Sustainable diversion limits and climate change: results from an integrated economic – hydrology model of the Murray-Darling Basin

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Summary

Climate change and the proposed Murray-Darling Basin Plan both result in less water for irrigation. Climate change is projected to take water from all uses including the environment, whereas the likely sustainable diversion limit in the Plan aims (amongst other things) to return water to the environment. We examine the impact on flows and the returns to irrigation of potential reductions in irrigation allocations, and the interaction with projected climate change impacts.

Our analysis is based on an integrated hydrology – economics model of the Murray-Darling Basin, described in Kirby et al. (2012a). The model can quickly and easily run new climate or other scenarios, accounting for flows at key environmental assets. It uses a statistically calibrated economic model that can closely predict drought outcomes accounting for allocation, climate and price circumstances.

We examined a 2,800 GL reduction to diversions, and compared it to a base case of no reductions. We modelled the flows and irrigation returns for the no reduction and reduction cases under the assumption of historical climate, a median climate change and a more severe climate change. The climate change projections were those examined in the CSIRO Murray-Darling Basin Sustainable Yields project, slightly extended for more recent years.

The broad results of this analysis are that:
- The reduction of water available to irrigation under the sustainable diversion limit results in a less than proportional reduction in returns to irrigation. A 25 % reduction in water available on average over 114 years is estimated to reduce the gross value of of irrigated agricultural production by about 3 % on average. This is consistent with observation of reduced water availability in the drought (Kirby et al., 2012b, Conner et al., 2012).
- Future droughts projected under climate change might be more severe that those experienced to date, with an expectation of greater economic impact;
- A median climate change projection removes from the overall system slightly more water than is gained for the environment under the sustainable diversion limit. Under current sharing rules, this reduction in water comes primarily from the environment. The exact impact on flows varies from valley to valley. The impact of climate change is not considered in other analyses of the Murray-Darling Basin plan.

- The returns to irrigation are not much affected by a median climate change, with a 2 % reduction in gross value resulting from 3 % reduction in water availability (on top of the reductions due to the diversion limit). This detail in this result depends on the exact form of water sharing rules, and rules will change in the future; we used a default assumption that the behaviour resulting from the rules will be much as it is now.

1 Introduction

The Murray-Darling Basin is currently subject to great change in water availability and use, partly because of the recently released proposed Murray-Darling Basin Plan (MDBA, 2011a), partly because of other factors like climate change (CSIRO, 2008), and partly because of other changes such as rise of water trading (eg. Kirby et al, 2012b).

Our aim in this paper is to explore the impact of sustainable diversion limits and climate change in the Murray-Darling Basin on flows available to the environment and on the value of irrigated agricultural production.

The Guide to the Murray-Darling Basin Plan (MDBA, 2010) and the Proposed Plan (MDBA, 2011a) were accompanied by several studies of the impacts on irrigated agriculture and the more general economy of and employment in the basin; studies for the Proposed Plan are compiled and summarised in MDBA (2011b). Several analyses suggest that the impact on irrigated agriculture and the basin economy is likely to be small overall, but some communities could bear more substantial costs. For example, ABARES (2011, summarised in MDBA 2011b) estimated that the gross value of irrigated agricultural production would decline 12.7 percent with a reduction of 2,800 GL/year in water available to irrigation, but this would be somewhat offset by the Australian Government's Water for the Future programs.

These studies, however, are not directly linked to flow impacts. Here, we use an integrated hydrology and economics model (described in more detail by Kirby et al., 2012a, this conference) to examine the impacts of reduced water availability under a sustainable diversion limit on flows available to the environment and on the value of irrigated agricultural production.

The Proposed Plan (MDBA, 2011a) does not deal with climate change directly. Rather, it recognises climate change as a significant risk, with potential impacts both to water requirements and to water availability. The Plan supports the incorporation of new knowledge from further research into revisions of the Plan in 2015, and also requires that state water resource plans must take such new knowledge into account (MDBA, 2011a).

Here, we use the integrated hydrology and economics model to examine the impacts of climate change in addition to the sustainable diversion limit on water available for irrigation and the resultant irrigation sector economic impact.

2 Method

We used an integrated hydrology – economics model to assess the flows available to the environment and the value of irrigated agricultural production for several scenarios including a base case (no sustainable diversion limit and no climate change), base case plus a sustainable diversion limit, and base case plus a sustainable diversion limit plus climate change. The comparison of the scenarios forms the basis of our assessment.

Integrated hydrology – economics model

The hydrology component of the integrated hydrology – economic model is based on a simple, monthly water balance stocks and flows model of the Murray-Darling Basin, subdivided into 58 catchments. In each catchment, the rainfall and potential evapotranspiration are used to partition the rain between actual evapotranspiration and runoff. Runoff accumulates in the rivers, and flows downstream; it is stored in dams, fills lakes and wetlands from which it evaporates, spills onto and is partly consumed on the floodplains, is diverted for irrigation, eventually (if enough water remains) flowing out of the mouth. This hydrology part of the model is calibrated against observations of flow at the downstream flow gauge of the 58 catchments (the records of which vary from a few years to the full 114 years of our typical simulation period from 1895-2009). It simulates reasonably well the full range of flows, and the development of dams and irrigation diversions. The details are described by Kirby et al. (2012a) elsewhere in this conference.

The economics part of the model is based on regressions of the observed areas, production, water use and gross value of production of irrigated agriculture. Each of these dependent variables was regressed as a function of water available, evaporation and rainfall, and crop prices, for ten major commodity groups and for 17 regions and four recent years during the drought. The data covered a wide range of water uses, water availability, rainfall, evaporation and commodity price circumstances observed during the drought. The regression model captures intermediate time frame response; it is neither a truly short-run (within year) nor a long-run (full capital adjustment) model, but has a mixture of effects resulting from the actual experience of the drought.

In the integrated model, the hydrology model first determines the availability of water for irrigation in the 58 catchments and also calculates the flows, on a monthly cycle. Once per year, the water availability values are aggregated to the 17 economic regions. The regression equations estimated in Connor et al (2012a) are used in statistical simulation which involves holding levels of prices at the mean observed in the regression data and varying the rain, evapotranspiration, and water available for irrigation based on 114 year hydrology simulation to determine areas under each commodity group in each region and the gross value of production.

Scenarios

1. <u>Base case</u> scenario – current development with historical climate. The purpose of the scenario is to provide a base case, against which to compare other

scenarios. The scenario is based on the historic climate from 1895 – 2009, and the current irrigation development.

2. <u>2,800 GL SDL</u> scenario - sustainable diversion limit with 2,800 GL returned to the environment, with historical climate. The purpose of the scenario is to examine the impact on flows and diversions of reducing the average annual diversions by 2,800 GL. We simulate the flows and allocations expected with the reduced diversion, and with historical rainfall and potential evapotranspiration. The Guide (MDBA, 2010) describes a 3,000 GL sustainable diversion limit scenario, and gives percentage diversion reductions for each major valley to achieve the overall reduction. In our 2,800 GL scenario, we reduced the diversion catchment by catchment by an amount equal to 28/30 of the 3,000 GL sustainable diversion limit scenario valley diversion reductions in the Guide. The Proposed Plan (MDBA, 2011a) is less specific about where the reductions are to come from.

3. <u>2,800 GL SDL with median climate change</u> scenario - sustainable diversion limit with 2,800 GL returned to the environment, and water availability reduction resulting from the CSIRO median climate change scenario. The purpose of the scenario is to examine the impact on flows and diversions of climate change together with reducing the average annual diversions by 2,800 GL. We simulate the flows and allocations expected with the reduced diversion, and with Cmid rainfall and potential evapotranspiration, where Cmid is the median climate change scenario of the Murray-Darling Sustainable Yields project (CSIRO, 2008). The climate sequences of CSIRO (2008) are extended by three years to 2009.

3 Results

We present the results of the sustainable diversion limit and climate change scenarios in terms of the difference from the base case.

2,800 GL SDL compared to base case

The ranked flows (monthly flows ranked from greatest to least) calculated at two locations in the Murray-Darling Basin are shown in Figure 1. The calculated flows, particularly medium to high flows, are increased by the return of water to the river. The effect is greater in the Murray than the Darling, as expected, because the allocations, and hence reductions to allocations, are greater in the Murray. The ranked allocations in sixteen regions are shown in Figure 2. The main consequence of the way in which the sustainable diversion limit was implemented can clearly be seen: the reduction is in the largest diversions, in wet years (and years when the dams are full). The variation of allocation from year to year is thereby reduced. Indeed, since dams are projected to be less often emptied, they often have more water in drier years, so allocations are greater at the dry end in some regions.
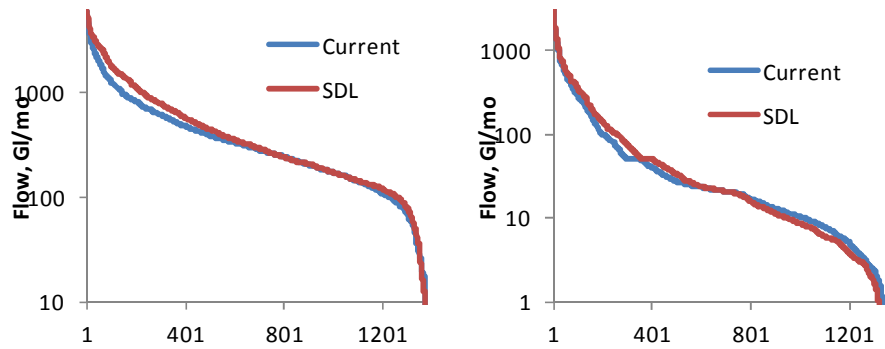
Figure 1. Current development scenario (blue line) and 2800 GL sustainable diversion limit (red line) cumulative flows at Euston on the Murray (left) and Weir 32 on the Darling (right).

The impact of the diversion limit on the gross value of irrigated agricultural production is shown in Figure 3. Note that Figure 3 is based on the statistical regions defined in ABS (2010), whereas the diversions in Figure 2 are based on hydrological catchments, to allow comparison with diversion figures available from the MDBA (2011c). In many regions, the diversion limit is projected to have little effect on the gross value of irrigated agricultural production. The diversion limit is calculated to reduce gross value in the Condamine, Central West, Namoi, Murrumbidgee and Murray in particular. In a few regions, such as the Gwydir, the diversion limit is calculated to reduce the gross value in the years of greater gross value, but increase it in the years of lesser gross value. This results from the impact on allocations, which in the Gwydir are calculated to reduce in wet years, but increase in some dry years.

The impact on commodities is shown in Figure 4. Rice, cotton and to some extent beef are all calculated to decline in value. This is consistent with the findings of Kirby and others (2012b, this conference) that the much greater reduction in water availability during the drought had a small impact on most commodities. Dairy, while using less diverted water for irrigation, substitutes bought-in feed, and maintains its gross value, which in turn buoys up the value in the Goulburn region (Figure 3) despite the lesser diversions (Figure 2). Higher value tree crops (fruit and nuts), vegetables and grapes maintain their value through trading in water; thus the gross values of those regions is maintained.

2,800 GL SDL plus climate change compared to base case and 2,800 GL SDL

The ranked flows calculated at two locations in the Murray-Darling Basin are shown in Figure 5. The increase in flows resulting from the imposition of the sustainable diversion limit is reversed by the assumed climate change scenario (compare Figure 1 with **Error! Reference source not found.**). This finding is consistent with the findings of the Murray-Darling Basin Sustainable Yields project (CSIRO 2008), which showed that the median climate change scenario (specifically, Cmid in the terminology of CSIRO, 2008) would result in a 13 % reduction in the total flows of about 24,000 GL, which amounts to a reduction of about 3,100 GL – that is, the median climate change scenario takes away roughly what is gained by a 2,800 GL sustainable diversion limit.
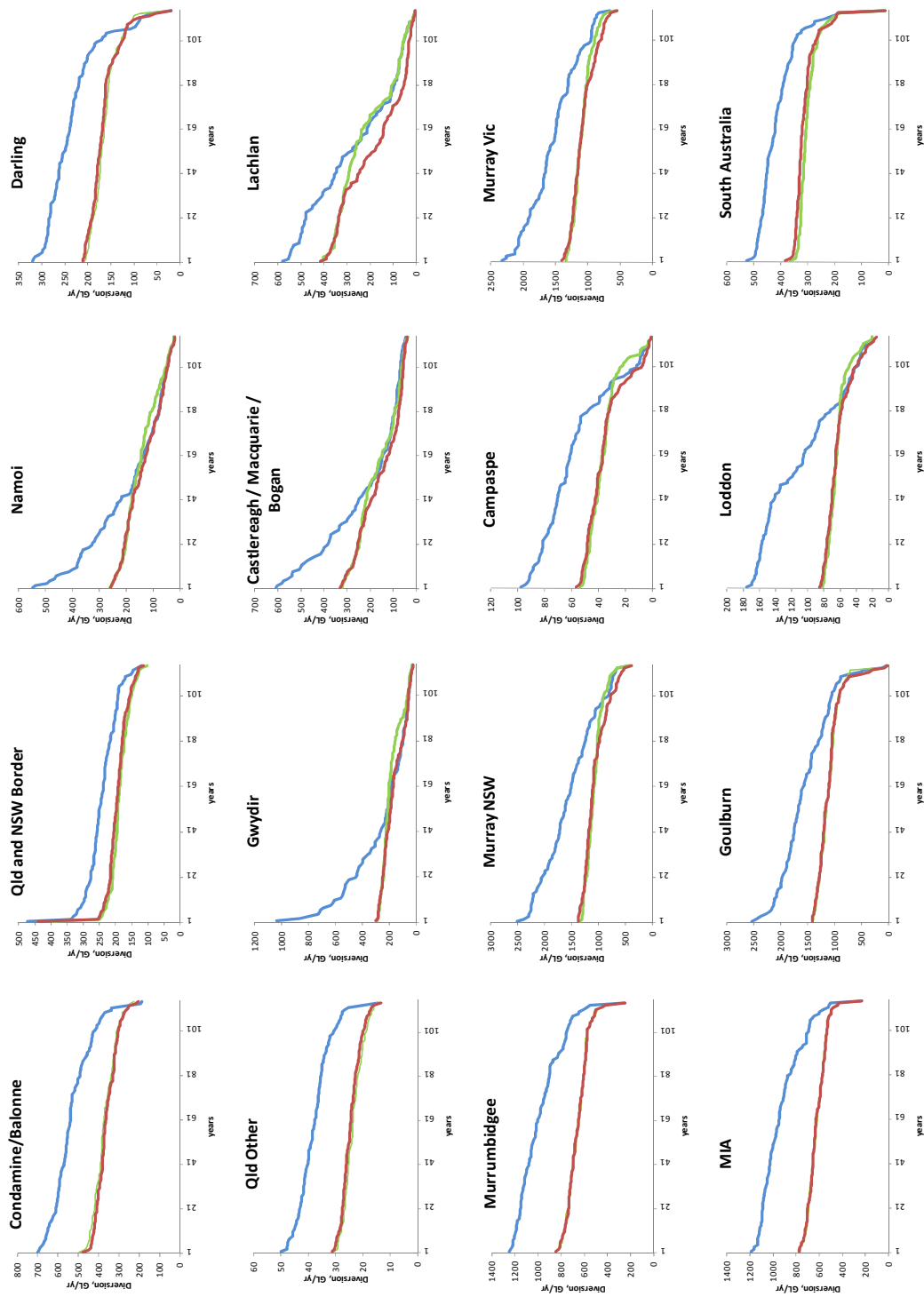
Figure 2. Ranked allocations for base case (blue line), 2800 GL sustainable diversion limit (green line) and 2800 GL sustainable diversion limit with median climate change (green line) in the main catchments in the Murray-Darling Basin. The Y axes are diversions in GL/year, ranked from greatest to least value, and the X axes are years.
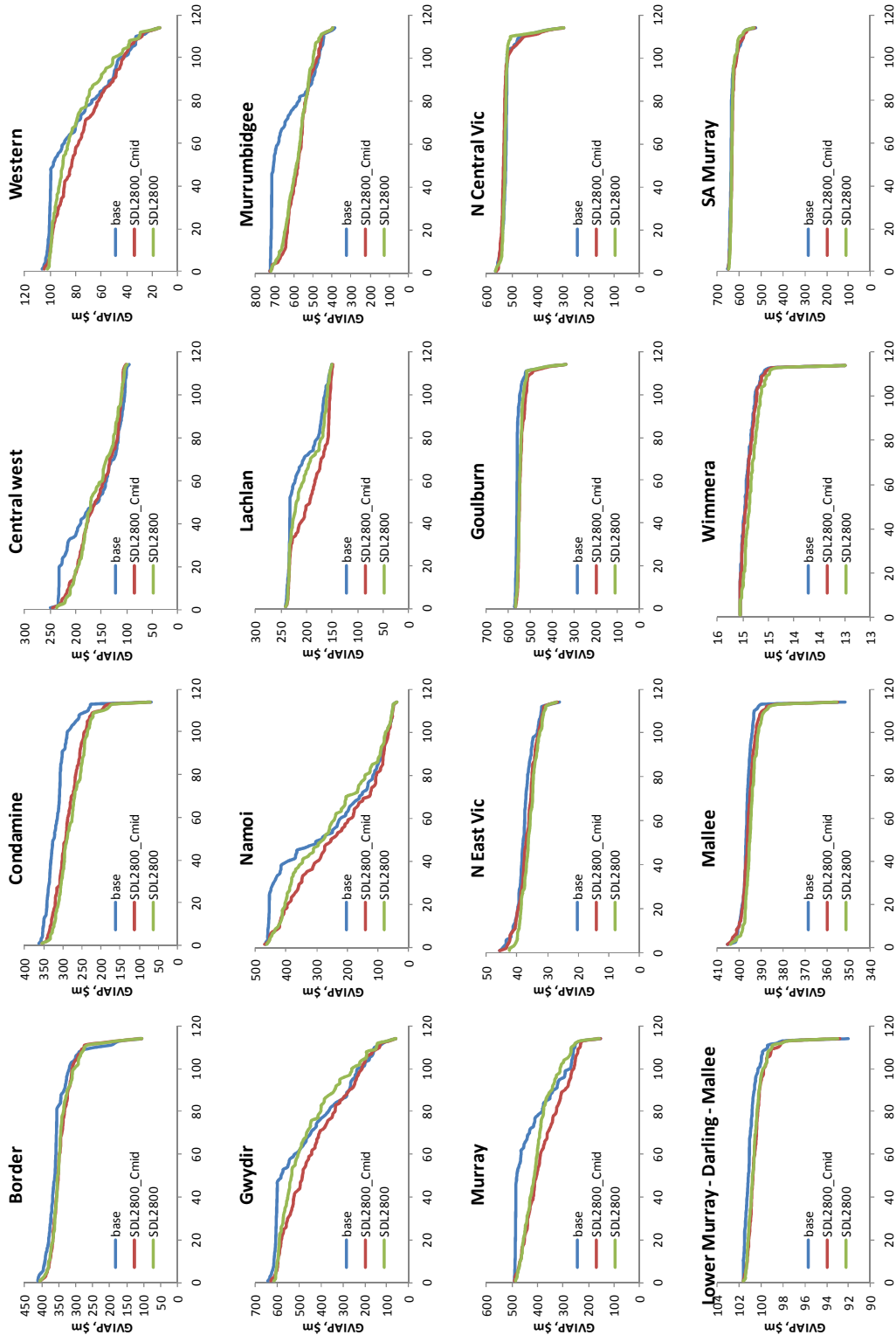
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Figure 3. Gross value of irrigated agricultural production (ranked) for the base case (blue line), 2800 GL sustainable diversion limit (green line) and 2800 GL sustainable diversion limit plus median climate change (red line) in the main irrigation regions in the Murray-Darling Basin. The Y axes are gross value of irrigated agricultural production in $m/year, ranked from greatest to least value, and the X axes are years.
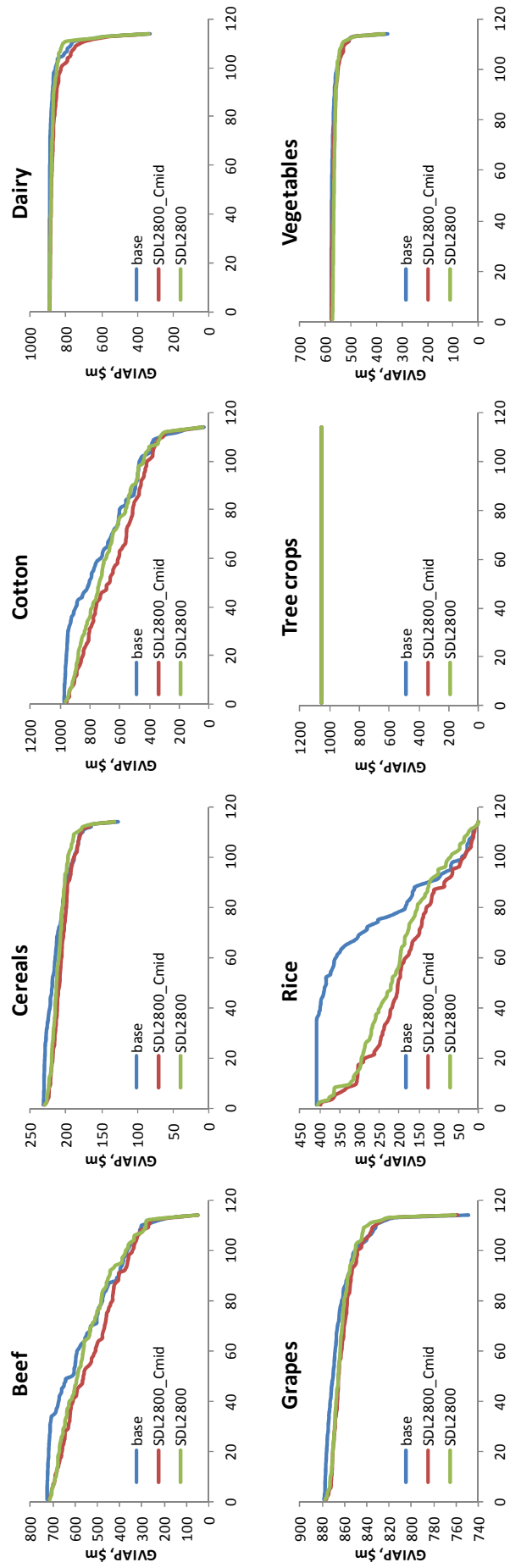
Figure 4. Gross value of irrigated agricultural production (ranked) for the base case (blue line), 2800 GL sustainable diversion limit (green line) and 2800 GL sustainable diversion limit plus median climate change (red line) for the main commodity groups in the Murray-Darling Basin. The Y axes are gross value of irrigated agricultural production in $m/year, ranked from greatest to least value, and the X axes are years.
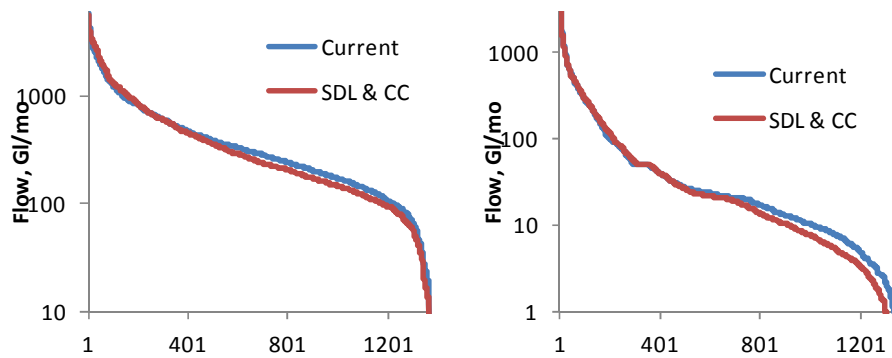
Figure 1. Current development scenario (blue line) and 2800 GL sustainable diversion limit with climate change (red line) cumulative flows at Euston on the Murray (left) and Weir 32 on the Darling (right).

The ranked allocations in seventeen regions plus the full basin are shown in **Error! Reference source not found.**. The reduction in allocations resulting from climate change adds little further impact to the reduction from the imposition of the sustainable diversion limit. Again, this is consistent with the findings of CSIRO (2008) that, under current water sharing rules, diversions in the basin are projected to decrease about 4 % (compared to a total reduction in availability of 13 %) across the basin.

The impact of a median climate change on the gross value of irrigated agricultural production is shown in Figures 3 and 4. Climate change generally adds little more to reductions resulting from the diversion limit. The result is expected from the impact on allocations.

4   Discussion and conclusions

We have simulated the impact of a sustainable diversion limit and climate change on the flows, allocations and gross value of irrigated agricultural production in the Murray-Darling Basin. In so doing, we have made several assumptions:

- the distribution amongst regions of acquisitions of water for the environment is not determined by the proposed Murray-Darling Basin Plan (MDBA 2011). We assumed that the distribution of 2,800 GL / yr savings was in direct proportion to that identified in the 3,000 GL/yr scenario in the Guide to the Murray-Darling Basin Plan (MDBA 2010). The final distribution could be different, and the distribution of impacts will be different from that calculated here.

- The water sharing rules are to be changed, and again the final form is unclear. In addition, the management of the environmental water is not yet clear. These will both affect flows, and the water sharing rules will affect allocations and diversions. Again, the distribution of impacts will be different from that calculated here.

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- Furthermore, the manner in which sustainable diversion limits may be changed to account for climate change is left open in the proposed Murray-Darling Basin Plan (MDBA 2011). The actual outcomes could be very different from those shown here, and will depend on how climate change is taken into account, and how the states implement the management and operation of water sharing rules under sustainable diversion limits.

- We have also assumed for the purposes of this assessment that several others factors will remain similar to past experience. In particular, we have assumed that commodity prices will not change, and thus will not affect the distribution of commodities.

- We have also implicitly assumed that trading will remain much as experienced during the last few years. There may be reason to suppose that trading patterns and volumes will change in the future. Firstly, trading (particularly inter-regional trade) is a relatively new phenomenon (Kirby et al., 2012b, this conference; NWC, 2010a), and the learned behaviour may see new patterns emerge. Secondly, recent trading behaviour has been affected by the entry of the Australian Government into the markets (NWC, 2010a), and this will not continue past the current buy-backs program.

- Finally, the economics analysis is based on a regression model of the economic impact of reduced water availability in the drought (Connor et al., 2012, this conference). While neither truly a short-run nor a long-run model (to the extent that both short- and long-run effects were evident in the observed behaviour regressed in the model), the model does not include some clear long-run effects; in particular, it does not include the long-run capital adjustments likely to follow the imposition of a limit on diversions.

Notwithstanding the simplifications in the assumptions above, and in the integrated hydrology – economic model itself (Kirby et al., 2012a), the general results agree with expectations and other evidence. The reduction of water available to irrigation under the sustainable diversion limit results in a less than pro-rata reduction in returns to irrigation. This is consistent with economic theory, where the marginal uses are the first to disappear, and with observation of reduced water availability in the drought (see the paper on the impact of the drought by Kirby et al., 2012b, this conference). Thus, the greatest impacts are likely to be felt on industries such as rice and cotton, and hence on the main rice growing areas in the south of the basin and the cotton growing areas of the north. Dairy will likely reduce its water use, but maintain its gross value through the use of substitute bought-in feed. High value industries such as fruit and nuts, and vegetables, may maintain their water use through water trading.

The analysis also shows that a median climate change projection removes from the overall system, and thus from environmental flows, slightly more water than is gained for the environment under the sustainable diversion limit. The result is not available from other analyses, but is consistent with the findings of CSIRO (2008) who examined climate change impacts but not diversion limits. However, most of the impact on irrigation results from the imposition of the diversion limit, and climate change does little further. This detail in this result depends on the exact form

of water sharing rules, and rules will change in the future; we used a default assumption that the behaviour resulting from the rules will be much as it is now.

Our results show the impact of these effects on the variation of flows, allocations and gross value of production. The allocations are calculated in some catchments to have a lesser variation under a sustainable diversion limit than at present, because dams are less frequently run dry by the demands for diversions. Under the median climate change, the average availability of water is projected to decrease, but so too is the water in a drought. Thus, future droughts are projected to be longer and deeper than those experience in the drought (see also Kirby et al., 2011). In terms of gross value of production, our calculations show that this will have the greatest impact on rice (see Figure 4). The result depends in part on the assumption, discussed above, that the behaviour resulting from the rules will be much as it is now.

Finally, there are avenues for exploring operations and planning to achieve desirable outcomes under the sustainable diversion limits. We explore these in Kirby et al. (2012c).

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