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Benefits of increased irrigation efficiency in the Murrumbidgee Irrigation Area

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Limited water availability in the face of increasing competing demands for water, including water for environmental purposes, has highlighted the need to make the most efficient use of the available water in the Murray Darling Basin. This study focuses on the Murrumbidgee Irrigation Area (MIA) and considers the benefits of increasing irrigation efficiency. A model of the MIA which incorporates both on and off farm components is used to evaluate the benefits of adopting two on-farm options — twin furrow irrigation for horticultural farms and water reuse systems for horticulture and broadacre farms. The study found these on-farm water saving options can be profitably adopted leading to savings of river diversions of up to 27 GL a year.

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Introduction

In recent seasons, reduced availability of irrigation water, increased water demand in agriculture and for other purposes, and the high cost of investment in new dams and associated infrastructure in the southern Murray Darling Basin (MDB), have highlighted the need to make the most efficient use of existing water resources.

Improving on-farm irrigation and water use efficiency is likely to lead to a range of benefits including maintaining or increasing production from existing or less amounts of water; expanding irrigated areas; and reducing river diversions. These benefits can translate to increased income to irrigation regions.

In addition to the on-farm benefits, many environmental benefits can also be obtained from improving irrigation and water use efficiency. Concerns about rising water tables contributing to waterlogging and salinity in some areas have highlighted the benefits of reducing accessions to the groundwater table. Reductions in excess water use can also minimise the movement of pesticides, nutrients and salt downstream, reducing damage to aquatic ecosystems and other downstream water users. Government initiatives, through water market reforms towards more efficient allocation and pricing of water and trade in water entitlements, combined with the increasing need to allocate water for the environment are all expected to increase the opportunity cost of irrigation water in the future. Adoption of water saving technologies and practices is one way of mitigating the negative impacts of higher water values, and at the same time leading to savings in water diversions.

This paper presents some of the preliminary results from ABARE’s ongoing work on water use efficiency, focussing on the benefits of adoption of twin furrow irrigation for horticultural farms and water reuse systems.

The Murrumbidgee Irrigation Area

The Murrumbidgee Irrigation Area and Districts are situated between the Lachlan and Murrumbidgee Rivers in south-western New South Wales, and consist of the Yanco and

Mirrool Irrigation Areas, plus the Benerembah, Tabbita and Wah Wah Irrigation Districts. Irrigated agriculture is an important contributor to regional revenue with the total irrigated output from this area estimated to be $325 million in 1997 (Hope and Wright, 1999, p.48).

Of the available water saving technologies and practices, there has been limited uptake of alternative application technologies in the southern New South Wales regions. Flood/furrow irrigation is the main application method for irrigated crops on broadacre, dairy and horticulture farms in the Murrumbidgee region. In 1996-97, the average farm had 97 per cent of its irrigated pasture area and 96 per cent of its barley area irrigated by flood. The remaining irrigated pasture and barley areas were irrigated by travelling irrigators or movable sprays. Around 74 per cent of horticultural area was irrigated by flood, with the next most common irrigation system in horticulture being drip irrigation.

Most of the recent uptake of alternative irrigation systems and crop water management practices has occurred on horticultural farms (Sigred Tijs, CSIRO, personal communication, July 1999). For broadacre farms, improving irrigation and soil moisture management was considered the most effective water saving approach rather than changing the water application method. This included the use of soil moisture monitoring, irrigation scheduling tools and water reuse systems (Sigred Tijs, CSIRO, personal communication, July 1999).

In 1996-97, just under half of the farms in the Murrumbidgee region used some form of irrigation scheduling tool, and only 35 per cent of the total irrigated area in the Murrumbidgee region fed into a water reuse system.

For irrigated broadacre and dairy farms, most of the irrigated area has been landformed in some way, however, only a small percentage is formed into beds and rows. Improvements in soil mapping through techniques such as EM31 and the use of laser levelling, allows farmers to plan their farm layout to maximise water use efficiency. The farm layout is also important for the installation of water reuse systems to maximise water saving benefits.

Potential for water savings in the MIA

Potential water savings exist both on and off farm within the MIA. Water balance studies carried out for the NSW Land and Water Management Plan estimate that a total of 97,000 ML of both irrigation and rain water runs off farms in the Mirrool and Yanco irrigation areas (Morgan and Glasson, 1995 and Neeson, 1995). Large area farms contributed 81 per cent of this run off volume, with the remainder coming from horticultural farms. Irrigation run off contributes 71 per cent of the total run off from large area farms compared to 82 per cent from horticultural farms. The total volume of irrigation water run off from Mirrool and Yanco areas in an average year is estimated at 71,000 ML, with an average of 28 000 ML draining back into the Murrumbidgee river, (Sinclair Knight Merz 1995). The remainder eventually drains into Barren Box Swamp at the end of the system, which is then used to supply the MIA Districts.

In addition to surface water run off, the Yanco and Mirrool irrigation areas also yield approximately 34,000 ML of net ground water accessions both from irrigation water and rain fall (Morgan and Glasson, 1995 and Neeson, 1995). Part of the ground water yield from horticultural farms is drained by tile drains, which also intercepts some of the ground water inflows occurring under these farms. The tile drains are estimated to discharge around 12,000 ML of water annually to the Barren Box Swamp.

Water losses also occur from the system when there is significant rainfall at key times. When on-farm water demands are met by rainfall then irrigation water is no longer required. This water then exits the system through drains or outfalls which can increase the losses for that season.

The Barren Box Swamp acts as an on-line storage to store and then reuse drainage water coming from the Mirrool and Yanco irrigation areas. The Wah Wah irrigation district is supplied with regulated releases from Barren Box Swamp while the Benerambah irrigation district is supplied with drainage water from Mirrool Creek supplemented with irrigation water from the Sturt Canal.

The Barren Box Swamp has a storage capacity of around 85,000 ML with overtopping occurring at 98,000 ML. The main purpose of the Barren Box Swamp is to provide on-line storage for the Wah Wah irrigation district, however as its storage capacity is larger than required for this purpose it also helps store channel escapes coming from the Mirrool and Yanco irrigation areas.

Due to the expansion in irrigated agriculture in the MIA, the storage capacity of the Barren Box Swamp has fallen short of that required to store all of the inflows. Consequently, releases to the Mirrool Creek floodway have become a frequent occurrence with an estimated 43,000 ML of excess water being released annually to the

Mirrool Creek floodway in recent years. In an average year, the volume of water discharged to the floodway from the Barren Box Swamp is estimated to be 25,000 ML in excess of the capacity of the floodway. The cost of flooding of the land along the floodway is estimated at $473,000 a year in 1995 (Land & Water Management Plan 1995). After netting out the benefits to some farms, which access the floodwater for irrigation, the net cost of this flooding is estimated at $378,000 a year. Most of the water spilled to the floodway is lost through seepage, escapes and evaporation while some water finds its way to the Lachlan River. The water lost through seepage may cause some environmental damage due to ground water accessions.

Apart from the on-farm water losses, off-farm losses occur through seepage, leakage, evaporation and escapes from delivery channels. This, combined with the on-farm losses, and water losses through discharges to the river and floodway, constitute the real losses to the MIA and districts irrigation system.

Impediments to increasing water use efficiency

Physical, economic and institutional factors as well as risk affect the adoption of water saving technologies. Policies to influence the adoption of water saving technologies and management practices need to focus on the institutional impediments while considering the physical constraints.

The physical constraints relate primarily to the quantity and quality of the land in a particular region and access to different sources of water. The types of technology finally adopted will be heavily influenced by a range of physical factors. These include the soil type, the suitability of the farming activities to different water application technologies and practices, and the form of delivery network in each region. For example, trickle/drip systems are more appropriate for heavier clay soils and micro sprays are more appropriate for lighter, sandier soils.

Economic factors, such as commodity prices, the availability of finance, and changes in the costs of other inputs with the adoption of water saving technologies, will also have an influence. However, farmers or policy makers are unlikely to be able to directly influence these factors.

Policy makers are able to have the most influence over institutional factors that can directly affect the adoption of water saving technologies and practices. The overall institutional setting faced by the irrigators affects their incentives to adopt water saving measures. These factors include water charging policy, the efficiency of water markets, the type of irrigation delivery infrastructure and capacity constraints, and environmental cropping and irrigation regulations such as, for example, rice area limits.

Higher water prices, combined with well functioning water markets, will motivate farmers to adopt water saving technologies within the physical constraints on their farms. Improved irrigation efficiency could allow irrigators to maintain existing areas of irrigated activities while releasing water for sale to other irrigators or reduce the need to purchase water in addition to their entitlement. However, if there are restrictions on the sale of water, the economic incentive for farms to adopt water saving technologies is reduced.

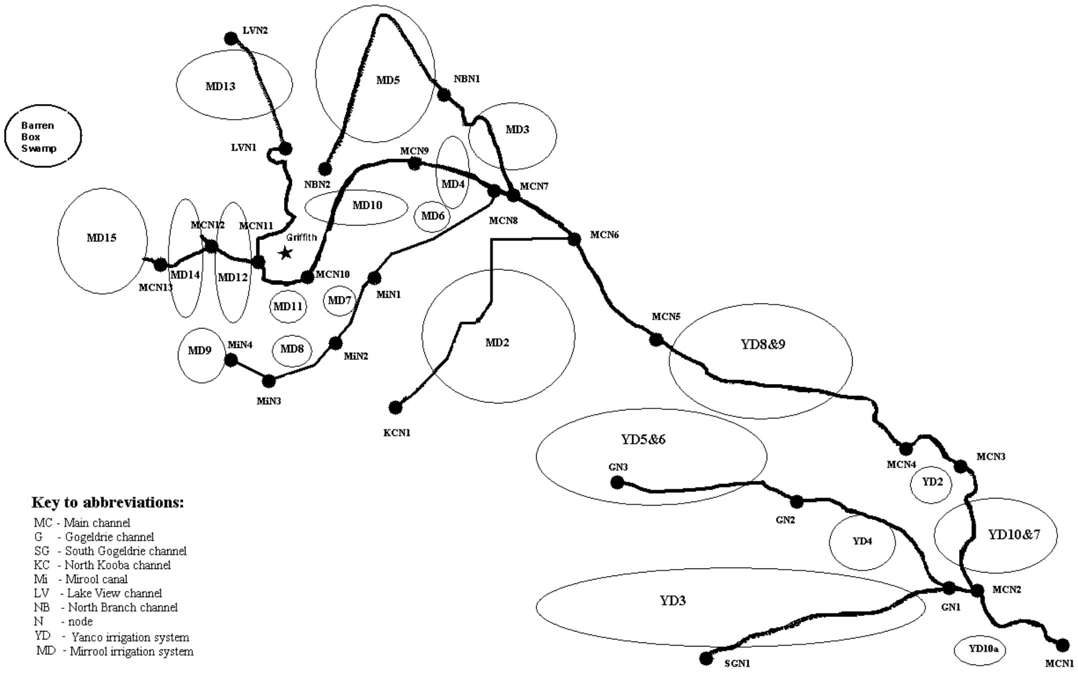
The availability and cost of labor is also important as some management practices (such as run off monitoring and adjusting irrigation timing) may involve the substitution of labor for water, in order to increase water use efficiency.

Once a farmer has invested in a new application method such as an overhead spray or micro irrigation system, water will be saved every year whether the saved water is used or not. The variable nature of water supplies could influence the adoption of such water saving technologies while efficient soil moisture management practices can be particularly beneficial in balancing water, particularly in a drought year.

A model of the MIA

The model developed for the Yanco and Mirrool areas incorporates the Main canal and the major branch canals and represents 2400 farms grouped into 26 existing irrigation divisions of the MIA and district system covering the majority of irrigated agriculture in the MIA (figure 1 and table 1). The model has three inter linked components: the farms in the area, an off farm water delivery system and a water authority. The price of water is the same for all divisions and is determined within the whole model. The model simultaneously solves for an optimal uniform price of water for all divisions, the allocation of water between divisions, and within each division the optimal allocation of resources between alternative production activities, and for each cropping activity the optimal mix of water application technologies, subject to a set of constraints. For each division, the set of constraints specified includes constraints on the quantity and quality of land available, the quantities of family labor and alternative sources of water namely reuse and ground water.

Figure 1: Diagrammatic representation of Mirrool and Yanco irrigation systems



The economic parameters in the on-farm component include prices of crops and livestock commodities, variable input costs, annualised cost of water application technologies, annulised investment cost of storage built for the reuse system and costs of pumping to deliver water to the reuse storage and to pressurise water for drip irrigation.

Table 1: Specification of the Yanco and Mirrool irrigation systems included in the model

Primary	Secondary	Tertiary	Reach No	Division(s) included	Channel capacity (ML/day)	Horticulture land (Ha)	Broadacre irrigation land (Ha)	Broadacre dry land (Ha)
Yanco								
Main canal			Reach 1	Yanco 10a	6500	144	153	147
	Gogeldrie		Reach 1		1600	0	0	0
		South Godgeldrie	Reach 1	Yanco 3	600	61	10904	5422
	Gogeldrie		Reach 2	Yanco 4	900	735	1580	1144
	Gogeldrie		Reach 3	Yanco 5 & 6	750	819	16991	8807
Main canal			Reach 2	Yanco 10 & 7	4700	1868	2873	2345
Main canal			Reach 3	Yanco 2	4600	337	1581	949
Main canal			Reach 4	Yanco 8 & 9	4500	400	20947	10556
Total					6500	4364	55029	29370
Mirrool								
Main canal			Reach 5		3000	0	0	0
	North Kooba canal		Reach 1	Mirrool 2	700	562	6707	3181
Main canal			Reach 6		3000	0	0	0
	North branch canal		Reach 1	Mirrool 3	400	1226	893	0
	North branch canal		Reach 2	Mirrool 5	309	1171	4732	2583
Main canal			Reach 7		3000	0	0	0
	Mirrool canal		Reach 1	Mirrool 6	1500	543	2884	1500
	Mirrool canal		Reach2	Mirrool 7	661	1453	677	932
	Mirrool canal		Reach 3	Mirrool 8	425	1546	674	811
	Mirrool canal		Reach 4	Mirrool 9	228	624	4769	2360
Main canal			Reach 8	Mirrool 4	1500	1138	924	903
Main canal			Reach 9	Mirrool 10	1500	1289	887	952
Main canal			Reach 10	Mirrool 11	1500	659	305	0
	Lake view canal		Reach 1		220	0	0	0
	Lake view canal		Reach 2	Mirrool 13	220	1079	5394	2833
Main canal			Reach 11	Mirrool 12	1500	1326	715	893
Main canal			Reach 12	Mirrool 14	1000	2088	1132	97
Main canal			Reach 13	Mirrool 15	500	278	8315	3761
Total					3000	14982	39008	20806
System total					**6500**	**19346**	**94037**	**50176**

Technical parameters include irrigation requirements for a normal, a wet and a dry year for each crop derived by netting out rainfall and capillary rise from the potential evapotranspiration requirement. A set of run off, deep percolation and capillary rise coefficients is used to calculate net water losses from irrigation. The reuse system when chosen stores both rain and irrigation run off water to be reused on or off-farm. The deficit in the potential evapotranspiration requirement after taking into account rainfall, capillary rise and the run off water that can be profitably reused is met by irrigation water from the off farm delivery system (Hafi, Kemp and Alexander 2001).

Using this model of the MIA, the benefits of the adoption of twin furrow irrigation systems by horticulture farms and investment in water reuse systems both on and off farm were evaluated. Each of these options were evaluated individually and jointly and their performance was measured against a baseline in which existing conditions within the MIA are represented.

Base case

The base case represents existing conditions both on and off-farms within the Yanco and Mirrool irrigation areas. The existing pattern of allocation of land between different cropping enterprises is represented, while for each crop, the most prevalent water application technology is assumed. Furrow irrigation is the main application technology in horticultural farms, with around 92 per cent of citrus and 85 per cent of wine grape farms adopting it whereas flood-furrow irrigation is being adopted for broadacre crops. Only a few farms have adopted reuse systems, consequently both irrigation and rainfall run off water is discharged to the district drains.

As the Benerambah and Wah Wah districts are not included specifically in the model the entire run off water is assumed to drain out from Yanco and Mirrool irrigation areas, which are included in the model. The existing conditions of the delivery network in different parts of the system are represented with corresponding rates of conveyance losses and channel capacity constraints, particularly at known water choke points. The average annual allocation of water for the whole system is assumed to be equal to the average annual diversion at Berembid weir plus net sales of water out of the system.

The flow requirements of irrigation divisions not represented in the model but supplied by the tail reaches of the main and the Mirrool canals are incorporated in the model. A water delivery charge of $14.00 per ML and an average temporary water entitlement (TWE) premium of $20.00 per ML are assumed. Trading of water between farms within the system is implicitly assumed while the water authority charges a uniform delivery cost per ML regardless of the location of the farm (Hafi, Kemp and Alexander 2001).

Adoption of twin furrow irrigation systems by horticulture farms

The twin furrow irrigation system has a smaller wetted area compared to the common broad furrow system and consists of two narrow furrows close to the vine or citrus rows instead of a single broad furrow. Under experimental conditions, the twin furrow system was found to reduce the volume of water applied by 40 per cent, without any loss of productivity (Neeson, 1995). A twin furrow system requires investment in an on-farm piped delivery system with a low head (3 metre) pump to pressurise water. The water is delivered through a riser and then twin taps to the head of each row at a flow rate of up to 1.5 litre/second. In this option, the twin furrow irrigation system is included as another option in addition to broad furrow and drip application technologies included in the baseline model.

Investment in water reuse systems both on and off-farm.

Reuse of run off water, either on or off-farm, involves collecting and storing irrigation and rainfall run off water for immediate or later reuse. Both on and off farm storage for reuse are considered as on-farm storage may not be feasible on many existing horticultural farms due to land constraints.

It is assumed in this study that in each division, a storage capacity large enough to store up to a third of the run off produced in the division will be built. The storage capacity for a division may comprise of a number of small on and off farm storages. The on farm reuse system recommended by NSW Agriculture consists of a pump installed at one location of the farm where a large area of the farm drains and storage built at the highest point on the farm. The run off water is pumped to the storage while the flow from the storage for reuse is gravity fed. Inclusion of a reuse system on-farm has a number of costs associated with it. A capital cost of between $20000 to $43000, costs of operating the pump, maintenance of the system and loss of some productive land. These costs are shown in table 2.

Table 2 Cost of adopting on-farm reuse systems

Storage size (ML)	Storage area (Ha)	Capital cost ($)	Pumping cost ($/ML)	Maintenance cost ($/year)
5	0.24	20,091	2.03	683
10	0.74	29,000	2.25	683
26	1.61	33,560	3.15	833
48	2.40	42,980	3.26	833

It is assumed that each storage built will be of 48 ML capacity. For each division, the model selects the optimal number of storages by taking into account the availability of run off water and the various costs of investment given in table 2. The annual equivalent of the capital cost of $42980 for a 48 ML storage calculated at a 7 per cent discount rate and a productive life of 30 years amounts to $3464. Little data is available on the cost of off-farm storages, therefore the cost of supplying reuse water off-farm is assumed to be equal to that for on-farm storages.

The model incorporates evaporation losses for water stored. An evaporation rate increasing from 7 per cent in August to 17 per cent in January and December and then falling to 6 per cent in May is used. Seepage losses from the storages are assumed to be negligible, as these storages are likely to be located on land with low soil permeability.

It is also assumed that the volume of run off water stored for reuse in the Yanco and Mirrool areas can not exceed a third of the total volume produced. In this manner adequate run off water is made available for use by the Districts while the run off water lost to the system through releases to the flood way and the Murrumbidgee river is reduced.

The impact of investment in reuse systems in the Yanco and Mirrool areas is assessed by comparing the system wide financial performance with that under the base case. A study undertaken in 1995 for the NSW Land and Water Management Plan found that the inclusion of on-farm reuse systems in the Yanco and Mirrool irrigation areas was not financially viable with a benefit cost ratio of less than 1. However, the same study found that the inclusion of reuse systems with storage capacities over 26ML was viable with rates of return of over 14 per cent as the environmental benefits and costs were included (Neeson, et. al, 1995). Another study (Hafi, Chapman and van Hilst , 1998) found that the inclusion of reuse systems on dairy farms in the NSW Murray region was financially viable with financial rate of return of around 10 per cent.

Results

The impact of increased irrigation and water use efficiency was evaluated by comparing the performance of more water use efficient options with that of the base case. A number of indicators can be used to compare the performances between options. In this study, the measures used were: the volumes of river diversions; run off not reused after being applied to crops; and returns to diverted water and water applied to crops.

All of the options simulated resulted in some increase in the availability of water within the system and decrease in water losses to the system. A switch from broad furrow to more efficient twin furrow irrigation by horticulture farms (option 1) reduced the amount of water that needed to be applied to meet crop water requirements, with a consequent reduction in run off and deep percolation.

Investments in on and off farm reuse systems (option 2) created an alternative source of water in the system, and also reduced the volume of run off water discharged from the system.

When these two options are combined (option 3) then the overall impact on the system water balance was determined by the interactions between the individual impacts of the first two options. If, in the base case, the availability of water after making an allowance for transmission losses is less than the volume that needed to be applied to crops to obtain the maximum profit from the system, then any of these options will lead to more water being applied to crops.

Impact on land use

The total irrigated broadacre area increased for all of the options compared to the baseline largely due to the use of some of the saved water for irrigated cropping on land previously planted to dry crops in the base case (table 3).

Table 3 Irrigated cropping on broadacre land by scenarios

	Base (Ha)	Twin furrow (Ha)	Reuse (Ha)	Twin furrow & Reuse (Ha)
Rice				
Yanco	18954	19715	21203	21203
Mirrool	9546	9661	11699	11858
Total	28500	29377	32902	33061
Coarse grains				
Yanco	19376	19376	19370	19371
Mirrool	13631	13631	12882	12936
Total	33007	33007	32253	32308
Oil seeds				
Yanco	8055	8055	8055	8055
Mirrool	6485	6485	6478	6478
Total	14540	14540	14533	14533
Vegetables				
Yanco	200	200	200	200
Mirrool	1002	1002	1002	1002
Total	1202	1202	1202	1202
Pasture				
Yanco	6676	6974	5707	5791
Mirrool	3140	3182	2665	2549
Total	9816	10155	8372	8339
Total				
Yanco	53260	54320	54535	54620
Mirrool	33804	33961	34726	34823
Total	87065	88281	89261	89443

The total rice area increased for all of the options while the total area under all other crops decreased in all except the twin furrow scenarios. Each of the options resulted in an easing of the channel capacity constraints at the Berembid Weir, head reach of the North Branch and Lake View canals and the tail reach of the Main Canal, particularly in December when the rice crop has its highest irrigation requirement. Some irrigated land that in the base case are planted to annual pasture and wheat, and do not require irrigation in December, are allocated to rice in the reuse and combined reuse, twin furrow options, with the easing of the channel capacity constraints. Total pasture area increased in the twin furrow option due to the timing of the increased volumes of water available, but decreased in all other options, while coarse grains and oil seeds areas remained unchanged in the twin furrow option but decreased in the other options.

Impact on water use

The volume of water diverted decreased in all of the options considered while the volume of water applied to crops increased in all options except the twin furrow option (table 4). The volume of irrigation water run off from the system also decreased in all options. The increase in the volume of water applied to crops in option 3, where the twin furrow and water reuse systems were introduced simultaneously was significantly less than the sum of the impacts of individual technologies when they were introduced separately. With much of the potential water needs met and both the total allocation of water and channel capacities becoming less binding, the savings in river diversions increased significantly in the option where water saving technologies were introduced simultaneously.

In the reuse option, a total of 20 GL of storage capacity is created to store annually 72 GL of run off water for reuse within the MIA in addition to the existing 85 GL capacity of the Barren Box Swamp located outside the MIA (tables 4 and 5). This is done after allowing 128 GL of run off water annually (41 GL of irrigation and 87 GL of rainfall) to leave the MIA to be stored in the Barren Box swamp. Therefore, the availability of run off water for the Benerembah and Wah Wah districts from Yanco and Mirrool areas is reduced only by 72 GL a year in this example. Given an almost equal volume of water is lost from the MIA and Districts through discharges to the floodway and Murrumbidgee river, the reuse option is not expected to adversely affect the availability of water for the Districts.

Table 4 Water balance by scenarios - MIA

	Base (GL/yr)	Twin Furrow (GL/yr)	Reuse (GL/yr)	Twin furrow & reuse (GL/yr)
River diversions	783	777	769	756
Conveyance losses				
Seepage	34	33	33	32
Escapes	55	55	54	53
Use of runoff water				
Rain	0	0	49	49
Irrigation	0	0	24	19
Water applied to crops	694	689	755	738
Application losses				
Runoff	65	52	42	34
Net accession	19	16	25	20
Evaporation from dam	0	0	1	1
Total loss	172	156	154	140
Savings in river diversions	0	5	13	27
Efficiency				
Conveyance (%)	89	89	89	89
Application (%)	88	90	91	93
System (%)	78	80	80	81

With the easing of the channel capacity constraints in December in the scenario where reuse storage is introduced simultaneously with the twin furrow system, the value of storing water over the spring months until December is reduced so that the storages are available for more frequent emptying and refilling if required. Consequently, when the reuse storages are introduced simultaneously with the twin furrow system, the ratio of the volume of water reused to storage capacity increased from the reuse option level (table 5).

Table 5 Distribution of storage capacity for reuse of run off water

	Reuse		Reuse & Twin furrow	
	Storage Capacity (GL)	Volume of water reused (GL/Yr)	Storage Capacity (GL)	Volume of water reused (GL/Yr)
Yanco				
Main canal (Up)	1.13	3.66	0.49	3.34
Gogeldrie	2.93	12.68	2.72	12.46
South gogeldrie	2.12	6.52	1.49	6.75
Main canal (Down)	3.30	14.47	3.15	14.37
Total	9.48	37.32	7.85	36.92
Griffith				
Main canal (Up)	0.40	1.69	0.21	1.40
North Kooba	0.98	4.51	0.93	4.43
North Branch	1.91	5.15	1.91	4.42
Mirrol	2.15	9.28	1.51	8.35
Lake view	1.68	3.68	1.63	3.41
Main canal (Down)	3.55	10.58	2.87	9.13
Total	10.67	34.88	9.05	31.12
MIA	20.15	72.20	16.90	68.04

The sum of the seepage and evaporation losses from channels and the volume of water deep percolated from irrigation is estimated to decrease in the twin furrow option from the base case levels. As seepage and deep percolated water contribute to ground water accession, any reduction in these volumes has some environmental benefits.

Economic benefits of improving water use efficiency

The economic benefits of increased irrigation efficiency should include the value of all environmental and on farm benefits. The environmental benefits come from reduced river diversion, ground water accession, and off-site pollution due to a reduction in the volume of contaminated run off water discharged to the district drains and river. Another benefit to the MIA and districts is the reduced cost of flood damage to low-lying areas. In order to account for the environmental benefits and costs, an appropriate value for water, which reflects the value forgone by not using the water for the environment and all the costs of externalities including ground water accession and off-site pollution should be used in the model.

A water value of $34/ML was assumed in the model and was based primarily on available data on the traded values of water. These values reflect the value of water mainly for agricultural uses. For these reasons, in this study only the on-farm financial benefits are estimated, with any savings of river diversions being valued at the assumed value of water. For the twin furrow and reuse options, the cost of technology is included in the analysis.

The aggregate return to land, water entitlements and family labor in the MIA increased by $2.2 million and $3.8 million per year under the twin furrow and reuse options respectively, compared with the base case. With the introduction of water saving technologies existing channel capacity constraints became less binding and the value of these constraints decreased (table 6). The less binding the channel capacity constraints, the smaller were the incremental benefits of a water saving option. The return to water diverted and applied to crops increased under the twin furrow option as less water was diverted and water was applied to crops more efficiently. In the water reuse option, return to irrigation water increased as less water was diverted but the return to water applied to crops decreased as the area under marginally profitable crops increased with the increased availability of water.

Table 6 Financial performance by scenarios (MIA)

	Base ($m/yr)	Twin furrow ($m/yr)	Reuse ($m/yr)	Twin furrow & reuse ($m/yr)
Profits before water and hired labor	210.51	210.53	216.06	215.11
Cost of upgrading land	0.12	0.12	0.12	0.12
Delivery charge on channel water	9.72	9.65	9.55	9.38
Cost of storing and pumping water	0.00	0.00	2.04	1.73
Cost of hired labor	0.00	0.00	0.00	0.00
Net farm profits	200.67	200.76	204.35	203.87
Off farm income	41.40	43.42	41.30	43.33
Return to land and family labor	242.08	244.17	245.64	247.20
Income from selling water outside	0.98	1.09	1.24	1.51
Return to land, family labor and water	243.05	245.26	246.88	248.71
Return to irrigation water ($/ML)	239.43	243.70	248.45	254.79
Return to water applied ($/ML)	269.97	274.78	253.29	260.81
Marginal value of channel constraints ($/ML)	148.49	147.66	100.36	96.37

Conclusions

The adoption of a range of on-farm options to improve irrigation and water use efficiency can result in higher farm incomes through the use of saved water on-farm. In addition there are potential environmental benefits from reduced river diversions, ground water accessions and off-site pollution due to a reduction in the run off of contaminated water.

Therefore, when considering the economic benefits of increased irrigation efficiency the value of all environmental and other benefits as well as the increased on-farm benefits should be included. If environmental values and externalities are internalised to farmers, the opportunity cost of water may rise such that there are greater benefits from increasing irrigation efficiency.

Currently there are no clearly defined and enforceable water rights for environmental uses and the existing water entitlements are almost exclusively for consumptive or out of stream uses. Allocations based on the consumptive market alone may not produce an efficient outcome if the reduced river flows has opportunity costs. Some initiatives, including the creation of market based environmental water entitlements are proposed in the White Paper on water recently released by the NSW DLWC for public comment. If such rights are allowed and there are no legal restrictions on water transfers between irrigation areas and states, environmental users could probably purchase and retire irrigation water rights. Once the required institutional mechanisms are in place, the environmental water users could interface with diverters and irrigation users through a water market.

However, in the absence of market based environmental water rights, increasing irrigation efficiency may need policy changes if public benefits exceed private benefits for the greater adoption of water saving technologies – for example - subsidies for investments in water saving technologies. Some incentives in this direction are already available through the NSW Rural Assistance Authority’s Special Conservation Scheme which offers loans of up to $100 000 to upgrade on-farm irrigation systems and tax deductions for capital expenditure for farm improvements that have some environmental benefits.

The external cost of irrigation run off and ground water accession and the potential of water saving technologies to reduce the effects of the externality at source, add another impetus to improving water use efficiency. Therefore, cost effective solutions to increase irrigation efficiency and externality problems need to be sought simultaneously.

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