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Economic effects of water recovery on irrigated agriculture in the Murray-Darling Basin*

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In October 2010, the Murray-Darling Basin Authority (MDBA) proposed that a range of 3000–4000 GL per year, on average, of additional water be made available for the environment in the Murray-Darling Basin (MDB) to mitigate the effects of what it considers to be inadequate environmental flows. To help quantify the costs of this water reallocation, a hydro-economic model was constructed based on the 19 regions of the MDB. The model results indicate the following: (i) substantial reductions in surface water extractions of up to 4400 GL per year impose only a moderate reduction on net profits in irrigated agriculture, Basin wide, given competitive water markets, but the effects are much more pronounced in particular regions/catchments and (ii) the costs of the water reallocation are comparable with the amount budgeted by the Australian government to acquire water from willing sellers and increase environmental flows if inter-regional water trade is unrestricted.

Key words: Murray-Darling Basin, water modelling, water reform.

1. Introduction

In October 2010, a guide to the proposed Murray-Darling Basin (MDB) plan was released by the Murray-Darling Basin Authority (MDBA). This guide identified 19 separate regions for Basin planning purposes and recommended that volumes of between 3000 and 7600 GL/year, on average, of additional water be provided for the environment (MDBA 2010) so as to achieve the goals of the Water Act 2007. It also recommended that additional water for the environment should be no more than 4000 GL/year based on socioeconomic considerations. The additional environmental water would be implemented via sustainable diversion limits (SDLs) that would limit combined

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water interception and extraction for each of the 19 regions at an environmentally sustainable level.

The proposed SDLs, by region, are presented in Table 1 relative to 2000–2001 surface water use by irrigated agriculture and calibrated to a hydro-economic model of the Basin. The percentage reductions range from 0 per cent (Paroo region) to 64 per cent (Goulburn-Broken region) in an additional 3000 GL environmental water scenario and if this were obtained entirely from reductions in irrigated water use. If implemented, the reallocation of water from extractive to *in situ* uses would represent the most far-reaching water reform that has ever undertaken in Australia and in a location that provides about half of the country's total irrigated agricultural production (MDBA 2010, p. 21). To quantify the foregone profits and gross value of production in irrigated agriculture from this proposed reform, we develop a 19-region hydro-economic model of irrigated agriculture for the entire MDB. The model is used to examine four possible reductions in surface water extractions: 3000, 3500, 4000 and 4400 GL/year under two cases: a 'normal'

Table 1 Irrigated agriculture surface water use (GL) in the Murray-Darling Basin *without* inter-region water trade given the proposed sustainable diversion limits based on 2000–2001 data and % reduction relative to base case

Catchment	Base case	3000-GL water recovery (%)	4000-GL water recovery (%)
Paroo	0	0 (0)	0 (0)
Lachlan	218	174 (−20)	149 (−32)
Wimmera–Avoca	110	110 (0)	110 (0)
Condamine–Balonne	600	395 (−34)	325 (−46)
Warrego	36	18 (−49)	16 (−55)
Moonie	38	26 (−32)	24 (−37)
Border Rivers	441	355 (−20)	329 (−25)
Gwydir	727	638 (−12)	606 (−17)
Namoi	603	531 (−12)	509 (−16)
Macquarie–Castlereagh	483	379 (−22)	348 (−28)
Barwon-Darling	26	26 (0)	26 (0)
Lower Darling	36	20 (−44)	15 (−58)
Ovens	28	18 (−35)	17 (−39)
Goulburn-Broken	698	250 (−64)	99 (−86)
Loddon	347	309 (−11)	304 (−12)
Campaspe	244	204 (−16)	192 (−21)
Murrumbridgee	2657	1978 (−26)	1747 (−34)
Murray	2639	1550 (−41)	1180 (−55)
Eastern Mt Lofty Ranges	60	57 (−5)	56 (−7)
Total	9991	7038 (−30)	6052 (−39)

Notes: The actual agricultural water use in 2000–2001 was 10,516 GL while the calculated amount based on the hydro-economic model of irrigated agriculture in the Basin is 9991 GL. It is assumed that the reduction in 'take' to satisfy the proposed sustainable diversion limits arises entirely from reduced water use in irrigated agriculture. The water reductions for each region are obtained from MDBA (2010). The MDBA (2010) proposes for the Barwon-Darling region, 43-GL sustainable diversion limit for 3000-GL water recovery Basin wide and 56-GL sustainable diversion limit for 4000-GL water recovery Basin wide. As the simulated 2000–2001 water use in the Barwon-Darling region (26GL) is lower than these volumes, we assume no reduction in surface water use within the Barwon-Darling region.

year and a 'dry' year of inflows. The model results inform the current policy debate about reform in the MDB by quantifying the costs of water reallocation on net profits in irrigated agriculture by region and Basin wide.

Section two provides a brief overview of existing economic models of the MDB and their key results. Section three presents the methods employed in this study and a detailed description of the 19-region integrated irrigated agriculture water model used to calculate the trade-offs from reducing surface water extractions. Section four presents model results, a comparison with other models, and caveats. Section five offers concluding remarks.

2. Economic models of the Murray-Darling Basin

Various economic models have been developed of the MDB. These have been used to evaluate three key issues: (i) the economic effects of drought (Horridge *et al.* 2005); (ii) the impacts of climate change (Quiggin *et al.* 2008; Adamson *et al.* 2009; Connor *et al.* 2009; Goesch *et al.* 2009); and (iii) market-based water recovery, whereby governments purchase permanent water entitlements from willing sellers so as to increase environmental flows. We focus our review of model results on water recovery.

Dixon *et al.* (2009) used an updated version of the TERM-H2O model, used previously by Peterson *et al.* (2004), to analyse the economic impacts of a water recovery equal to 1500 GL/year in the southern MDB. They calculated that the impact of this water recovery on the southern MDB economy is small and predicted that it would reduce real gross regional product by <1 per cent. A follow-up analysis by Dixon *et al.* (2011) showed that if 1500 GL of water entitlements was recovered from willing sellers by government purchases over an 8-year period; beginning in 2009, there would be a marginal *increase* in household consumption in the Southern MDB.

Based on the historical inflows of the Murray River for 1980–1999, Mainuddin *et al.* (2007) developed a model to assess the effects on irrigated agriculture from increased environmental water allocations (250, 350, ..., 1500 GL/year). Their integrated hydrologic-economic model was calibrated to 2000–2001 conditions in the Southern MDB. They found that economic activity following 1500 GL of water recovery, at least in the short run, is virtually unchanged. Qureshi *et al.* (2007) also examined the economic effects of water recovery in the southern MDB. Their key finding is that a proportional (equal share) recovery of water for the environment is *not* as cost-effective as a targeted water recovery from catchments where water has lower value in use.

Research funded by the MDBA to assess the economic impacts of SDLs includes work by The Australian Bureau of Agricultural & Resource Economics and Bureau of Rural Sciences (ABARE-BRS) and a team at the University of Queensland (Mallawaarachchi *et al.* 2010). ABARE-BRS (2010) found that, for the Basin as a whole, reductions in surface water diversions of between 3000 and 4000 GL/year by irrigated agriculture result in: (i) a lowering of foregone profits in irrigated agriculture of between 6 and

9 per cent; (ii) a fall in the gross value of irrigated agriculture (GVIAP) of between 13 and 17 per cent; and (iii) a decline in Basin employment of between 0.09 and 0.12 per cent. Mallawaarachchi *et al.* (2010, p. 2) reported that whether the current cap on water diversions in the MDB was to be reduced by 37 per cent, gross agricultural returns would fall by 16 per cent and the loss in regional economic surplus, not accounting for the economic benefits from the sale of water entitlements, would also be 16 per cent.

3. Methods

We use data from two periods: 2000–2001 that represents a 'normal' year in terms of inflows in the Basin and 2005–2006 that was a 'dry' year with inflows about 30 per cent less than the long-term average. Unlike other models that have been used to assess the economic effects of water recovery, our model perfectly matches the 19 SDL regions specified by the MDBA. The land use data in these 19 regions were extracted from the 2000–2001 and 2005–2006 Australian Land Use Map provided by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) and are the two most recent periods where there is adequate data to calibrate the model.

Using the 19-region boundaries, we extracted a 'tif' file that was compressed into an 'ecw' file for use in ESRI ArcInfo software. Based on the 19-region boundaries in the ecw file, the Australian Government Information of crop data was obtained using satellite NDVI reflectance data. The irrigated regions were then separated from the total data using the field calculator which uses SQL database commands.

Our hydro-economic model includes water delivery loss rates and water availability in regions from the CSIRO sustainable yields work (CSIRO 2008). In the economic component, the model uses data from the Australian Bureau of Statistics (2008) and Bryan and Marvanek (2004) to model the seven largest uses of water diverted by irrigators: (i) pasture and hay; (ii) rice; (iii) cotton; (iv) cereals (excluding rice); (v) grapes; (vi) fruit (excluding grapes); and (vii) vegetables.

The model accounts for physical constraints in trade that limit transfers of water from some catchments, such as the Paroo, Wimmera–Avoca and Lachlan Rivers, but assumes no market constraints on water trade. The water balance in each region is simulated as if each region/catchment receives inflows from upstream (if these regions have any upstream regions). After accounting for water uses and losses, the end-of-system flows are transferred to the next downstream region. Thus, for any catchment/region *i*, the end-of-system flows are calculated as:

$$F_e = F_{in} + F_r - W_u - W_e - W_l, \tag{1}$$

where F_e is the end-of-catchment/region flows that benefits the next downstream catchment/region, F_{in} is the combined inflows from the upstream regions if region i has any upstream catchments/regions, F_r is the water inflow generated by region i, and W_u is the net water used for diversions in region i. In any catchment/region i, W_e represents environmental flows in region i that remain in the catchment, and W_l are evaporative and conveyance losses. W_u is the total water demand from all seven irrigated agriculture activities defined by eqn (2),

$$W_u = \sum_{j=1}^{7} L_j \times R_j \tag{2}$$

where L_j is the irrigated land area for activity j in region i and R_j is the irrigation water rate for activity j in 2000–2001 (Australian Bureau of Statistics 2008, p. 74) defined as the amount of water in ML/ha. The amount of water used in region i is constrained to be equal to or less than upstream inflows *plus* inflows from the catchment/region itself *less* than any water allocated for environmental flows.

The objective function is to maximise eqn (3) subject to irrigated land area constraints (eqn 4) and water diversion constraints eqn (5),

$$\text{Maximise net profits} = \sum_{i=1}^{19} \sum_{j=1}^{7} \prod_{ij} \times L_{ij} \tag{3}$$

$$L_{ij} \leq \bar{L}_{ij} \tag{4}$$

$$W_{ij} \leq \bar{W}_{ij} \tag{5}$$

where:

Π_i is the net profit to irrigation activity j in catchment i;
L_{ij} is the land area devoted to activity j in catchment i;
$\bar{L}_{ij}$ is the total irrigated land available to activity j in catchment i;
W_{ij} is the water use of activity j in the catchment i; and
$\bar{W}_{ij}$ is the total available water to activity j in catchment i;

The model calculates the net profit from all irrigation activities in region i as per eqn (6):

$$\Pi_i = \sum_{j=1}^{7} L_j \times E_j - \sum_{j=1}^{7} V_j - \sum_{j=1}^{7} FC_j \tag{6}$$

where Π_i is the net profit from all irrigated agriculture activities in region i, L_j is the irrigated land size for activity j in region i, E_j is the gross returns from activity j, FC_j is the fixed costs, operating costs, labour costs and depreciation associated with irrigation activity j ($/ha), and V_j represents variable costs associated with irrigation activity j that includes water costs. All data are from the study by Bryan and Marvanek (2004, p. 86).

The model provides a quantitative assessment of the foregone net profits in terms of irrigated agriculture from reduced water diversions associated with market-based water recovery by catchment and over the entire MDB. The model assesses short-run effects of reduced water diversions at two points in time — 2000–2001 which was a 'normal' year in terms of inflows and 2005–2006 which was a 'dry' year in terms of inflows. On a Basin level, the model calibrates well to recorded data on irrigated land use in 2000–2001 (1.792 million ha. in model versus 1.824 million ha. actual) and water use (9991 GL versus 10,516 GL actual).

4. Economic effects of water recovery on irrigated agriculture

For the 'normal' year 2000–2001, the model calculates the economic effects on irrigated agriculture of reductions in surface water diversions of 3000, 3500, 4000 and 4400 GL. A 4400 GL/year reduction in water diversions corresponds to a recommended increase in environmental flows provided by the Wentworth Group of Concerned Scientists in association, *et al*. (2010). For the dry year 2005–2006, the model calculates the economic effects on irrigated agriculture of reductions in irrigated agriculture surface water diversions of 30, 35, 40 and 44 per cent that are equivalent, in percentage terms, to the modelled reductions in surface water use for 2000–2001.

4.1. Regional and basin-wide effects on irrigated agriculture

The model results, in terms of the change in water use by catchment, are summarised in Table 2 for a 'normal' year of inflows in 2000–2001 (agricultural surface water diversions were simulated as 9991 GL/year). Table 2 shows the possible regional reductions in surface water extractions of 3000, 3500, 4000 and 4400 GL/year with the biggest reduction occurring in the Murrumbidgee and Murray regions. The projected reductions in surface water use (Table 2) by region are what might be expected with water trade and, if the water was acquired from willing sellers, at least cost. The actual reductions in surface water extractions by region, however, would be determined by the prices the Australian government chooses to pay for water entitlements from willing sellers, presumably based on the cost per expected environmental benefit, and the water entitlement offer prices provided by irrigators.

Using agricultural surface water diversions over the two periods (2000–2001 and 2005–2006), Tables 3 and 4 quantify the effects of water recovery on annual net profits. Using the 2000–2001 agricultural surface water diversions, Table 3 indicates that with an optimal allocation of water across all catchments, 3000 GL/year of water recovered for the environment reduces net profits by about 10 per cent while 4000 GL/year water recovery lowers annual net profits by 17 per cent relative to the base case. The regional impacts on irrigated profits of water recovery equivalent to 3000 and 4000 GL/year are highlighted in Figure 1 using 2000–2001 data and show

Table 2 Irrigated agriculture surface water use in the Murray-Darling Basin under different SDL scenarios (GL), 2000–2001, and % reduction in water use relative to base case with inter-regional trade

Catchment	Base case	3000-GL reduction (%)	3500-GL reduction (%)	4000-GL reduction (%)	4400-GL reduction (%)
Paroo	0	0 (0)	0 (0)	0 (0)	0 (0)
Lachlan	218	218 (0)	218 (0)	218 (0)	218 (0)
Wimmera–Avoca	110	110 (0)	110 (0)	110 (0)	110 (0)
Condamine–Balonne	600	549 (−8)	549 (−8)	549 (−8)	549 (−8)
Warrego	36	36 (0)	36 (0)	36 (0)	36 (0)
Moonie	38	37 (−3)	37 (−3)	37 (−3)	37 (−3)
Border Rivers	441	422 (−4)	422 (−4)	422 (−4)	422 (−4)
Gwydir	727	712 (−2)	712 (−2)	712 (−2)	712 (−2)
Namoi	603	546 (−9)	546 (−9)	546 (−9)	546 (−9)
Macquarie–Castlereagh	483	458 (−5)	458 (−5)	458 (−5)	458 (−5)
Barwon-Darling	26	26 (0)	26 (0)	26 (0)	26 (0)
Lower Darling	36	34 (−6)	34 (−6)	34 (−6)	33 (−11)
Ovens	28	21 (−26)	21 (−26)	21 (−26)	21 (−26)
Goulburn-Broken	698	681 (−2)	679 (−3)	679 (−3)	679 (−3)
Loddon	347	347 (0)	347 (0)	347 (0)	342 (−1)
Campaspe	244	242 (−1)	237 (−3)	237 (−3)	237 (−3)
Murrumbridgee	2657	825 (−69)	705 (−73)	705 (−73)	705 (−73)
Murray	2639	1668 (−37)	1294 (−51)	794 (−70)	400 (−85)
Eastern Mt Lofty Ranges	60	60 (0)	60 (0)	60 (0)	60 (0)
Total	9991	6991 (−30)	6491 (−35)	5991 (−40)	5591 (−44)

Notes: The actual agricultural water use in 2000–2001 is 10,516 GL. Inceptions such as farm dams and forestry plantations are not examined in this study.

that the largest proportional reductions in profits are located in the Murrumbidgee (−32 and −35 per cent) and the Murray (−11 and −32 per cent) for 3000 and 4000 GL/year reductions in surface water extractions based on 2000–2001 data. The percentage reductions in the gross value of irrigated agricultural production are very similar falling by 10 and 16 per cent, Basin wide, for reductions in surface water diversions of 3000 and 4000 GL/year.

The proportional change in water use from water recovery varies considerably across the Basin. As some regions are not connected with the major river systems and cannot contribute any environmental water, these regions are barely affected (such as the Warrego) using 2000–2001 agricultural surface water diversions, even with large Basin-wide reductions in water diversions. By contrast, in other catchments where lower profit crops dominate, water trade can occur, and where there are large flows from upstream in the Basin (such as the upper Murray and Murrumbidgee Rivers), there are relatively large reductions in profits.

Using a discount rate of 5 per cent and assuming agricultural surface water diversions over the 2000–2001 period, the reductions in net profit in present value terms within irrigated agriculture from reduced water diversions equal $2.7 billion with 3000-GL water recovered and some $4.6 billion with 4000-GL water recovered. However, the foregone net profits from water recovery are higher for a fixed volume of water acquired if agricultural surface water

Table 3 Annual net profits in irrigated agriculture in the Murray-Darling Basin under different SDL scenarios (million), 2000–2001, and % reduction in profits relative to base case with inter-regional trade

Catchment	Base case	3000-GL reduction	3500-GL reduction	4000-GL reduction	4400-GL reduction
Paroo	0	0 (0)	0 (0)	0 (0)	0 (0)
Lachlan	33	33 (0)	33 (0)	33 (0)	33 (0)
Wimmera–Avoca	37	37 (0)	37 (0)	37 (0)	37 (0)
Condamine–Balonne	77	76 (−2)	76 (−2)	76 (−2)	76 (−2)
Warrego	4	4 (0)	4 (0)	4 (0)	4 (0)
Moonie	4	4 (−1)	4 (−1)	4 (−1)	4 (−1)
Border Rivers	74	73 (−1)	73 (−1)	73 (−1)	73 (−1)
Gwydir	85	84 (−1)	84 (−1)	84 (−1)	84 (−1)
Namoi	71	70 (−3)	70 (−3)	70 (−3)	70 (−3)
Macquarie–Castlereagh	76	75 (−1)	75 (−1)	75 (−1)	75 (−1)
Barwon-Darling	3	3 (0)	3 (0)	3 (0)	3 (0)
Lower Darling	21	21 (0)	21 (0)	21 (0)	20 (−1)
Ovens	4	3 (−7)	3 (−7)	3 (−7)	3 (−7)
Goulburn-Broken	102	101 (−1)	101 (−1)	101 (−1)	101 (−1)
Loddon	51	51 (0)	51 (0)	51 (0)	50 (−1)
Campaspe	31	31 (0)	30 (−1)	30 (−1)	30 (−1)
Murrumbridgee	285	193 (−32)	186 (−35)	186 (−35)	186 (−35)
Murray	454	404 (−11)	362 (−20)	307 (−32)	263 (−42)
Eastern Mt Lofty Ranges	33	33 (0)	33 (0)	33 (0)	33 (0)
Total	1445	1296 (−10)	1248 (−14)	1193 (−17)	1148 (−21)

Notes: Net returns = gross value – variable costs – fixed and labour costs. Gross value equals the price of the product multiplied by the yield (quantity of production) per hectare. Gross values in this study are from Bryan and Marvanek (2004, p. 86). Variable costs include the quantity-dependent costs, area-dependent costs and water costs. Variable costs in this study are from the study by Bryan and Marvanek (2004, p. 86).

diversions in the MDB were at their 2005–2006 levels. If inter-regional water trade was *not* permitted and the reductions in consumptive use were as specified in Table 1, the present value of foregone profits would be substantially larger. For instance, with no inter-regional water trade and at a 5 per cent discount rate, the present value of reduced net profits in the Basin would be \$3.9 billion with a reallocation of 3000 GL/year to increased environmental flows. By comparison, the Australian government has allocated over a 10-year period \$3.1 billion for the purchase of water entitlements and \$5.8 billion for subsidies to improve on- and off-farm water-use efficiency (Grafton 2010).

4.2. Model comparisons

ABARE-BRS (2010) and Mallawaarachchi *et al.* (2010) have undertaken similar studies in terms of the effects of SDLs. Their models are similar to our own and use a network structure of the Murray-Darling Basin. However, their work differs in terms of regional boundaries and the number of regions. In our model in this paper, we use the 19 SDL region boundaries as specified in the guide to the proposed Basin Plan released in October 2010. By contrast, although

Table 4 Annual net profits in irrigated agriculture in the Murray-Darling Basin under different water recovery scenarios (million), 2005–2006 and % reduction in profits relative to base case with inter-regional trade

Catchment	Base case	30% reduction (%)	35% reduction (%)	40% reduction (%)	44% reduction (%)
Paroo	0	0 (0)	0 (0)	0 (0)	0 (0)
Lachlan	46	46 (0)	46 (0)	46 (0)	46 (0)
Wimmera–Avoca	26	26 (0)	26 (0)	26 (0)	26 (0)
Condamine–Balonne	69	67 (−3)	67 (−3)	67 (−3)	67 (−3)
Warrego	3	3 (0)	3 (0)	3 (0)	3 (0)
Moonie	6	6 (−1)	6 (−1)	6 (−1)	6 (−1)
Border Rivers	64	63 (−2)	63 (−2)	63 (−2)	63 (−2)
Gwydir	63	62 (−1)	62 (−1)	62 (−1)	62 (−1)
Namoi	36	35 (−3)	35 (−3)	35 (−3)	35 (−3)
Macquarie–Castlereagh	43	42 (−2)	42 (−2)	42 (−2)	42 (−2)
Barwon-Darling	1	1 (−1)	1 (−1)	1 (−1)	1 (−1)
Lower Darling	22	22 (−1)	22 (−1)	22 (−1)	22 (-1)
Ovens	14	14 (0)	14 (0)	14 (0)	14 (0)
Goulburn-Broken	133	132 (0)	132 (0)	132 (0)	132 (0)
Loddon	56	56 (0)	56 (0)	56 (0)	56 (0)
Campaspe	24	24 (0)	24 (0)	24 (0)	24 (0)
Murrumbridgee	227	162 (−29)	162 (−29)	162 (−29)	162 (−29)
Murray	485	426 (−12)	381 (−22)	335 (−31)	299 (−38)
Eastern Mt Lofty Ranges	47	47 (0)	47 (0)	47 (0)	47 (0)
Total	1365	1234 (−10)	1189 (−13)	1144 (−16)	1108 (−19)

Notes: Net returns = gross value – variable costs – fixed and labour costs. Gross value equals the price of the product multiplied by the yield (quantity of production) per hectare. Gross value in this study are from the study by Bryan and Marvanek (2004, p. 86). Variable costs include the quantity-dependent costs, area-dependent costs and water costs. Variable costs in this study are from the study by Bryan and Marvanek (2004, p. 86). All price and cost data are based on 2000–2001 data.

Mallawaarachchi *et al.* (2010) use 19 regions, their boundaries differ while ABARE-BRS (2010) use 18 regions and the boundaries defined by CSIRO (2008). Summary results from Mallawaarachchi *et al.* (2010) and ABARE-BRS (2010) are compared with our own model in Table 5 using 2000–2001 data with the assumption of no water trade restrictions across regions.

At the basin scale, the simulated reductions in irrigation profits from our model are very similar to those in the study by Mallawaarachchi *et al.* (2010), but substantially larger than the results from ABARE-BRS (2010). For a 3000 GL/year reduction in water use, our model reports a 14 per cent profit reduction while Mallawaarachchi *et al.* (2010) simulate a 16 per cent decline in irrigation profits. By contrast, ABARE-BRS (2010) report an 8 per cent profit reduction, although their predicted declines in GVIAP are the same as our own. The difference to ABARE-BRS results may be explained by the differences in regional boundaries and also the definition of profit used by ABARE-BRS, but which is not provided in their model documentation. For all three models, however, the results indicate that the proportional reductions in profits are much less than the percentage reduction in surface water use.

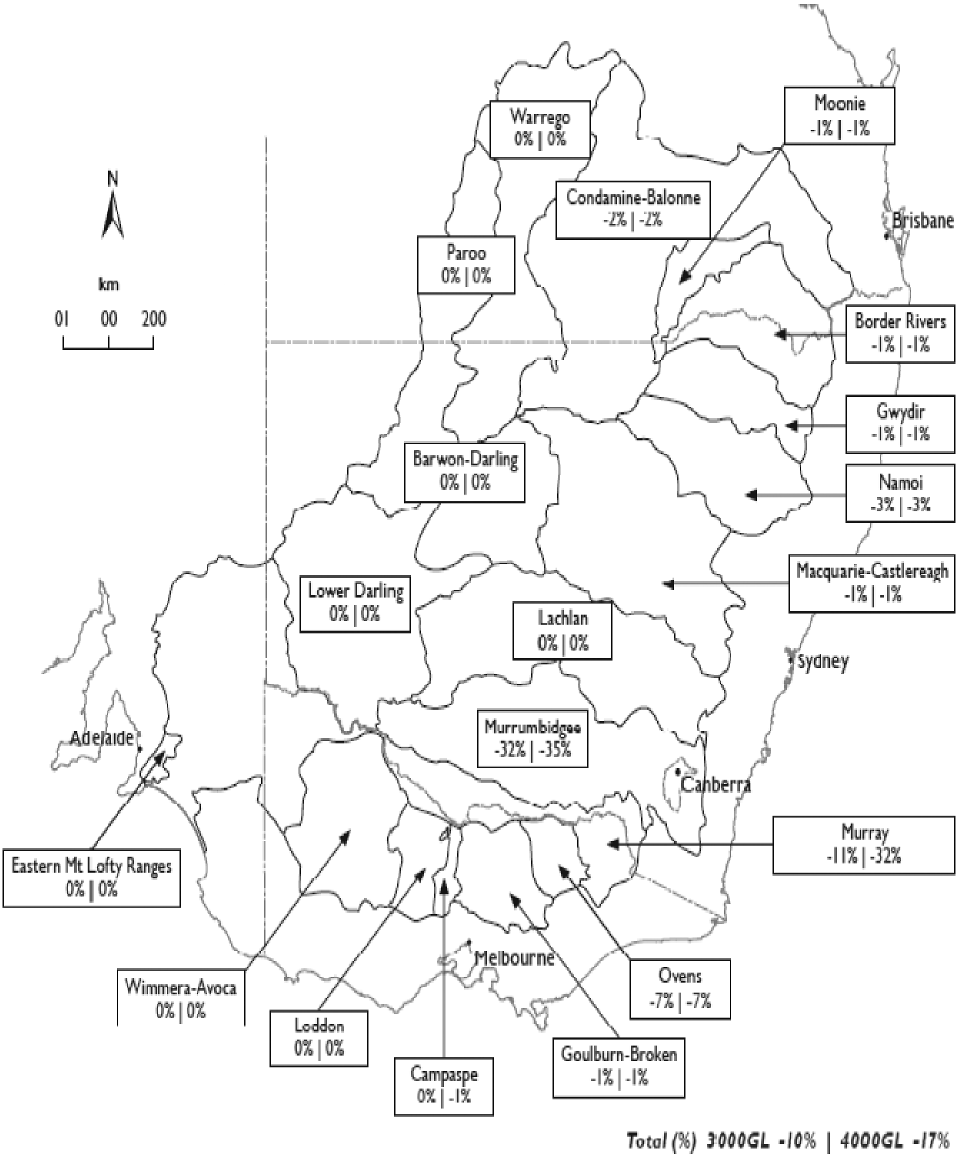

Figure 1 Change in Profits in Irrigated Agriculture by Region and for the Basin *with* inter-regional trade, 2000–2001 data.

4.3. Caveats

Our results require a number of caveats. First, we do not consider crop price fluctuations that could affect the optimal cropping mix. Second, our results are based on conditions existing at two points in time, namely 2000–2001 and 2004–2005, and are only calibrated to these two periods. Third, the expected impact of SDLs on farmers is based on the effects of reduced surface water availability whereby reductions in seasonal allocations are treated identically

Table 5 Comparison of simulated profit losses of SDLs across different models

SDL scenario (%)	This paper (%)	ABARE-BRS (2010a) (%)	Mallawaarachchi *et al.* (2010, p. 2)
3000 GL (−26)	−10	−6	NA
3500 GL (−30)	−14	−8	−16%
4000 GL (−34)	−17	−9	NA

Notes: The simulated water recovery in Mallawaarachchi *et al.* (2010, p. 2) is 3746 GL that is slightly larger than the 3500-GL target. The proportion of water use reductions are reported by ABARE-BRS (2010). All simulations are based on the 2000–2001 data.

whether they occur from reduced inflows or through a decision to reallocate water from consumptive to non-consumptive uses. In the planned reallocation of water to the environment water, entitlements will be purchased by the Australian government from willing sellers and subsidies will be provided to improve on-farm water-use efficiency (Connell and Grafton 2011, p. 4). Both expenditures would be expected to mitigate the reductions in profits as some farmers would likely invest in equipment and practices that would offset reductions in water availability.

5. Concluding remarks

The Murray-Darling Basin is undergoing its most important ever water reform. This process involves a proposed reallocation of water from irrigated agriculture so as to generate additional environmental flows. The proposed magnitude of this change is large – equivalent to at least 30 per cent of long-term average surface water use in irrigated agriculture – has never been undertaken on such a scale in Australia and possibly anywhere else in the world. A critical issue for governments, water planners and regulators undertaking such a reallocation is the economic effects on irrigated agriculture.

To inform the water reform process, we develop a hydro-economic model of the Basin to calculate the regional impacts of net profits in irrigated agriculture, the gross value of irrigated agricultural production and the impacts by crop activity. The model evaluates the economic effects of reduced surface water diversions by irrigators and divides the entire Murray-Darling Basin into 19 different regions/catchments used for water planning purposes by the Australian government. Results from this model, based on 2000–2001 irrigated surface diversions, indicate that a 3000 GL/year, on average, reduction in surface water extractions by irrigated agriculture – the minimum increase in environmental flows proposed by the Murray-Darling Basin Authority in October 2010 – would lower annual net profits, Basin wide, by about 10 per cent. A 4000-GL reduction in surface water extractions would reduce annual net profits, Basin wide, by about 17 per cent.

While the direct economic impacts of substantial water recovery are moderate, even with large reductions in water extractions over the entire Basin, the effects are nevertheless substantial in particular regions/catchments. The model's regional results in terms of reduced irrigated land area and net profits provide an indication of the possible magnitude of indirect and community economic losses associated with water recovery.

Overall, the results indicate that with inter-regional water trade, the reductions in net profits from water recovery are much less than the overall funds set aside by the Australian government to increase environmental flows and to assist irrigators to adjust to reduced water availability. The model results suggest that if the $8.9 billion currently budgeted for water reform were spent in a cost-effective manner on the purchase of water entitlements rights from willing sellers, and with no arbitrary restrictions on water trade, the Australian government would be able to increase environmental flows by at least 4000 GL/year, fully compensate irrigators for reduced extractions, and have funds leftover.

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