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Sustainable irrigation: How did irrigated agriculture in Australia's Murray–Darling Basin adapt in the Millennium Drought?

Mac Kirby[a,*], Rosalind Bark[b], Jeff Connor[c], M. Ejaz Qureshi[d], Scott Keyworth[e]

[a] CSIRO Water for a Healthy Country, GPO Box 1666, Canberra 2601, ACT, Australia
[b] CSIRO Ecosystem Sciences, 41 Boggo Road, Dutton Park 4102, QLD, Australia
[c] CSIRO Ecosystem Sciences, PMB 2, Glen Osmond 5064, SA, Australia
[d] ACIAR, 38 Thynne Street, Bruce, Canberra 2601, ACT, Australia
[e] CSIRO Water for a Healthy Country Flagship, GPO Box 284, Canberra 2601, ACT, Australia

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ABSTRACT

The recent drought in south-eastern Australia saw the lowest inflows on record in the Murray–Darling Basin in 2006. As reservoirs were drawn down water availability for irrigation was cut. In 2007–2008 and 2008–2009, irrigators received about one third of their pre-drought allocations. Understanding how the irrigation sector adapted to less water will help planning for the next drought and a future in which irrigation water use will be reduced permanently in the basin.

The aggregate responses that we report are consistent with reported data on strategies used by irrigators to adapt to less water, including water trading, input substitution, changes to crop mix, and improvements to technology leading to reduced water application rates and yield increases. These responses likely also provide some insight on how irrigators will adapt to future more permanent reductions in irrigation water and assist in the identification of constraints to adaption.

1. Introduction

The Murray–Darling Basin is Australia's largest river basin, occupying about one million square kilometres. The basin accounts for more than 40% of Australia's gross value of dryland and irrigated agricultural production. Irrigation in the basin consumes more than 60% of water diverted nationally for irrigation (CSIRO, 2008). The recent drought (sometimes referred to as the Millennium Drought) was the worst in the last 110 years (Timbal, 2009), which is the period of high quality records available for such comparisons. Inflows into the Murray River in the ten years to 2009 were about half the historic average (MDBA, 2009, and Fig. 1), and those in 2006 were considerably less than the previous historic minimum. Inflows during the main inflow period from June to October 2006 were less than 10% of those in the long term mean. A significant feature of the drought was temperatures higher than those experienced in past droughts (Murphy and Timbal, 2007), and the changed seasonal pattern of the reduced rainfall (Timbal, 2009), with much reduced autumn rainfall.

The drought in the Murray–Darling Basin exposed the vulnerability of the basin's ecosystems to water sharing arrangements. In response the new federal manager of the basin developed a Basin Plan with new diversion limits (MDBA, 2011a), under which an annual average 2750 gigalitres (GL)[1] will be re-allocated from irrigation to environmental uses. This translates into a permanent reduction of about 20% in surface water available for irrigation from the cap placed on irrigation diversions in 1997 (MDBC, 1998). The debate in the process of developing the Basin Plan was accompanied by a range of figures about the impact of reduced water availability on irrigation and on the wider Murray–Darling Basin economy including employment (Bark et al., 2011; MDBA, 2011b).

The capacity to adapt to less irrigation water is of particular interest. The severe drought across the Murray–Darling Basin from 2003 to 2010 provides a natural experiment to learn how irrigators in the Murray–Darling Basin adapted to less water, although, as pointed out by Wittwer and Griffith (2011), the drought is a temporary phenomenon, whereas the Basin Plan will result in a permanent cut in irrigation water availability. In a drought

* Corresponding author. Tel.: +61 2 6246 5921.
E-mail address: mac.kirby@csiro.au (M. Kirby).

[1] A gigalitre is the preferred unit in Australia and is equal to a million cubic metres (1 mcm), the unit more commonly used internationally. We use gigalitres since this is the unit referred to in the various plans for the Murray–Darling basin.

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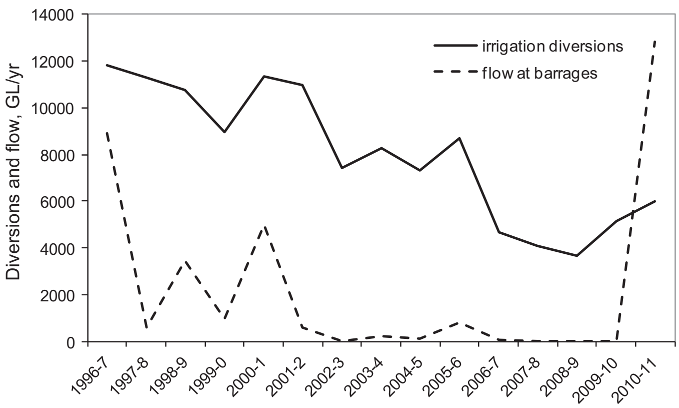

Fig. 1. Irrigation diversions in the Murray–Darling Basin and flow at the barrages. Source: MDBA (2012).

irrigators can access only short-term adjustment measures but with permanent reductions they can plan longer-term.

There are two main approaches to the assessment of economic impacts of reduced water availability. Modelling approaches use integrated representations of irrigation technology, crop water response, and irrigated crop supply and substitution economics to allow the simulation of likely production choices and economic consequences of reduced water availability. This has been the predominant approach to assessing the impacts on irrigation of reduced water availability in the Murray–Darling Basin to date. Using a simulation model, Adamson et al. (2009) calculated that a reduction of 44% in water use in a drought under the current climate (they also estimated climate change impacts) results in 57% reduction in social value in the Basin (Table 4 of Adamson et al., 2009). ABARE-BRS (2010) estimated that a 29% reduction in total water use will reduce average annual gross value of irrigated agricultural production (GVIAP) in the Basin by around 15%. Mallawaarachchi et al. (2010) estimated that without trade a 29% cut in irrigation water use would reduce area irrigated by 14% and GVIAP by 20%. In full trade scenario, they found a reduction of about 7% in regional economic impacts of the Basin Plan. Jiang and Grafton (2012) estimated that a reduction in water use of 13% (recent drought scenario) and 81% (dry extreme scenario) will reduce profit by 5% and 44%, respectively. Similar modelling studies in the USA include Frisvold and Konyar (2012) and Ward et al. (2006).

The main methodological alternative to modelling is to study actual responses to past reductions in water availability. While there are few examples of this approach for the Murray–Darling Basin, it has been pursued at regional or industry-wide scales in California. Zilberman et al. (2002) used data from the 1987–1991 drought to demonstrate how the agricultural sector responded to water scarcity by investing in more efficient water delivery, increasing the use of groundwater, and fallowing of land with low value crops. Water trading was introduced in the last year of the drought. Michael et al. (2010) and Christian-Smith et al. (2011) examined the impact of the 2007–2009 drought and showed that agriculture used several strategies to maintain production and revenue despite water cutbacks. Strategies included investments in water saving, increased groundwater use, switching to lower water use and/or higher value crops (with field and seed crops reducing while high value fruit and nut crops were prioritised), fallowing land, and water market transfers.

To date, in Australia, empirical studies of actually observed irrigation drought response appear to be limited to assessments of individual irrigator responses to reduced water availability. For example, Sanders et al. (2010) described a range of adaptations such as water trading, changing crop mix, carry-over of water to the next season, and farm management and irrigation technology. Wheeler et al. (2013) showed that farmer beliefs about climate change influenced responses to reduced water availability, in particular whether farmers were likely to plan contraction or expansion of their operations. Wheeler et al. (2014) showed that selling water had a positive impact of allowing some irrigators to restructure debt and remain in farming, and a negative impact of less water for production and/or higher production costs. Additional Australian studies of observed responses including Bjornlund et al. (2011), Loch et al. (2013), and NWC (2012), demonstrate how water trading is an important part of irrigators' management for reduced water availability.

No study of the Murray–Darling Basin to date has evaluated broader adaptations to drought such as aggregate crop area, supply changes or water use intensity changes at the whole of basin scale. Our aim in this paper is to address this deficit by examining the empirical evidence of drought water availability impacts on major regional irrigation commodities. A challenge arises in interpreting historic observed irrigation adaptation because it is a response to less water but also to varying weather, economic and policy conditions. Following authors such as Zilberman et al. (2002), we provide evidence from time series trends in water allocation, irrigated crop area, irrigation application rates, and gross value. We find large growth in production value per unit of water and revenue reductions that are considerably less than proportional to water use reduction. We then outline published evidence suggesting that there appear to have been five main and interacting adaptations mechanisms at work as Murray–Darling Basin irrigators adjusted to drought: crop mix changes, water trade, substitution in dairy production of purchased feed for irrigated pasture, irrigation efficiency improvements, and irrigated crop yield improvements. In conclusion, we suggest some areas where further exploration of drought response could provide a basis to improve models of irrigation drought adaptation so that they better reflect observed responses.

2. Methods

We use water use and gross value of irrigated agricultural production (GVIAP) data by agricultural commodity and region within the Murray–Darling Basin from the Australian Bureau of Statistics (ABS, 2008, 2012) and commodity price data and production data (where available) from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES, 2011a,b). These data are available for 2000–2001 and for each year from 2005–2006 to 2010–2011. Production data were not available for all commodities: for the commodities without production data, production was estimated as gross value divided by price. Summary tables (Tables A1–A7) for the main agricultural commodities in the basin are given in Appendix 1. Whereas the ABS water use and gross value data were available by region within the basin, we present only the basin totals.

The published GVIAP data provide nominal values of the commodities at the price obtained at the time. Our interest is to examine the impact of changed water availability, so we aimed to remove the price effect by deflating GVIAP to 2000–2001 prices. However, price data are not available for all commodities for all years, so the deflated GVIAP cannot be calculated directly for all commodities. For each commodity for which there are data, GVIAP in a later year, $GVIAP_{200X}$, is adjusted according to the price in that year, P_{200X}, and the price in 2001, P_{2001}, as follows:

$$GVIAP^{\mathrm{Adj}}_{200X} = GVIAP_{200X}\left(\frac{P_{2001}}{P_{200X}}\right) \quad (1)$$

The industries for which data are available are cotton, dairy, wheat, grapes and meat (beef, and lamb plus other) (see Fig. 2). We assume that cereal prices are correlated to wheat prices. In the years