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murray darling basin

economic implications of water scarcity

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- *Climate change and a number of other factors could lead to increased water scarcity in the Murray Darling Basin in the medium term.*
- *In this article the economic impact of an illustrative reduction in irrigation water availability on irrigated output in the Murray Darling Basin, and the flow-on impacts to regional economies are examined. This type of analysis will help to identify the costs and benefits of alternative allocation arrangements between consumptive and environmental use.*
- *The role of government in water resource management and the type of policies that governments could adopt to help alleviate the impacts imposed on the irrigation sector in response to reduced water availability are also discussed.*
- *For example, policies that provide irrigators with the flexibility to carry over part of their current allocation into the next season, or reduce existing barriers to interregional trade in water, can reduce the costs associated with reduced access to irrigation water.*
- *Furthermore, governments may be able to minimise the potential for an inefficient allocation of water by requiring enterprises engaged in expanding water intercepting activities such as forestry to purchase water entitlements to account for increased interception.*

The outlook for water in the Murray Darling Basin is likely to be one of increasing scarcity, with a study by CSIRO (Van Dijk et al. 2006) identifying climate change as the major risk to water availability. CSIRO also identified a number of activities that have the potential to reduce runoff into streams and aquifers — mainly land use change and farm dam construction — as well as the potential for increased demand for groundwater by irrigators to reduce surface water availability in physically connected water systems.

Demand for water will also be affected by government policy to increase flows in environmentally stressed water systems. Moreover, policies aimed at mitigating the effect of climate change could stimulate carbon sequestering activities, such as forestry, that could further reduce the volume of water entering streams and aquifers.

Reduced access to irrigation water will have a direct impact on irrigators' incomes, as well as an indirect impact on regional economies. Irrigators may

not only reduce their expenditure on household items, but may also reduce their demand for inputs into irrigated agriculture from local suppliers, which may be offset only slightly by an increase in demand for inputs into dryland farming, where irrigated land reverts to dryland production. Reduced irrigated output will also have an impact on any relevant downstream processing activities located within these regions.

outlook for water

In 2006 the CSIRO released a report commissioned by the Murray Darling Basin Commission identifying a number of risks to shared water resources in the basin (Van Dijk et al. 2006). These risks included climate change, increased groundwater use, increased number of farm dams, bushfires and afforestation.

These risks have the potential to reduce the total volume of water entering streams and aquifers via a change in water supply caused by changes in rainfall or, conversely, via an increase in the demand for water resulting from water intercepting activities. A fall in the volume of water entering surface and groundwater systems will reduce the size of the total quantity of water available for consumptive and environmental uses, adversely affecting irrigators (the main consumer) and the environment. Irrigators' access to water will also be affected by any rebalancing of shares of the total pool of water in favour of the environment.

impact of climate change on water supply

The CSIRO study on shared water resources identified climate change as the main risk to water availability in the Murray Darling Basin (Van Dijk et al. 2006). It was concern over the threat that extreme weather posed to water availability in eastern Australia that culminated in the November 2006 water summit, which in turn led to the National Water Commission commissioning the CSIRO to undertake a comprehensive assessment of water availability in the basin. This assessment was to consider both surface and groundwater systems, as well as the potential impact of climate change and future development on water availability (CSIRO 2007a).

CSIRO is yet to release water availability estimates for all regions located in the basin. To date, findings have been released for eight of the eighteen contiguous regions that comprise the Murray Darling Basin — these regions are the primary drainage basins of the Murray and Darling rivers. Initial findings suggest that significant threats to water availability exist in some regions in the basin, especially in the southern basin. For example, initial results indicate that climate change could reduce surface water availability in 2030 by around 10 per cent in the Gwydir region in northern New South Wales and 21 per cent in the Wimmera region in Victoria, compared with historical levels (CSIRO 2007b,c).

increased water interception

The volume of water entering streams and aquifers can also be affected by an increase in demand for water through water intercepting activities. For example, water availability may be affected by an increase in the number of farm dams, or an expansion in the area of land converted from lower water intercepting activities such as grazing to commercial forestry. Surface water availability may also be affected by an increase in groundwater extractions in physically connected water systems.

farm dams

The 2006 CSIRO study identified farm dams as the second biggest threat to water availability in the basin, citing research identifying a significant expansion in farm dams in recent years (Van Dijk et al. 2006). The extent to which farm dams will reduce future inflows into streams and aquifers will depend on future agricultural development and any restrictions on the construction of new dams.

State governments have already imposed a number of restrictions on new farm dams that will limit the potential for these dams to reduce inflows into the basin. For example, farmers in New South Wales can capture only 10 per cent of average annual runoff from their property without incurring a licence fee. In Queensland the interception of overland flows by farmers is regulated for all activities other than for stock and domestic purposes. Restrictions also apply in Victoria, where irrigation or commercial use of water from new dams must be licensed, with anyone proposing to build a new dam needing to buy a water entitlement from another irrigator. Dams used for stock and domestic purposes do not require a licence, however.

CSIRO suggests that the impacts of farms dams on inflows will depend on the effectiveness of such legislation. Advancements in technologies such as satellite imagery could help monitor new farm dam activity, which in turn may reduce the risk of any illegal expansion in this activity through the increased risk of getting caught.

groundwater extractions

The CSIRO study on shared water also identified increasing groundwater extractions as a serious threat to surface water availability (Van Dijk et al. 2006). Increasing demand for irrigation water and reduced access to surface water could lead to the activation of groundwater licences that are currently unused, or only partially used. If this occurred in physically connected water systems, it could lead to a reduction in the volume of surface water flows available for downstream use.

According to Earth Tech Engineering (2003), 'groundwater management units' in the Condamine, Lower Gwydir, Upper Namoi, Lower Macquarie,

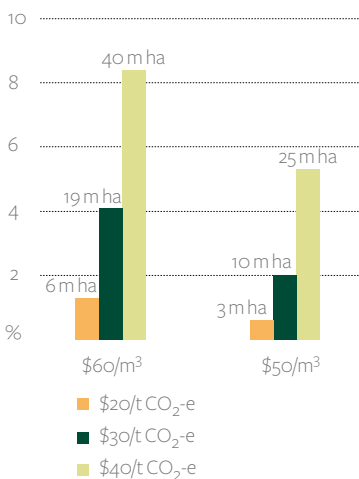
Upper Lachlan, Murrumbidgee and upland Victoria systems exhibit medium to high stream aquifer connectivity. Despite efforts to improve the management of groundwater systems in some jurisdictions, groundwater systems tend to be complex, with interactions often difficult to observe. This uncertainty increases the risk that an increase in groundwater extractions could lead to depletion in surface water flows in some systems.

afforestation

CSIRO also identified afforestation as a threat to water availability in the Murray Darling Basin (Van Dijk et al. 2006). There were around 284 000 hectares of plantation forestry in the basin in 2006, with this area projected to increase by another 50 000 hectares by 2020 (BRS 2007). This projection does not factor in a commercial return to carbon sequestration. Policies aimed at mitigating the impact of climate change could further stimulate an expansion in carbon sequestering activities such as forestry, which could have the unintended consequence of reducing runoff, and hence water available for downstream use, including environmental use.

The attractiveness of converting land from broadacre activities, such as grazing and cropping, to forestry is dependent on the net present value of the returns to forestry and carbon being higher than the net present value of returns to grazing or cropping. The returns to forestry and carbon will be influenced by carbon prices, carbon sequestration rates, timber productivity and future log prices. Figure a illustrates preliminary abare analysis that provides some insight into the potential for conversion of broadacre farm land into forestry under a range of hypothetical carbon prices.

a potential for agricultural land to switch to forestry in australia as a percentage of land currently under agricultural management



environmental demand

While an expansion in water intercepting activities would reduce total inflows into the basin, irrigators’ access to water could also be affected by efforts to return overallocated systems to more environmentally sustainable levels of extraction. Under the National Water Initiative (Commonwealth of Australia 2004), state and territory signatories are required to make substantial progress in achieving this goal by the end of 2010.

economic impact of reduced water availability

The Murray Darling Basin covers an area of around 1 million square kilometres, is located in south eastern Australia, and accounts for around 40 per cent of Australia’s gross value of agricultural production. While the vast bulk of the land is used for dryland agriculture, including grazing and cereals, there is also a substantial irrigation industry, with around 18 000 square kilometres being irrigated in 2001 (Bryan and Marvanek 2004). The main irrigated agricultural activities in the northern basin were cotton and pasture, while in the southern basin they were pasture, cereals and rice.

The main horticultural regions are located in southern New South Wales, northern Victoria and along the Murray River in South Australia.

The following analysis examines the direct and indirect economic impacts of a reduction in water availability for irrigated agricultural activities in the basin in the medium term. The analysis is confined to the impact of a reduction in water availability on irrigated agriculture, and does not consider the potential for projected changes in temperature and carbon dioxide fertilisation to affect productivity. The seasonal pattern of rainfall is also assumed to be unchanged.

scenarios

The climate scenario modelled assumes a 20 per cent reduction in runoff resulting from 10 per cent reduction in rainfall. It also assumes that these reductions occur uniformly across the basin. The greater reduction in water available for irrigation than the reduction in rainfall reflects the fact that reductions in rainfall tend to induce a more than proportional reduction in runoff (Jones et al. 2007).

The scenario used in this study is intended to represent a 'moderate' climate change scenario for a change in rainfall. While a reduction in rainfall will also affect dryland agriculture, these impacts are not considered in this analysis. For an analysis of the potential impacts of climate change on dryland agriculture, see Heyhoe et al. (2007).

method

The analysis involves the use of an irrigation model developed within abare (referred to as the water trade model) to estimate the distribution of the direct impacts of reduced water availability on irrigated farming activities located within the basin (see Heaney et al. 2004 for a description of the framework used to develop the water trade model). These impacts are then fed into abare's AusRegion general equilibrium model to examine the indirect flow-on effects to regional economies (see abare's website for a detailed description of the AusRegion model).

irrigation

abare's water trade model is used to simulate the direct impacts of a reduction in water available for irrigation. The regions contained in the model are linked, so that the quantity of water available for use in downstream regions depends on upstream water use. The model allocates the volume of water available for irrigation within a region under the cap on irrigation extractions in such a way as to maximise the net returns from different irrigated activities within that region. This means that the model simulates optimal water trade within regions, and does not allow water to be traded between regions. It is also assumed that a 20 per cent reduction in water availability

translates into a 20 per cent reduction in the cap on extractions for irrigation in all regions. Any impacts of changes in commodity prices are not taken into account here.

The baseline (reference case) used in this analysis assumes:

- no change in water availability for irrigation from long term historical levels and
- a regional pattern of land use similar to that observed in the 2001 agricultural census (ABS 2003).

economywide impacts

The results from the irrigation model were then fed into abare's AusRegion model. This model is a computable general equilibrium model. Such models estimate how changes in one sector of the economy affect other sectors of the economy. AusRegion was used to estimate the medium term impacts on regional economies, as well as the national economy, of reduced irrigated agricultural output caused by reduced rainfall and runoff. The version of AusRegion used in this analysis was designed to examine agricultural impacts in detail, and includes eighteen agricultural commodities and four related processing commodities.

results

The results reported here are indicative of the type of impacts that could be expected in the medium term if there was a 20 per cent reduction in water available for irrigation. Such a reduction in water available for irrigation is estimated to reduce irrigated farm profit and output in all regions in the basin, relative to the reference case. The pathways through which reduced water availability can reduce irrigators' profitability include:

- a reduction in the area of land irrigated
- a reduction in the volume of water applied to irrigated land and
- an increase in costs associated with less water intensive management techniques.

In reality, irrigators' profitability is also likely to be affected by changes in salinity as a result of reduced water availability. abare's water trade model is still being developed, and will consider these impacts in later versions.

Table 1 contains regional profit estimates for irrigators located in the Murray Darling Basin. The estimates indicate that a 20 per cent reduction in water available for irrigation may reduce irrigated farm profit by around 5.5 per cent across the basin, relative to what otherwise would be the case. While this impact is significant, there are regional differences, with the greatest impacts occurring in the Riverina (-6.8 per cent) and eastern

1 annual farm profit from irrigation in the murray darling basin

under different water availability scenarios, in 2001 dollars

	water availability scenarios		
	reference case a	alternative case	change
	\$m	\$m	%
queensland	375	353	-5.8
northern new south wales	533	500	-6.2
riverina	849	791	-6.8
western new south wales	144	136	-5.4
eastern victoria	389	363	-6.6
western victoria	614	580	-5.5
south australia	569	560	-1.6
total	3 473	3 284	-5.5

a The reference case assumes no change in water availability for irrigation from long term historical levels and a regional pattern of land use similar to that observed in the 2001 agricultural census.

Victoria (-6.6 per cent). In contrast, the model estimates suggest that South Australia will be least affected, with a 1.6 per cent reduction in farm profit. This is because profit earned from lower value activities (cereals and dairy) in South Australia comprises a relatively low proportion of total irrigation profit compared with the proportion of irrigation water used by these activities. As can be seen in table 2, a 20 per cent reduction in water available for irrigation in South Australia is largely confined to these lower value activities, with irrigators ceasing to irrigate cereal crops and the area of land devoted to irrigated dairying activities declining by around 94 per cent.

The reduction in water availability considered in this study is estimated to have a significant impact on land use in some regions, with around 15 per cent of the area of land under irrigation in the reference case moving out of irrigation into dryland production as a result of the reduction in water availability.

2 change in irrigated land use in the murray darling basin

from a 20 per cent reduction in water availability, relative to reference case

	horticulture	cotton	rice/grains	dairy
	%	%	%	%
queensland	-3.2	-18.7	33.1*	-68.2*
northern new south wales	-1.2	-19.1	-3.9	-3.2
riverina	-1.2	-16.2*	-18.2	-2.3
western new south wales	-1.7	-21.7	12.9*	-31.1*
eastern victoria	-3.1		-52.2*	-18.0
western victoria	-1.6		-41.7*	-16.8
south australia	-3.1		-100.0*	-93.7
total	-2.2	-19.2	-16.9	-13.8

* Represents less than 3 per cent of total land use for that activity group in the basin.

3 change in regional basin production

from a 20 per cent reduction in water availability, relative to reference case

	change %
northern new south wales	-0.49
riverina	-1.19
eastern victoria	-2.01
western victoria	-0.63
queensland	-0.94
south australia	-1.38
basin total	-1.03

The regional land use estimates in table 2 indicate that the area devoted to horticulture tends to decline less than the areas of alternative, often lower value, activities following a reduction in water availability. This is because water is reallocated from lower value activities to higher value activities.

The area of some irrigated land uses is expected to increase. For example, in Queensland the area of irrigated grains is estimated to increase by around 9000 hectares as the cost of expanding production fell relative to other land uses (when water prices rise, land values fall).

Reduced agricultural activity will have flow-on effects to regional economies, as well as to basin and national economies. The AusRegion model results indicate that a 20 per cent reduction in inflows within the basin may lead to a relatively modest 1.0 per cent decline in gross regional product across the basin (relative to the reference case – see table 3), and a 0.1 per cent decline in gross domestic product at the national level.

The results indicate that the regional basin economies of eastern Victoria and South Australia may be more vulnerable to a decline in agricultural activity than other regional economies, with gross regional product estimated to decline by around 2.0 per cent in eastern Victoria and around 1.4 per cent in South Australia. The most vulnerable regional economies will tend to be those where the direct effects of reduced water availability are substantial, or where the agricultural and related processing industries comprise a relatively large proportion of economic activity. For example, the agricultural and related processing industries comprise a relatively large proportion of economic activity in South Australia.

role of government

The goal of water resource management is to maximise the long term value derived from water use. These values include both market and nonmarket values. Given that there is no market for environmental water, the government will need to ensure that these nonmarket values are taken into consideration when allocating access to water. Once the government has identified an appropriate split in the allocation of water between environmental and consumptive uses, its main role will be to facilitate the efficient allocation of water between consumptive users.

Free markets will often lead to the most efficient allocation of resources. A problem will arise, however, where there is no market for a particular resource use. This is the case for environmental water. This type of market failure provides a rationale for governments to intervene to ensure that these values are taken into consideration in the allocation process. The reality is that it is usually difficult and expensive to estimate these values with any acceptable degree of accuracy using current valuation techniques.

To date, governments have attempted to address the absence of a market for environmental water by regulating access to water through the imposition of a cap on extractions for consumptive use. Another option being pursued under the National Plan for Water Security (Commonwealth of Australia 2007) is to reallocate water to the environment by purchasing water from irrigators.

Once a decision has been made on the allocation of water between consumptive and environmental uses, the government's role may be limited to creating a framework that:

- minimises the cost of achieving environmental outcomes and
- provides consumptive users with the necessary incentives to maximise the consumptive value of water.

minimising the cost of environmental flows

Environmental watering demands may generally be categorised by their timing or frequency. Some environmental demands are regular, with water required in all or most periods (for example, minimum flows), whereas other environmental demands are irregular, and may only occur every few years (for example, flooding of wetlands). The flexibility in meeting irregular environmental demands provides some scope to reduce the costs of acquiring environmental water, as well as to reduce the costs incurred by irrigators from reduced access to irrigation water.

For example, governments could acquire large volumes of permanent water entitlements for the environment, and sell allocations attached to these entitlements back to irrigators in dry years when the environmental value of this water is relatively low and the productive value for irrigation relatively high. Conversely, governments could acquire a smaller volume of permanent water entitlements, and purchase temporary allocations from irrigators in wet years to supplement high flow natural events. The relative value of additional water for irrigation is likely to be low in wet years (and hence the cost of acquiring these flows will be relatively low), whereas the environmental benefits associated with high flow events are likely to be high.

The potential benefits associated with the increased flexibility of allowing water to be traded between uses is recognised in the National Plan for Water Security, where it is stated that 'the counter-cyclical nature of environmental watering will allow some water to be made available to irrigators during dry years' (Commonwealth of Australia 2007).

property rights and markets

In 1994 the Council of Australian Governments (COAG) agreed that markets were the most appropriate mechanism for allocating water between

irrigators. To allocate water efficiently, however, the market will need to be underpinned by a system of property rights that are well specified, transferable and enforced.

The current water market suffers from a number of flaws. These flaws arise primarily from the poor specification of property rights or restrictions on the transferability of water between irrigators in different regions, between irrigators and other consumers, and between seasons. Addressing these flaws could lead to an increase in the consumptive value of water, and reduce the costs incurred by consumptive users stemming from reduced water availability.

trade restrictions

Governments have the ability to increase the efficiency of water use by increasing the number of participants in the water market. They can do this by removing restrictions on who can participate in the water market, and by extending the geographic range of the market. To increase the number of competitors for water, they could extend the market to allow trading between irrigators, domestic water utilities, industrial users and mining companies. The value of water used for industrial and mining activities will usually be higher than for irrigated activities. For utilities that have access to river systems that are linked to irrigation regions, sourcing water from irrigators will often be more cost effective for augmenting water supplies than alternative options.

Extending the geographic coverage of the market can also increase the value of water. This is because the market will then tend to cover a broader range of irrigation activities, increasing the incentive to trade water to higher value uses. It should be noted that this trade is mutually beneficial to buyers and sellers. Extending geographic coverage will also reduce the production risk faced by irrigators when seasonal conditions are poor as it may be possible to source water from other regions. It should be noted that there may be legitimate restrictions on interregional trade in some cases because of the potential for increased environmental damage, such as that associated with increased salinity. (See box 1 for examples of restrictions on interregional trade in water.)

A number of studies have been undertaken estimating the benefits from removing barriers to interregional trade in water. For example, Adamson et al. (2007) estimated that irrigators' incomes in the Murray Darling Basin would be around 20 per cent higher in the absence of restrictions on interregional trade than with restrictions on interregional trade. Heaney et al. (2003) estimated the opportunity cost of reducing allocations in the southern basin from an increase in environmental flows. This study found that free interregional trade had the potential to reduce the opportunity

cost incurred by irrigators by around a third, compared with a situation of no interregional trade.

restrictions on intertemporal transfers

There is also the potential to further reduce irrigators' production risk in the event of lower and more variable water supplies by providing them with greater control over the management of their water entitlement over time. Management of irrigation water entitlements over time involves a

box 1 restrictions on trade in water

Currently, there are a number of restrictions on trade between irrigators and other consumers, and between irrigators in other regions in connected river systems. For example, trade in permanent water entitlements out of irrigation areas in the Murray Darling Basin is currently capped at a maximum of 4 per cent of total water entitlements in an irrigation area in any one year. While the signatories to the National Water Initiative have agreed to remove this cap in the northern catchments of the basin by 2014, a more conservative approach has been taken in the southern basin, where the potential for interregional trade is much higher. The commitment in the southern basin is to review the cap in 2009, after which a decision may be made to increase the cap if considered appropriate (Commonwealth of Australia 2004).

There are also impediments to interregional trade in temporary water allocations in the basin. While these restrictions are less explicit than restrictions on trade in permanent entitlements (all signatories to the National Water Initiative agreed to the immediate removal of barriers to temporary trade), they still have the potential to act as significant impediments to effective trade. For instance, there can be significant delays in getting temporary transfers processed, with transfers in the Victorian part of the basin often taking over a month (see table below; Waterexchange 2008). Such impediments will act to reduce the value of interregional trade.

average temporary transfer processing time for selected regulating authorities ^a

	current days	2006-07 days	2005-06 days
murrumbidgee irrigation	1.7	1.9	1.6
murray irrigation limited	8.0	2.5	5.4
nsw state water – gwydir	15.5	4.2	5.2
first mildura irrigation trust	31.8	4.2	2.0
nsw state water – murray	38.2	72.2	8.7
nsw state water – murrumbidgee	38.4	18.0	7.4
lower murray water	39.2	5.8	3.3
goulburn murray water	41.1	6.1	2.7

^a Estimates based on intra and interregional transfers through Waterexchange.
Source: Waterexchange (2008).

consumption–storage decision, where the benefits of consuming water today are to be evaluated against the uncertain benefits of storing water in dams for future use.

Traditionally, state governments have centrally managed water storages, making decisions on the volume of water available for use in the current season (allocations) given the volume of water held in storage and expected future inflows. This centralisation of the decision process does not take into account that many irrigators may have a different attitude to risk than that assumed by the government on the irrigators' behalf. While some jurisdictions have eased restrictions on water use over time, significant restrictions remain and recent history has highlighted the potential for sovereign risk to restrict irrigators' access to water (see box 2 for a brief discussion on carryover water and sovereign risk).

Irrigators who are not allowed to carry any water over have the option of using all of their allocation, selling all or part of their allocation or forfeiting any unused allocation at the end of the irrigation season. Some irrigators may forfeit any unused allocation because they receive it too late in the season to be useful for irrigation, and if other irrigators in the region are engaged in similar activities there may not be a market for this water. Even irrigators who do sell water may prefer to carry this water over for future use if they had this option because the value they expect to receive from using it next season may be higher than the sale price in the current season.

An alternative to central control of water storage management is to decentralise the decision process by issuing storage property rights to irrigators. Storage property rights could potentially involve some form of capacity sharing. Capacity sharing is a system of allocating property rights to water from shared storages, first proposed by Dudley (1988). Rather than

box 2 carryover water

Some jurisdictions have attempted to provide irrigators with greater flexibility over water use over time by introducing a facility that allows irrigators to store a proportion of their seasonal water allocation for use in future seasons. For example, general security irrigators in New South Wales are allowed to carry over part of their allocation into the next season; this has recently been extended to irrigators in Victoria. Despite these efforts, there remain a number of significant restrictions on the use of these facilities. There is also the issue of sovereign risk, with the New South Wales Government suspending general security irrigators' access to carry over water in 2006-07. The effectiveness of a facility allowing irrigators to carry over part of their allocation in mitigating the risk of low or zero allocations will depend on jurisdictions honouring obligations to deliver water under such a facility.

allocating users a share of the pool of water available for consumption in the current period, each user is allocated a share of the total storage capacity, as well as a share of the inflows and losses from the storage. Capacity sharing has been adopted successfully by SunWater at the St George water supply scheme in south west Queensland. It should be noted that a carryover facility (see box 2) is significantly different from capacity sharing, since carryover provisions do not define explicit property rights to storage capacity.

While more research needs to be done on the costs and benefits of capacity sharing, it would seem that there may be benefits from introducing a system of capacity sharing to manage the intertemporal use of water. Improving storage management policies could lead to an increase in mean incomes, and importantly, to a significant reduction in the variability of incomes.

While governments have tended to focus on the benefits from relaxing constraints on interregional trade to date, there may also be significant benefits from relaxing constraints on water management over time, especially in the event the Murray Darling Basin is entering a period of lower and more variable rainfall due to climate change. Improvements to water management over time also have the potential to change the product mix within a region. For instance, if capacity sharing does reduce irrigators' production risk, some irrigators may invest in higher value irrigated activities that require access to a more reliable water supply.

When used in tandem, capacity sharing and free interregional trade have the potential to significantly reduce irrigators' exposure to production risk.

attenuation of irrigators' water property rights

Governments can also influence the level of risk attached to water entitlements through their selection of water users covered by these rights. If coverage is too narrow, water users outside the property rights system may be able to affect the availability of water for irrigation. If activities by water users outside of the property rights system have a significant impact on availability, it could lead to irrigators making inefficient investments because of uncertainty about future water availability. It could also lead to an inefficient allocation of water if water is intercepted by lower value activities.

As mentioned earlier, CSIRO (Van Dijk et al. 2006) has identified a number of activities that have the potential to attenuate the property rights of existing irrigators. These include changes in land use and on-farm water harvesting activities that lead to increased interception and reduced runoff into streams and aquifers. Surface water irrigators may have their rights further attenuated by an increase in groundwater extractions in water systems where groundwater and surface water are linked.

While governments could regulate these activities by, say, setting a uniform limit on the amount of water that can be harvested on farm or limiting the area of land within a catchment that can be converted to forestry, this type of regulation is likely to be arbitrary, and unlikely to yield an efficient allocation of water. An alternative to regulation would be to include farmers or foresters in a system of water property rights. They would then have to purchase a water entitlement from an existing entitlement holder if they wanted to expand their water harvesting or forestry activities.

The National Water Initiative recognised the potential for interception activities in water systems that are overallocated, fully allocated or approaching full allocation to reduce irrigators' access to water. As a result, signatories to the National Water Initiative agreed to:

- identify and record any significant interception activities
- require entities engaged in expanding interception activities above an agreed threshold to acquire a water entitlement and
- implement a robust compliance monitoring regime.

The states have agreed to implement these measures no later than 2011 (Commonwealth of Australia 2004).

The inclusion of these activities in a property rights system will protect the rights of existing irrigators, and if the transaction costs are not excessive, improve the allocation of water. This improved allocation will occur through mutually beneficial trade based on the true marginal value of water use, with entities engaged in higher value activities purchasing water entitlements.

While extending water property rights to include water intercepting activities could lead to a more efficient allocation of water, the costs and benefits of extending these rights will need to be taken into consideration. For example, governments will need information on interception rates, the potential for expansion and marginal returns if they are to make informed decisions on the inclusion of these activities in the property rights system. The costs of gathering this type of data, as well as the costs of enforcing any expansion in the coverage of activities, may be quite high, whereas the benefits in some instances may be quite low. For example, extending water property rights to include farmers changing from grazing to dryland cropping may not be warranted if this created little change in the availability of water for irrigation. Under these circumstances the costs from extending property rights are likely to outweigh any benefits from intervention.

reducing uncertainty by keeping irrigators informed

The provision of information relating to the potential impacts of climate change is important because it has the potential to aid the adaptation

process whereby irrigators make more appropriate water use and investment decisions than they would have made in the absence of this information. However, the provision of information alone should not be considered the end result of climate change research — this information will need to be disseminated in a usable form so that farmers are aware of the implications of this research and can use it to improve their adaptation strategies. This can be achieved through a number of avenues, including extension programs and workshops.

Beyond informing irrigators of developments in climate change research, and the implications of this research, the role for government may be limited. The price of water should reflect increased water scarcity, which in turn should lead to appropriate decisions on water use, trade and investments in irrigation infrastructure. The change in price due to increased water scarcity should also stimulate investment in research and development of new water savings technologies, which should further aid adaptation to lower water availability. It will be important that any government expenditure on upgrading irrigation infrastructure does not distort any long term decisions by irrigators on the location and use of water in the basin.

conclusion

Some of the main factors affecting the future supply and demand for water in the Murray Darling Basin have been identified in this paper. Climate change appears likely to affect future water supply, whereas it seems likely that society will demand increasing levels of environmental water.

A reduction in the volume of water available for irrigation will lead to less irrigation and lower incomes in the irrigation sector. The distribution of the impact on irrigators' incomes of an illustrative reduction in the volume of water available for irrigation in each of the regions comprising the Murray Darling Basin has been demonstrated through the use of abare's water trade model. These direct impacts were then fed into abare's AusRegion model to identify the flow-on effects to the regional economies in which these irrigators operate. The most vulnerable regional economies will tend to be those where the direct effects of reduced water availability are substantial, or where the agricultural and related processing industries comprise a relatively large proportion of economic activity.

Government policy can influence water use decisions and, as a result, has the potential to mitigate the impact of reduced water availability to some degree. For example, the removal of barriers to interregional trade in water that are not based on environmental concerns, and reducing constraints on irrigators' use of water over time would result in a more efficient allocation of water. Extending property rights to include major water intercepting

activities also has the potential to increase the security of irrigators' entitlements, which will enhance their ability to make more efficient water use and investment decisions. The extension of these property rights will also aid the efficient allocation of water. This will occur through mutually beneficial trade. And finally, the government has a role to invest in climate change research, and to disseminate this information so that irrigators (and farmers more generally) can adapt to climate change. This adaptation will involve irrigators making more informed water use and investment decisions.

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