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Estimating Impacts of Climate Change on Lower Murray Irrigation, Australia

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TITLE: Estimating Impacts of Climate Change on Lower Murray Irrigation, Australia

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ABSTRACT

This article evaluates irrigated agriculture sector response and resultant economic impacts of climate change for a part of the Murray Darling Basin in Australia. A water balance model is used to predict reduced basin inflows for mild, moderate and severe climate change scenarios involving 1^0, 2^0, 4^0 Celcius warming, and predict 13%, 38% and 63% reduced inflows. Impact on irrigated agricultural production and profitability are estimated with a mathematical programming model using a two-stage approach that simulanteously estimates short and long-run adjustments. The model accounts for a range of adaptive responses including: deficit irrigation, temporarily fallowing some areas, and permanently reducing irrigated area and changing the mix of crops.

The results suggest that relatively low cost adaptation strategies are available for moderate reduction in water availability and thus costs of such reduction are likely to be relatively small. In more severe climate change scenarios greater costs are estimated, adaptations predicted include a reduction in total area irrigated, investments in efficient irrigation, and a shift away from perennial to annual crops as the latter can be managed more profitably when water allocations in some years are very low.

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1. INTRODUCTION

Climate change and increasing levels of diversion, threatens to increasing water scarcity in the MDB. This paper is an evaluation of the economic impacts of reduced water allocation in the Lower Murray main stem, in Victoria below Swan Hill and in South Australia. Three climate change scenarios are considered. Irrigated agricultural production sector management and profitability changes likely to result from climate induced water supply changes are estimated. The methodology applied is using a two-stage profit maximisation linear programming model similar to the water resource economics applications by McCarl et al. (1999). The first stage modelled is long-run decision making (decisions on capital investment in irrigation and land). The second stage is short-run decision making (decision on rates of water to apply and area of land to fallow). The second stage decisions are made once the state of nature is revealed. In this case the states of nature represent a probability distribution of levels of water allocation levels across years. With more severe climate change, the mean level of water allocation decreases, and the variance increases.

2. Estimating water allocation impacts of climate change

Potential impacts of climate change on water allocations were modelled with a water use account (Kirby et al., 2006). The model was used to estimate flow impacts for mild, moderate, and severe climate change scenarios involving temperature increases of 1, 2, and 4 degrees Celsius. The scenarios were chosen because they are consistent with recently published studies such as Pittock, 2003.

Estimated climate change induced changes in inflows to the basin influence water allocation in the two states in our analysis (Victoria and South Australia) differently via the dam water storage sharing rules; we assume sharing rules similar to and with consistent with the

current Murray-Darling Basin Agreement. To predict how changes in river flow and runoff will be allocated between these two states under the different climate change scenarios, we use the Murray-Darling Basin Commission's river operations model—BIGMOD MSN. Results are shown in Table 1. Notably, predicted runoff reductions are greater than assumed rainfall reductions, a result of the fact that rainfall-runoff partitioning is a non-linear relationship with runoff being more responsive than rainfall to climate change events.

Table 2 presents the probability distributions associated with different water allocation levels to the irrigation sector under each of the climate changes scenarios considered, including a baseline case of no change. Different climate changes scenarios translate into different water availability possibilities—low, moderately low, moderately high, and high—for the South Australian and Victorian Lower Murray irrigation sectors.

As indicated in Table 2, the results from the "no climate change" scenario represent the fact that under the climate conditions that existed between 1975 and 2000 both regions nearly always received 100% of their water allocations. Under the mild climate change scenario, Victoria is predicted to continue to receive 100% of its irrigation allocation, while South Australia receives 100% of its allocation 88% of the time (e.g., in 88 years out of 100), and 80% of its allocation 12% of the time. Again, there are low, moderately low, moderately high, and high water availability years under each climate change scenario; the frequency of each, though, changes depending on climate change scenario with low availability years becoming more the norm as climate moves from no change to severe. As highlighted in Table 2, quite significant reductions in water allocation reliability are predicted for the moderate climate change scenario, with greater reductions predicted for the severe climate change scenario. Also notice that there are substantial differences across the two states in terms of the mean water availability under the different climate scenarios.

3. Estimating Irrigation Sector Impacts of Climate Change

The objective function for the two-stage profit maximisation problem for each region is expressed in equation (1) as follows:

Maximise

$$[-\sum_j \text{crop_establishment_cost}_j - \sum_j \sum_h \text{irrigation_establishment_cost}_{j,h}] * A_{j,h} \quad (1a)$$

$$+ \sum_s \text{prob}_s * \sum_j \sum_h \text{crop_price}_j * \text{YIELD}_{s,j,h} * AI_{j,h} \quad (1b)$$

$$- \sum_s \text{prob}_s * \text{water_variable_cost}_s * [\sum_j \sum_h \text{WATER}_{s,j,h} * AI_{s,j,h} - \text{allocation}_s] \quad (1c)$$

$$- \sum_s \text{prob}_s * \sum_j \sum_h \text{other_variable_cost}_j * AI_{s,j,h} \quad (1d)$$

The choice variables include:

- $A_{j,h}$ ~ area (hectares) for crop j using irrigation system h;
- $AI_{s,j,h}$ ~ area (hectares) for crop j using irrigation system h that is irrigated in state of nature s (as opposed to being fallowed);
- $\text{YIELD}_{s,j,h}$ ~ yield level (tonnes) for crop j, irrigation system h, and state of nature s;
- $\text{WATER}_{s,j,h}$ ~ water (ML) applied to crop j using irrigation system h in state of nature s.

Similarly, the parameters in the objective function include:

- $\text{crop_establishment_cost}_j$ ~ fixed non-irrigation cost associated crop j;
- $\text{irrigation_establishment_cost}_{j,h}$ ~ fixed cost of irrigation system type h for crop j;
- crop_price_j ~ price per unit yield for crop j;
- $\text{water_variable_cost}_s$ ~ sum of the *cost per ML of water delivery*, which is constant across states of nature, and the *cost per ML of water allocation on the water market*, which varies across states of nature;
- $\text{allocation}_{s,j,h}$ ~ level of water allocation (ML) assigned in state of nature s for crop j grown with irrigation system h;
- $\text{other_variable_cost}_j$ ~ variable costs of production for crop j not related to irrigation.

Term (1a) characterises the long run (first-stage) irrigation and cropping infrastructure capital investment choices that must be made prior to knowledge of the annual stochastic outcomes. Terms (1b) to (1d) characterise the short-run (second-stage) decisions that can be varied after stochastically determined factors effecting production are revealed. This includes decisions to: irrigate or fallow land with irrigation capital and the amount of irrigation water to apply.

3.1 Modelling Water Trade and Water Price

In equation (1) above, term (1c) characterises decisions to buy and sell annual water allocations. The expression, $\sum_j \sum_h WATER_{s,j,h}*AI_{s,j,h}$ - $allocation_s$, represents the net level of water allocations transferred into or out of the region. When this term is positive, water is brought into the region through allocation purchases; when this term is negative, water is transferred out the region through allocation sales. The model is run with and without the option of water trade so as to evaluate the value of this policy option and how that value changes with greater water scarcity.

Table 3 presents summaries from actual water market transactions over the 25-year reference period under the column titled "Baseline." As indicated and expected, water prices are high in years of low water allocation and hot weather during the irrigation season, and low in years of high allocation and cool weather during the irrigation season (Bjornlund, 2004).

INSERT TABLE 3 HERE

Using regression analysis, Brennan (2006) estimates the relationship between water prices and water allocation. The resulting equation (R^2=0.89), which uses annual temporary water price and water allocation data from 1998 to 2004, is as follows:

$$\ln(P) = 7.0333 - 0.48466\ A - 0.0086\ R \qquad (2)$$

where P is the price of water ($/ML). Each irrigator in the region has an entitlement to be delivered an amount of water denominated in ML. Depending on dam storage levels the water authority chooses a percentage of entitlement (*A*) up to 100% to distribute to irrigators. This fraction of entitlement A is known as an irrigator's annual allocation. Finally, *R* in equation 2 represents the cumulative season rainfall (mm). We use this equation to estimate water prices that each region confronts based on the water allocations and rainfall outcomes applied to each climate change scenario. The results are presented in the remaining columns of Table 3. As expected, the lower the water allocation, the greater the market price for water and vice versa.

3.2 Modelling Temporary Fallowing of Irrigable Land

Evidence from actual water market transactions suggests that the area of lower value annual crops, particularly pasture, tends to expand in years of high allocations and thus low water price. This is because livestock farmers hold rather than sell their allocations in such years and use the allocations to produce their own fodder or pasture. In a low allocation (and thus high water price) year, on the other hand, livestock farmers tend to sell their water allocation and buy feed rather than grow their own fodder or pasture.

Alternatively, irrigators with permanent viticulture and horticulture plantings tend to buy water to make-up deficits in low allocation years, and are willing to pay high prices for additional water given the high value of forgone production as a result of reduced irrigation on such crops. When water allocation levels are very low and water prices high, however, the profit maximising response can be to forgo yields on some perennial crops by withholding irrigation. Such an outcome occurs when profits from fully irrigating the crops

(including the costs associated with purchasing additional water) are less than benefits of selling the water.

The possibility of foregoing irrigating some land equipped with the capital assets (including irrigation capital) in some years is included in the model. This possibility is introduced via the inclusion of two acreage choice variables: $A_{j,h}$, which is the acreage set aside with irrigated and non-irrigated capital investment, and $AI_{s,j,h}$, which is that portion of $A_{j,h}$ for which water is actually applied (dependent upon state of nature s). The remaining non-irrigated portion of $A_{j,h}$ is considered fallow. This relationship is represented by the following constraint that is imposed on the model:

$$AI_{s,j,h} \leq A_{j,h} \text{ for all s, j, h} \tag{3}$$

Hence, choosing a hectare of activity $A_{j,h}$ incurs the fixed costs associated with providing the capacity to produce an irrigated crop (such as land farm machinery, an irrigation system, and plant stock and trellising in the case of horticultural and viticultural crop). Variable costs, alternatively, are incurred only if activity $AI_{s,j,h}$ is chosen thereby indicating that a unit of potentially irrigable land is actually irrigated. Of course, when potentially irrigable land is fallowed variable costs are not incurred; additionally, fallowing land allows one to sell the excess allocation of water saved from fallowing.

3.3 Modelling crop yield response to water and deficit irrigation

We model irrigated crop yield as an increasing function of applied water up to a point beyond which additional water reduces yield due to lack of aeration in root zone (de Fraiture and Perry, 2002). The specific functional form consists of a quadratic yield-water response function that is calibrated based on local yield, water requirement, and water production data from Jayasuriya (2004) and Jayasuriya and Crean (2000). This function takes the form:

$$YIELD_{s,j,h} = a_j + b_j * EFFECTIVE_WATER_{s,j,h} + c_j * EFFECTIVE_WATER_{s,j,h}^2 \quad (4)$$

The parameters *a*, *b*, and *c* are the intercept, linear and quadratic coefficients, respectively. The function is an adaptation of the widely used Food and Agriculture Organization (FAO) crop-water yield functions (FAO 53), varying from the original FAO formulation with the inclusion of the quadratic term.

The variable $EFFECTIVE_WATER_{s,j,h}$ in equation (4) is defined as the total quantity of water available (ML/ha) for the crop, including irrigation water and effective rainfall when irrigation system efficiency is taken into consideration. Equation (5) identifies this relationship:

$$EFFECTIVE_WATER_{s,j,h} = (WATER_{s,j,h} * irrigation_efficiency_{,j,h} - rain_{s,j}) \quad (5)$$

where $irrigation_efficiency_{j,h}$ represents the fraction of applied irrigation water available to the crop as opposed to being lost to surface runoff or deep drainage.

An advantage of incorporating a yield-response function into the model is that it allows for the possibility of deficit irrigation, or applying less than the full crop-water requirements and, consequently, accepting a some yield deficit. Deficit irrigation is generally viable to some threshold level, beyond which yield is zero. The threshold level assumed in this research is 50% of the applied water rate which achieves maximum yield. In the case of perennial horticultural and viticultural crops, though, too much crop stressing can have deleterious effects on future yield potential. To account for this effect, for water application below 25% of that which achieves maximum yield, a yield penalty will ensue. The yield penalty will result in a revenue loss assumed to equal between 75% and 100% of the present value of a year's revenue from the crop at maximum potential yield.

The manner in which the threshold effects are incorporated into the quadratic yield response function is via constraints on the variable EFFECTIVE_WATER. This formulation, which follows Hillier and Lieberman (1986), results in a piecewise representation of yield. For perennial crops this involves three variables to represent effective water as shown in equation (6):

$$\begin{aligned} YIELD_{s,j,h} = \; & - potential_yield_j*(1- EFFECTIVE_WATER_1_{s,j,h}/et_{s,j}) \\ & + 0* EFFECTIVE_WATER_2_{s,j,h} \\ & + (EFFECTIVE_WATER_3_{s,j,h}\, a_j + b_j*EFFECTIVE_WATER_3_{s,j,h} \\ & + c_j*EFFECTIVE_WATER_3_{s,j,h}^2); \end{aligned} \tag{6}$$

with constraints (6a) to (6c):

$$0 \leq EFFECTIVE_WATER_1_{s,j,h} \leq 0.25*(et_{s,j} - rain_{s,j})/ie_{j,h} \tag{6a}$$

$$0.25*(et_{s,j} - rain_{s,j})/ie_{j,h} < EFFECTIVE_WATER_2_{s,j,h} \leq 0.50*(et_{s,j} - rain_{s,j})/ie_{j,h} \tag{6b}$$

$$0.50*(et_{s,j} - rain_{s,j})/ie_{j,h} < EFFECTIVE_WATER_3_{s,j,h} \tag{6c}$$

For annual crops, equation (6) is used, but with the following constraints:

$$EFFECTIVE_WATER_1_{s,j,h} = 0 \tag{6d}$$

$$0 < EFFECTIVE_WATER_2_{s,j,h} \leq 0.5*(et_{s,j} - rain_{s,j})/ie_{j,h} \tag{6e}$$

$$0.5*(et_{s,j} - rain_{s,j})/ie_{j,h} < EFFECTIVE_WATER_3_{s,j,h} \tag{6f}$$

3.4 Modelling Irrigation Efficiency Response

The range of irrigation system and management choices included in the model and the assumed irrigation efficiency of each irrigation technology are shown in Table 4. The values are based on regression analysis and literature review. Specifically, data for regression analysis was sourced from a local irrigation performance benchmarking study (Skewes and Meissner, 1997) which provided details of irrigation management and outcomes for 36 wine/grape irrigators and 39 citrus irrigators.

INSERT TABLE 4 HERE

The term *management* refers to an amalgamation of scheduling and maintenance levels which growers have control over and which influence the performance of the irrigation technology. These characteristics were used to classify irrigators as 'average,' 'above average' or 'below average' as shown in Table 5. Scheduling techniques deemed advanced were those that incorporated an objective means of feedback from the field conditions. Thus, a capacitance probe is considered 'advanced,' while a calendar or personal assessment is not.

INSERT TABLE 5 HERE

One component of cost influenced by choice among irrigation management is the fixed cost of capital associated with an irrigation system. This is represented in the model objective function as "irrigation_establishment_cost$_{j,h}$". The specific costs associated with this item include the costs of irrigation systems and capital required for irrigation monitoring (capacitance probes, telemetry stations). In much of the study area water is delivered to farms in pipes at pressure sufficient to run sprinkler systems without supplementary pumping. This is not the case in a limited number of districts where water is delivered at low pressure; these districts are the only part of the study area where a significant amount of furrow irrigation still exists. In these areas supplementary booster pumps are required to convert from furrow irrigation to sprinkler systems. This additional cost is accounted for by adding the capital cost of booster pumps to the cost of all sprinkler irrigation systems in these districts.

3.5 Crop Mix Constraints

A long standing challenge with mathematical programming models of profit maximisation where multiple crops are grown arises because such models tend to identify solutions

involving production a single most profitable crop. In fact, most agricultural regions consist of a mix of cropping activities that include some less profitable activities. Reasons for growers and regions being represented by a mix of crops include agronomic goals of disease control, economic goals of risk diversification, and land quality effects. In this modelling effort, the issue is dealt with through introduction of a crop mix constraint that requires maintaining a constant ratio of the areas of high value perennial horticultural, viticultural, and vegetable crops. The constraint takes the form:

$$0.15 * IP_j * A_{j,h} \geq \sum_h IP_j * A_{j,h} \qquad (6)$$

where IP_j is a vector of binary indicator variables taking values of one for perennial crops and zero for annual crops. The constraint requires a mix of perennial crops including at least 15% of each type rather than one perennial crop but allows substitution of annual for perennial crops if this is profitable. While in reality the mix of perennial crops changes over time depending on changing commodity price expectations, the long run changes in relative prices are difficult to foresee. Assuming constraints to the level of change in the mix of these commodities at current prices gives a reasonable approximation to the expected aggregate returns and water demands for these crops.

4. RESULTS

In a short-run analysis, water allocation reductions ranging from 10% to 90% are evaluated. Capital assets such as perennial planting acreage and crop mix are assumed fixed. Irrigators face the choices of reducing applied water rates and/or temporarily leaving some crops unirrigated. In a long-run analysis, it is assumed that the irrigation sector can adjust by changing crop mix, irrigation technology, irrigated land with irrigation infrastructure, and by engaging in the same short-run strategies.

Figure 1 presents the short-run agricultural impacts from a reduction in water availability to each state. Given that this is a short-run evaluation, the opportunities for growers to respond are limited and thus we would expect the short run impacts to be large relative to the longer term impacts. As shown, the impacts of up to a 30% reduction in water allocation are minimal; a 40% reduction suggests slightly more, albeit certainly not substantial, impacts on profits.

Optimal responses for these levels of reduction, given irrigation systems are fixed, seem to be *business as usual* except for some slight crop stressing. As shown, variable costs stay somewhat constant; the slight impact on profit is being driven by revenue reductions from lower yields as a result of the growers engaging deficit irrigation. As water allocations move from a 60% allocation down to 30%, growers engage in some deficit irrigation. Part of the short-run response in this allocation range involves temporary fallowing of annual crops by totally withholding irrigation and providing perennial crops with only the minimum required to avoid future yield loss. Revenue decreases substantially, particularly as growers fallow land and try to maintain a minimum level of water applications so as to forego future perennial crop damage from moisture stress. As allocations reach 20% and below, though, such long term damage is unavoidable as illustrated by the large negative profits that include more than simply fixed costs—they include the opportunity costs of foregone future production from perennial production.

Table 6 presents the long-run adjustments to reductions in water allocation under different climate change scenarios.

Table 6, indicates that as water allocations decrease (and subsequently water prices increase) from progressively worsening climate change scenarios, growers fallow more land, apply less water, and generate less drainage. More irrigation capital is left fallow in years of low allocation which occur more frequently with more severe climate change, especially in South Australia.

Counter to initial expectations, irrigation efficiencies show no definite trend. The reason is that there is a shift into annual crops from inherently more water use efficient perennial crops.

The Economic Indicators section of Table 6, indicates that, consistent with expectations, as water allocations decrease, revenues and profits decrease. The results indicate that the state of Victoria is more capable of dealing with projected impacts of climate change than is South Australia. For instance, under the Mild and Moderate Climate Change Scenarios, Victoria's regional agricultural profits decrease by 9% and 19%, respectively, compared to South Australia's 22% and 54%, respectively. This a result of water allocation rules that translate inflow reduction into greater allocation reductions in South Australia than in the Victorian Lower Murray.

A policy option that could help to mitigate impacts of lower water allocations is to open up the permanent water market giving growers access to more water, at a price, from elsewhere in the river basin. The last column in Table 6 evaluates the impact of the Moderate Climate Change Scenario, but where there is no constraint on how much water growers can purchase (or sell). As shown, if growers in these two states could have access to as much water as they like at equilibrium market price, the economic impacts of climate change would be substantially. Profits decrease by only 5% and 11% in Victoria and South Australia,

respectively, compared to 19% and 54% under the same climate change scenario without water markets.

5. SUMMARY AND CONCLUSIONS

This study provides an assessment of the economic impacts of potential climate change on the irrigation sector for an important part of Australian Murray Darling Basin. It includes an estimate of the response to a single year reduction in water available assuming no capital adjustments are possible. Because there are significant opportunities to deficit irrigate with relatively little yield loss, a 30% reduction in water allocations is estimated to result in a relatively limited economic impact on agriculture, i.e., a 3% reduction in revenues and a 9% reduction in profits. In contrast, the limited short-run responses to a 70% or greater reduction in water allocation results in substantial profit loss.

Long-run adjustments are also estimated for mild, moderate and severe climate change scenarios involving one, two, and four degree Celsius increase in temperature. Under the mild climate change scenario, the primary responses are increased deficit irrigation and greater investments in more efficient irrigation technology. The moderate and severe climate change scenarios for South Australia and the severe climate change scenario in Victoria are characterised by low reliability of water supply including years of very limited or zero supply. An interesting and important response to severe changes in water allocation is shown to be the switching out of perennial crops to predominantly or exclusively annual crops. This is because horticultural and viticultural crops suffer reduced future yield potential when minimal water can not be applied, whereas annual cropping fields can be fallowed in years of zero water supply and be returned to full productivity as soon as water supply is again available.

Finally, we found that to the extent that water is available for purchase from the upstream low-valued irrigated cropping sector, agricultural productivity could be expected to be maintained at near baseline levels, albeit with expenditures on water purchases rising to nearly five times their baseline levels.

This analysis is based on climate change scenarios that use some simplifying assumptions. The expected climate changes in the Murray-Darling Basin are not uniform across the basin, nor uniform throughout the year. The runoff, storage and flow in the river system may therefore differ from those shown here. Nevertheless, we believe that our scenarios cover a wide range of possible impacts and hence a wide range of economic outcomes.

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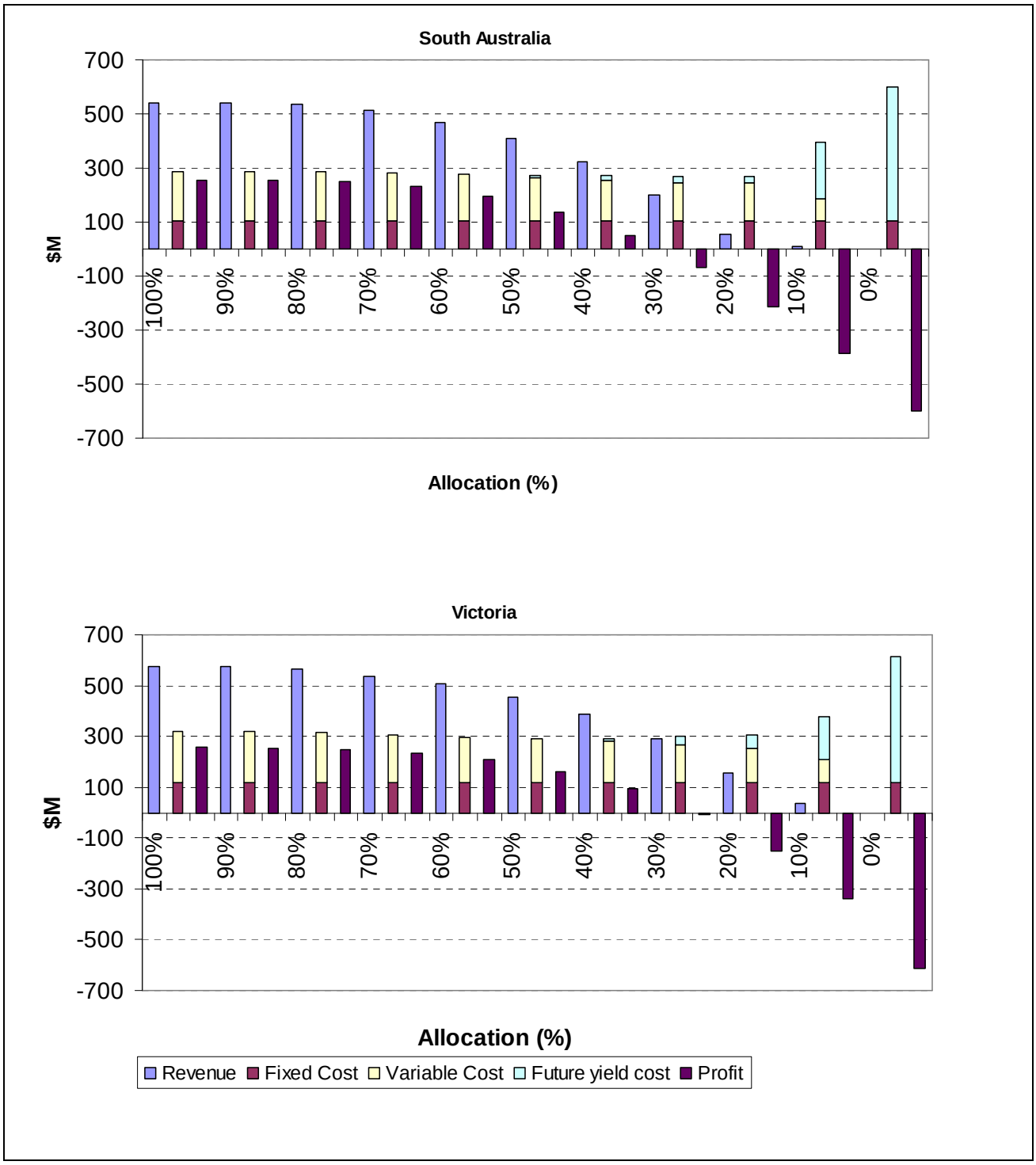

Figure 1: Estimated short-run revenue, cost and profit impacts of reduced water allocation for the South Australian and Victorian Lower Murray Irrigation Sectors

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Table 1: Climate Change Scenarios and Consequences on Rainfall and Runoff*

	Temperature Change (°C)	PET Change (%)	Rainfall Change (%)	Runoff Change (%)**
Mild	+1	+4	-5	-13
Moderate	+2	+8	-15	-38
Severe	+4	+15	-25	-63

* Estimates based on results from Pittock (2003) unless otherwise noted.

** Estimates based on Kirby et al., (2006).

Table 2. Predicted water allocation levels to SA and Victorian irrigators for alternative climate change assumptions

Climate Scenario	Water Availability	Probability	SA Water Allocation %	Victorian Mallee Water Allocation %
No change	Low	12%	100%	100%
	Moderately Low	30%	100%	100%
	Moderately High	24%	100%	100%
	High	34%	100%	100%
Mild	Low	12%	80%	100%
	Moderately Low	30%	100%	100%
	Moderately High	24%	100%	100%
	High	34%	100%	100%
Moderate	Low	12%	17%	39%
	Moderately Low	30%	54%	73%
	Moderately High	24%	67%	90%
	High	34%	100%	100%
Severe	Low	12%	0%	2%
	Moderately Low	30%	0%	16%
	Moderately High	24%	6%	43%
	High	34%	24%	84%

Table 3. Water prices ($/ML/year) predicted with regression for climate scenarios

Water allocation year	Climate Scenario			
	Baseline	Mild Climate Change	Moderate Climate Change	Severe Climate Change
Very low, 6th percentile	108	313	459	556
Moderately low, 24th percentile	62	180	278	459
Moderately high, 76th percentile	38	142	217	278
very high, 94th percentile	13	35	55	55
Scenario average	53	164	249	353

Table 4. Irrigation Efficiencies by Crop Type, Irrigation Technology, and Management Style

Good Management						
	Citrus	Wine	Apricot	Field Crop	Veg	Nuts
Drip	0.88	0.94	0.88	0.88	0.88	0.88
Pivot	na	Na	Na	0.88	0.88	Na
Furrow	0.8	0.8	0.8	0.8	0.8	0.8
Under Canopy	0.85	0.85	0.85	na	Na	0.85
Overhead	0.85	0.85	0.85	0.85	0.85	0.85

Average Management						
	Citrus	Wine	Apricot	Field Crop	Veg	Nuts
Drip	0.83	0.87	0.83	0.83	0.83	0.83
Pivot	na	Na	Na	0.83	0.83	Na
Furrow	0.75	0.75	0.75	0.75	0.75	0.75
Under Canopy	0.8	0.8	0.8	na	Na	0.8
Overhead	0.8	0.8	0.8	0.8	0.8	0.8

Poor Management						
	Citrus	Wine	Apricot	Field Crop	Veg	Nuts
Drip	0.78	0.82	0.78	0.78	0.78	0.78
Pivot	na	Na	Na	0.78	0.78	Na
Furrow	0.68	0.68	0.68	0.68	0.68	0.68
Under Canopy	0.73	0.73	0.73	na	Na	0.73
Overhead	0.73	0.73	0.73	0.73	0.73	0.73

Table 5. Irrigation Management Practices

Average	Irrigator does not use advanced scheduling techniques and exhibits maintenance levels within one standard deviation of the mean
Above average	Irrigator uses advanced scheduling techniques and exhibits maintenance levels greater than one standard deviation of the mean
Below average	Irrigator does not use advanced scheduling techniques and exhibits maintenance levels less than one standard deviation of the mean

Table 6. Summary of Irrigation Sector Production Responses under Alternative Climate Change Scenarios

Indicators \ Scenarios	Baseline*		Mild Climate Change		Moderate Climate Change		Severe Climate Change		Moderate Climate Change (w/ water purchase)	
	VIC	SA	VIC	SA	VIC	SA	VIC	SA	VIC	SA
BIOPHYSICAL INDICATORS										
Irrigated Area (ha)	51457	40911	51457	38841	49300	32529	41844	16542	51457	40911
Average Area Fallowed (ha)	0	0	0	-355	-2158	-4436	-5706	-16542	0	0
Total Water Applied (GL)	481.2	373.6	429.1	294.2	385.5	216.5	291.4	130.2	452.6	353.3
Total Drainage Generated (GL)	69.7	48.8	57.5	34.1	48.8	26.5	41.0	22.3	59.9	40.9
Average Irrigation Efficiency (%)	85.5%	86.9%	86.6%	88.4%	87.3%	87.8%	85.9%	82.9%	86.8%	88.4%
Crop mix										
% Perennial	100%	100%	100%	92.5%	91.6%	0%	0%	0%	100%	100%
- % Nuts	55%	55%	55%	50.8%	50.4%	0%	0%	0%	55%	55%
- % Grapes	15%	15%	15%	13.9%	13.7%	0%	0%	0%	15%	15%
% Annual Crops	0%	0%	0%	7.5%	8.4%	100%	100%	100%	0%	0%
% Yield Deficit	100%	100%	95%	92%	93%	97%	97%	98%	99%	99%
% Water Deficit	99%	99%	90%	85%	86%	87%	89%	92%	95%	95%
ECONOMIC INDICATORS										
Private cost benefit										
Irrigation Revenue as % of Baseline	873.5 ($m/yr)	694.2 ($m/yr)	95%	86%	89%	56%	58%	29%	99%	99%
Variable Water Costs as % of Baseline	25.1 ($m/yr)	19.5 ($m/yr)	265%	229%	358%	240%	366%	150%	448%	450%
Irrigation Profit as % of Baseline	382.5 ($m/yr)	298.4 ($m/yr)	91%	78%	81%	46%	48%	13%	95%	89%

* The economic indicators baseline levels are in absolute terms (millions of AUS$ per year), not percentages.