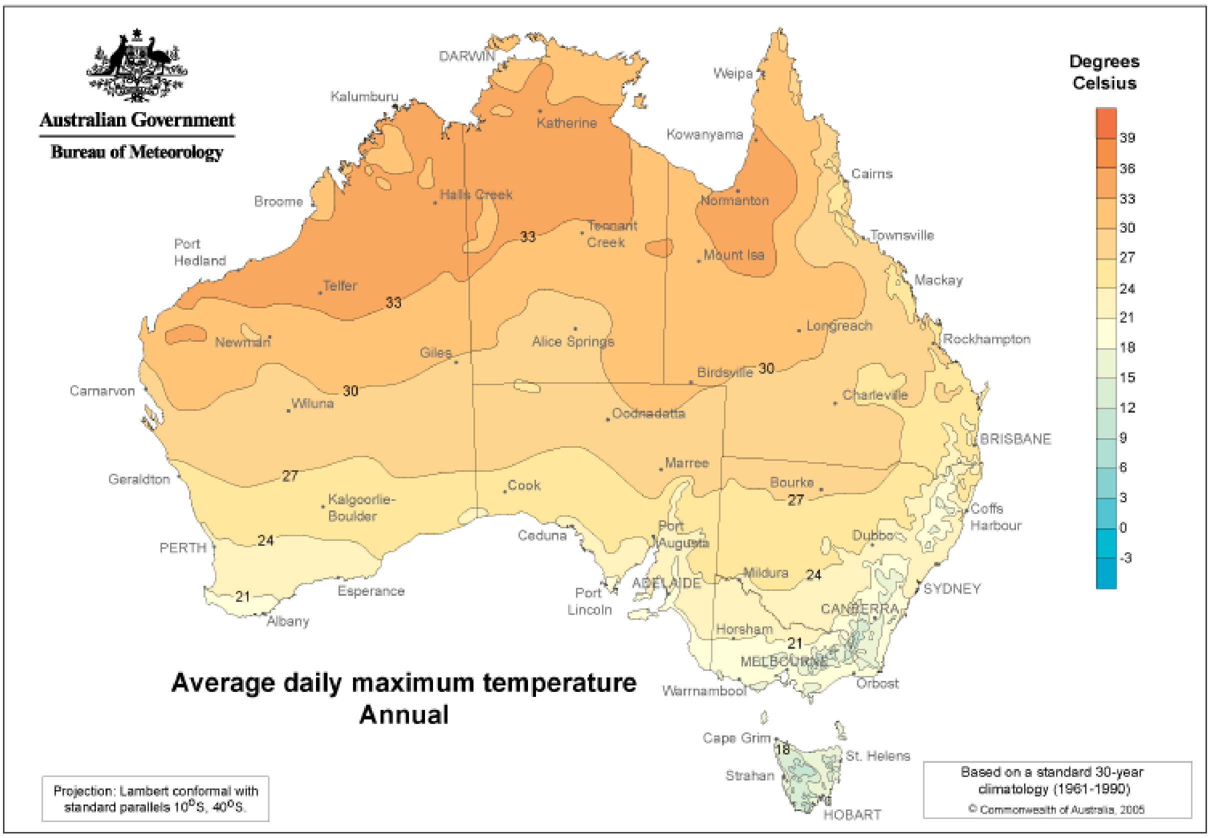
The initial idea of the Bradfield scheme was to divert water from the north of Queensland where few people live to inland regions where even fewer people live. There are good reasons they don't live there.

In the height of summer, the average maximum temperature on the land designated by the Bradfield Scheme exceeds 36C (97F), based on historical records that are 30 years out of date. Based on averages of the past decade of temperatures, a much larger area could be within the 36C isotherm shown in figure 6. Let's compare: Phoenix, Arizona, a city unliveable without air conditioning, has an average maximum temperature of 30.5C. Phoenix has a temperature range similar to that of Birdsville – the latter has slightly warmer winter days and slightly less hot summer days but with very similar averages.

Phoenix is only 600 km from Los Angeles: Birdsville is almost twice that distance from the nearest large city, Adelaide. Phoenix has been described as "the poster child for unsustainable development", due to it reliance on water pumped from the Colorado River. A coal-fired power station was built to provide energy for pumping (Robins 2019).

Note that fewer than 5% of Australia's population live on the 45% of land area that is north of the Tropic of Capricorn. In the north, there is about one person for every three square kilometres. The original Bradfield scheme ought to remain in the dustbin where it has been for over 70 years. However, modified water development schemes are at least worth exploring.

Figure 7: Average maximum temperatures, annual



The Flinders-Gilbert irrigation scheme

The first regional CGE modelling I did of an irrigation scheme in a very remote region was for CSIRO with Onil Banerjee.

From Wittwer and Banerjee (2013):

> In the political realm, there are periodic pushes to develop northern Australia. In the late 1950s, the Forster Committee was set up to devise a blue print for the development of agriculture in the Northern Territory. Professor Carl Forster, Dean of the Faculty of Agriculture at Melbourne University, chaired the committee, which also included CSIRO representation. A former farmer, Bert Kelly, a politician who was to become a minister under the Holt and Gorton governments in the late 1960s, joined the committee. As he went through the process of devising ways of clearing land and choosing crops, Kelly (1978) came to despair of each project. One entailed growing rice on coastal plains. At the time of year when irrigated water was required, it was too salty to use. When the water was fresh, seasonal rainfall rendered it unnecessary. Another scheme aimed to feed cattle during the lengthy dry season on peanut meal. Based on the condition of the cattle, the project worked well. But the costs of producing peanuts exceeded the benefits from fattening cattle. Kelly's experiences led him to conclude the following:
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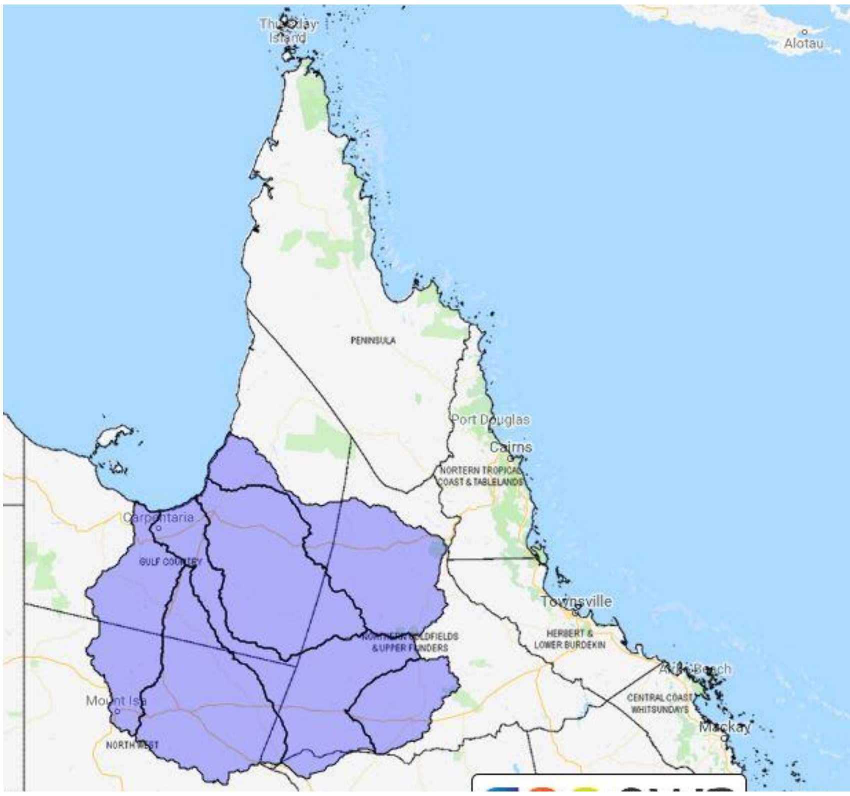
> *There is one golden rule we should always remember when developing land and that is never to let the government near it.* (Kelly 1978, p. 27).

Figure 8: The Flinders-Gilbert scheme



Using estimates from CSIRO concerning water yield possibilities and crop yield possibilities, Wittwer and Banerjee (2015) estimated that only with extreme assumptions concerning higher commodity prices would the scheme be welfare enhancing. But with hindsight we could question the notion that climate change by lowering global food supply increases the returns to the Flinders-Gilbert irrigation scheme. This is because the Flinders-Gilbert region may suffer from more extreme weather events associated with climate change, notably prolonged extreme heat events and more frequent floods. The nearest suitable ports for exporting Flinders-Gilbert produce are on the cyclone-prone east coast of Queensland.

On the other hand, the competitiveness of any export product depends substantially on the value of the local currency. At the time of the Flinders-Gilbert assessment, the Australian dollar was still well above its usual setting, due to the mining boom. Farm output prices in Australian dollar terms have strengthened as the dollar has depreciated.

The Flinders-Gilbert scheme creates jobs in its construction, but jobs move quickly back to base in the operational phase. This aligns with the observed job impact of the Ord River scheme.

The Royal Flying Doctor Service in the late 1920s and the School of the Air established in 1951 were extraordinary innovations for their time. Any innovations that lower the costs of providing essential services to remote communities will do much more to enhance living standards than irrigation schemes.

Comments on the "Bradfield" scheme

Various options are being assessed concerning water infrastructure in Queensland. The analysis is being undertaken by experts in various fields including engineers, scientists and economists. The aim is to move beyond politics: there is support for the scheme from the left and right in Queensland politics.

At its best, some water development projects may improve local water security, create new irrigation areas and, via pumped hydro, increase the storage capacity of electricity. The virtue of various proposals within the “Bradfield” set of possible projects is that the most likely will be subjected to cost-benefit and CGE modelling analysis.

In order to model irrigation developments, details on expected irrigation water availability, suitable crops and the expected number of hectares of irrigated land will be needed. These can be converted to dollar amounts. Pumped hydro development will increase the effective capacity of renewable electricity generation.

Modelling of the “Bradfield” options will need to consider a wider array of gross benefits than farm outputs alone. Pumped hydro plants will extend the effective capacity of renewable electricity generation. At an early meeting on “Bradfield” variants, a reasonable suggestion was that water capital costs should not exceed AUS $4000/ML (which is much higher than the asset value of most water rights in irrigation areas of Australia). NPV costs of $4000/ml at a 2.5% discount rate amount to an annualised cost of $100/ML.

Whether a project is worthwhile depends on one’s perspective. An economist might argue that a benchmark maximum cost of $4000/ML should decide whether a project proceeds. However, the Commonwealth government is funding 50% of the “Bradfield” project costs. Therefore, construction cost of between $4000 and $8000 per ML might be beneficial to the state while resulting in welfare losses nationally.

Dam construction and hydroelectric plant construction together provide additional electricity generation and storage. It follows that the unit costs of electricity generated should be compared with competing technologies. A 1.0 MW wind generator based on a 25% average of full generating output will produce 2.2 GW-hr of electricity per annum. Larger wind generators may cost only a few thousand dollars per MW capacity, imp. Hydroelectric constructions may struggle to compete.

The virtue of hydroelectric plants may be for pumped hydro, to use otherwise unutilised electricity to pump water upstream for storage and generation at times when generated electricity is more valuable. Even here, we have a cost comparison that indicates that pumped hydro may not be a competitive form of storage for long, at least for new constructions. The largest pumped hydro plant in the world in Bath County, Virginia, cost around US$4 billion. It has a storage capacity of 24 GW-hours. The first big battery built in Australia cost AUS$160m and has storage capacity of 0.19 GW-hrs. [4] These costings indicate (at an exchange rate of US$0.75 per AUS$1.00) that pumped hydro costs in this case are about one quarter of the expense of the battery per unit storage. However, batteries are likely to become much cheaper in the future as technologies develop to replace scarce lithium with abundant sulphur. At present, lithium-sulphur batteries are not durable enough to be commercially

[4] See https://en.wikipedia.org/wiki/Bath_County_Pumped_Storage_Station https://en.wikipedia.org/wiki/Hornsdale_Power_Reserve and https://energypost.eu/lithium-sulphur-batteries-cheaper-greener-hold-more-energy/

viable, but that is likely to change quickly: batteries may supersede pumped hydro in electricity storage in the next few years.

Main points about water modelling

An important part of developing a CGE model that is capable of depicting water allocations in a basin is to combine some knowledge of water supply, institutional arrangements concerning water allocations, farm technologies and regional economic structure. There are a number of models of water allocation that have been developed concerning the Murray-Darling Basin. A deficiency of many models is that they do not account for resource movements between dry-land and irrigated activities. These movements have become increasingly important. For example, during the drought of 2006 to 2008, dairy enterprises which formerly had relied on irrigated pasture substituted grain and fodder purchases for water. As water allocations dropped and the price of water increased many-fold, dairy farmers calculated that it was more profitable to abandon irrigated pasture temporarily and sell their diminished water allocations.

The Australian Bureau of Statistics provides many different types of data, necessary for putting together a CGE database and accompanying water accounts. Data include water accounts, agricultural census data, regional employment by industry from the national census, the national input-output table, product details for over 900 commodities, agricultural output data, and estimates of irrigated and dry-land outputs. We need to know crop water requirements per hectare. These vary with crop, temperature and rainfall. TERM-H2O includes “effective” rainfall, which is based on judgments about how much actual rain contributes to soil moisture. In the context of climate change, soaking winter rains appear to be diminishing and less effective summer rainfall increasing. This implies that effective rainfall is decreasing for a given amount of observed annual rainfall.

Without a comprehensive use of these data, any modelling, particularly in the southern Murray-Darling Basin, is likely to be partial and deficient in putting the marginal impacts of water policy into context. For example, it is not possible to reflect the relative contributions of water buybacks and drought to regional economies without database weights for dry-land and irrigated activity and modelling of water trading. Such perspectives are necessary when policies are being enacted during drought, or indeed during any time at which external forces such as a temporarily high currency exchange rate are affecting international competitiveness.

As with much other CGE modelling, in the context of the Murray-Darling Basin, in which water allocations and water trading are important, it was necessary to devise water accounts and equations dealing with water trading. TERM-H2O modelling replicates wide variations in annual water prices, not only in response to drought-induced reductions in water allocations, but also in response to drought-induced reductions in dry-land productivity.

In modelling the Flinders-Gilbert irrigation scheme, Wittwer and Banerjee (2015) did not include water accounts in the model. Instead, they relied on inputs from CSIRO on expected irrigated hectares of particular crops and yields. The modelling was more in the nature of a typical dynamic CGE exercise with construction and operational phases. In an isolated region, competing water uses are not as important in analysis as competing uses of funds. On this basis, it was justifiable to confine the dynamic CGE model to monetary units.

Urban water

Finally, with increasing urbanisation, many water allocation issues around the world are concerned increasingly with urban water. Adelaide, Brisbane, Melbourne, Perth and Sydney have dealt with urban water crises over the past 15 years. Desalination plants have been constructed to supplement existing supplies. In Perth, where inflows to metropolitan dams have declined by 60 percent since the early 1970s, desalination now contributes almost half of the city's drinking water supplies. [5] In responses to water crises, there has been a tendency towards overinvestment. For example, Brisbane now has a water recycling plant that refines wastewater to a potable standard. It is only used to supplement existing supplies when the dams fall below a certain level. Economic modelling of urban water supply augmentation may be incomplete if it does not consider risk benefits.

In the south-east Queensland context, given the investments in the past 15 years in desalination, Wyaralong Dam (100 GL storage), a major water recycling plant (115 GL per annum) and pipelines to expand the SEQ water grid, there does not seem to be a case for further water supply augmentation. One Qld premier threatened to shut down the recycling plant. To some extent, the use of desalination and recycling plants depends on which side of politics is in government in a given state.

Water issues have a local dimension. In Cairns, a 2.5 hour flight north of Brisbane, urban water infrastructure may no longer be sufficient for a growing population. The issue is then choosing the best means of supply augmentation. Is desalination preferable to stormwater catchment and managed aquifer recharge? Options require proper analysis.

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