Investing in salinity management options in Victoria

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Introduction

Interventions for addressing dryland and instream salinity include land use change and improved irrigation practices to reduce leakage into ground water systems, and engineering works to reduce ground water discharge. While a range of policy options are available to encourage or enforce the implementation of salinity management interventions, the feasibility and cost effectiveness of such options is likely to depend on the hydrological and agricultural characteristics of each region. The purpose of this paper is to evaluate some of the costs and benefits of potential salinity mitigation options in the Victorian catchments of the Murray Darling Basin and identify some key investment principles.

The evaluation was conducted using a simulation model incorporating the relationships between land use, vegetation cover, surface and ground water hydrology and agricultural returns. The model was developed at ABARE, in cooperation with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in a partnership project with the Murray Darling Basin Commission. The model, described in detail in Bell and Heaney (2000), has been designed to compare the costs imposed by salinity under a nonintervention or baseline scenario with alternative interventions.

The estimated cost of salinity in the baseline scenario is measured as the reduction in economic returns from broadacre and horticultural activities from those that are currently earned. Thus, only costs and/or benefits associated with changes in stream flows, salt concentration and the extent of high water tables from current levels are estimated.

Tradeoffs and the hydrological cycle

The interactions between precipitation, vegetation cover, surface water flows and ground water processes are complex. They have the potential to generate a wide range of tradeoffs when attempts are made to manage the problems of stream and dryland salinity through land use change. These tradeoffs are affected by the types of productive activity that can be undertaken, the response of the environment to changes in salinity and the hydrological system itself.

There are a number of variables that determine ground water flows, surface water yields and the mobilisation of salt within, and from, a catchment area. These variables include:

- precipitation,
- rates of evaporation and transpiration,
- ground water response times,
- soil types,
- ground water salinity and
- the morphology of the catchment.

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Precipitation is either returned to the atmosphere as evapotranspiration from the vegetation cover, flows over land into surface water bodies or enters the ground water system. On average, evaporation and transpiration increase with higher levels of precipitation. However, for any given increase in precipitation, evapotranspiration will not increase by the same amount; hence, the proportion of precipitation that will either flow over land or into the ground water system (ground water recharge) increases with precipitation.

Furthermore, the influence of vegetation cover on transpiration increases with higher precipitation (Zhang, Dawes and Walker 1999). In low rainfall areas (under 500 millimetres a year), different vegetation covers transpire about the same volume of water. In a high rainfall area, trees and other deep rooted plants transpire a substantially larger volume of water when compared with shallow rooted grasses. Hence, the impact of changing vegetation cover on surface water yields and ground water recharge increases with the level of precipitation.

The volume of precipitation that is not returned to the atmosphere through evapotranspiration will either flow overland or recharge the ground water. The fraction of this excess water that enters the ground water system depends on the rate of infiltration, the rate at which water can penetrate the soil surface, and percolation through the soil profile. The rate of penetration depends on several factors including the slope or gradient of the land, size and structure of the soil and the level of soil moisture. On more steeply sloped land there tends to be fewer and smaller local depressions to store water that can then infiltrate the soil. Clay soils have finer soil particles creating smaller gaps through which water can enter and move through the soil profile. Sandy and less compacted soils have larger gaps allowing water to enter and move through the soil profile more easily than in heavier soils.

Changing vegetation cover to increase the level of transpiration reduces both surface water yields and ground water recharge. The distribution of these losses depends on soil type and catchment topography. Losses of surface water yields will be greatest on sloped terrain with high clay content soils. The reduction in ground water recharge will be greatest on flat terrain with sandy soils.

The equilibrium response time of a ground water flow system is the time it takes for a change in the rate of recharge to be fully reflected in a change in the rate of discharge. One of the most important factors is the lateral distance of ground water flows, that is the distance between recharge and discharge. The greater the lateral distance the ground water flows, the slower the response time. Hence, the distance between where recharge and discharge is occurring will have a substantial impact on the timing of costs and benefits of revegetation.

There are a number of other important factors that influence the ground water response time, including the slope of the land and the permeability of the soil and deeper substrates. The equilibrium response time does not reflect the actual flow of water through the ground water system but the transmission of water pressure. The response rate increases as the slope of the land increases because of the increase in hydrological pressure. The more permeable the soil and deeper the substrates the less the resistance or friction, resulting in a faster response rate.

A catchment can contain a number of component flow systems. In a regional flow system, hydraulic gradients can be very flat, hence for a given lateral distance, a long period of time is required for the system to come to equilibrium. Over the flow system as a whole, however, the impact of changes in vegetation cover on discharge may not be seen for several hundred years.
Generally, the upper reaches of the catchment are more steeply sloped and these areas are characterised by local flow systems. In these local systems, ground water pressure pulses move through the aquifer rapidly and the delay between a change in the rate of recharge and the volume of discharge from the aquifer over a given distance may be fast in comparison to a regional flow system. Over the flow system as a whole, replanting native vegetation on cleared land may fully restore the balance between recharge and discharge within 100 to 200 years.

In both regional and local flow systems, actions can be taken that have a more immediate impact. For example, revegetating an area adjacent to a river or stream in a regional flow system may reduce discharge within 60 years. The same action in a local flow system may reduce discharge within 30 years.

The higher relief in a local flow system usually results in discharge directly into incised streams that is referred to as base flow. When the capacity for ground water to discharge into streams is exceeded, ground water is discharged to the land surface causing dryland salinisation. Saline ground water discharged into the top two metres of the soil profile can affect agricultural productivity and damage infrastructure.

Discharge from both base flow and land discharge systems may contain relatively high salt loads that will increase salinity in downstream areas of the catchment. Other things being equal, the benefits from revegetation may be greater where there are existing or emerging high water tables, as revegetation can mitigate the loss of productive land and other adverse impacts of dryland salinisation. This may be in addition to the benefits of reduced saline discharge into surface water flows.

However, as local flow systems in a catchment are not linked by a continuous aquifer, the water table of downstream areas is unaffected by changes in the upstream flow systems. Hence, revegetating a local flow system will not be an effective instrument to manage high water tables in lower reaches of the catchment. Addressing the problem of dryland salinity generally requires changes to the local landscape within the flow system in which water tables are rising.

The hydrological characteristics of the flow system determine the tradeoffs associated with changing land use to reduce recharge. For example, the timing and extent of the salinity benefits from reduced recharge need to be weighed against any possible reduction in surface water yield. The reduction in surface water yield arising from large scale afforestation is relatively immediate. In a slow responding aquifer, the reduction in saline discharge may not offset the costs to water users from the reduced availability of surface water, even in the longer term.

Furthermore, the combination of a relatively quick reduction in surface water yields with a slow reduction in salt loads means there may be a short term increase in stream salt concentrations. That is, there is less fresh water to dilute the total salt load. A judgment must be made on whether the longer term environmental benefits from reduced salt loads are greater than the potential costs of increased salt concentration in the short term.

The cost of dryland salinity to agriculture

The estimated cost of salinity in the baseline scenario is measured as the reduction in economic returns from broadacre and horticultural activities from those that are currently earned. The impacts of land salinisation on agricultural productivity can vary substantially between regions regardless of the timing and extent of the problem. The key factors that influence the costs of dryland salinisation include the salinity of the underlying ground water and soil structure, existing agricultural returns and the capacity to adapt production to increasingly saline water and soil resources.

The cost of increasing areas of dryland salinity depends on all of these factors making the assessment of mitigation options complex. Nevertheless, general principles can be developed and used to help prioritise land management options. The economic costs are estimated as the change in the rental value of land in agriculture, that is, the net present value of returns to keeping the land in agricultural production. The cost of dryland salinity, in terms of loss in agricultural returns, under a baseline, or no intervention scenario was estimated in different catchments and subcatchments in Victoria[11].

There are two important caveats in this analysis. First, the process of dryland salinisation is dynamic and production impacts increase as the problem persists over time. Second, impacts can only be measured in regions where dryland salinisation is projected to increase. However, given these caveats, the results derived from the baseline scenario are presented in table 1. The base land value is the imputed nominal value of non-salinised land. The loss in land value is also in nominal terms. Ground water salinity and a soil classification are also provided in the table. The soil types are an indication of porosity that is used in the ABARE model to determine recharge and the impact of ground water salinity on yield. Yield losses are greater on heavier, less porous soil types (MDBC 1999).

[11] The value of non-salinised and salinised land was imputed from average land values at the start and end of the simulation and the value of corresponding non-salinised and salinised land areas in each sub-catchment (the solution to a system of two equations with two unknowns).

Table 1: **Estimated loss in land value as a result of dryland salinity**

Catchment	**Base land value** $/ha	**Loss of land value** $/ha	**Salt concentration** mg/L	**Soil type**
Ovens–Kiewa				
Local	2544	155	250	Clay
Regional	2415	1504	900	Clay
Goulburn–Broken				
Local	2600	na	300	Clay
Intermediate	1169	193	400	Clay-loam
Regional	1649	609	1000	Loam-clay
Campaspe				
Local	2703	1643	1000	Clay-loam
Regional	2489	na	2000	Loam
Loddon				
Local	1616	1075	1000	Clay-loam
Regional	1875	1000	2000	Loam-sand
Avoca				
Local	747	299	1000	Loam-clay
Regional	636	304	2000	Loam-sand

Targeted reforestation

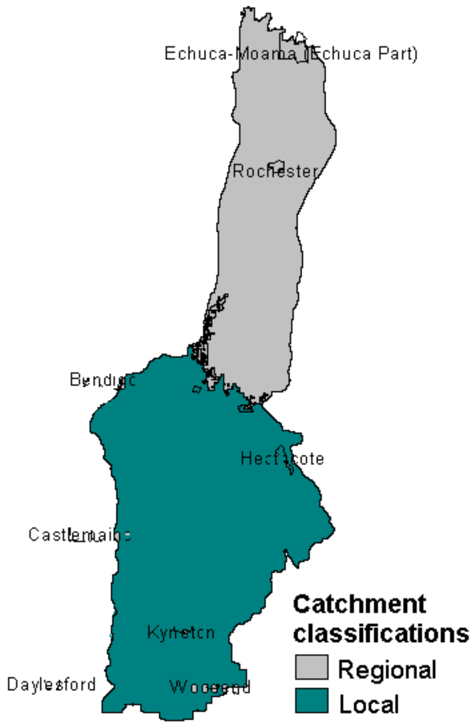
Reforestation is often considered as an option for reducing ground water recharge in the higher rainfall regions. However, the effectiveness of reforestation as a salinity management option is dependent on the physical and hydrological characteristics of the plantation area. Reforestation reduces surface water yields as well as ground water recharge. The distribution of these losses depends on soil type and topography with the highest losses in surface water yields occurring on sloped terrain with high clay content soils. The reduction in ground water recharge will be greatest on flat terrain with sandy soils.

Revegetation is a cost effective option for addressing the problems of salinisation where the benefits less the costs of revegetation are greater than the benefits of maintaining current land and water use in agriculture. Revegetation is an investment, imposing today the costs of establishment and forgone agricultural production for the benefits of reduced salinisation in the future. Furthermore, while the costs of revegetation are reasonably certain, the benefits are not as the processes that generate stream and land salinisation are not well quantified. Nevertheless, the driving physical, economic and agronomic principles are well established and can be used to identify the conditions that are more likely to lead to net benefits from revegetation options such as reforestation.

Reforestation targeted to areas with specific hydrophysical characteristics may be cost effective. These areas may include areas of high salinity impact where the hydrological processes generate more favorable tradeoffs. The objective in the analysis presented in this section is to highlight the type of landscapes in which a targeted approach to reforestation is most likely to be more cost effective than broad scale plantation forestry.

In the analysis presented here, a small subsystem was added to the ABARE model to represent a hypothetical subcatchment of 12 000 hectares located in the local or regional flow systems in the Campaspe catchment shown in map 1. Of this, 10 000 hectares were assumed to be used for dryland pasture production. Rainfall was 650 millimetres a year in the local subcatchment and 450 millimetres a year in the regional subcatchment. One thousand hectares was assumed to be suitable for subcommercial forestry.

Map 1. **Campaspe catchment, Victoria.**



In each simulation, the subsystem was given hydrological profiles with different aquifer equilibrium response times, soil types and ground water salinities. The purpose of the analysis was to establish the importance of identifying hydrological characteristics when selecting areas for targeted reforestation, rather than to estimate the full range of potential costs and benefits of reforestation.

Two general flow systems were investigated — a baseflow and a land discharge or wash system. Baseflow systems discharge ground water directly into streams and there is no area of dryland salinisation. A land discharge system occurs when the capacity for ground water flows to discharge into streams has been reached and ground water is discharged to the surface of the landscape causing dryland salinisation.

In the land discharge simulations presented here, the subsystems were simulated to have an emerging dryland salinity problem. The extent of salinisation that will occur over the simulation depends on the response time of the aquifer and the time when the land was initially cleared. It was assumed that agricultural land in the subcatchment had been cleared for 100 years.

Salinity benefits from forestry in a baseflow system are derived from reductions in the discharge of saline water directly into streams. To the extent that the reduced salt loads translate to lower salt concentrations, this benefits downstream areas of the catchment. Salinity benefits in land discharge systems are derived from two sources —

improvements in water quality as described above, and the mitigation of high water tables. The reduction in high water tables is restricted to the ground water flow system where forestry is established because of the lack of connection between local ground water flow systems.

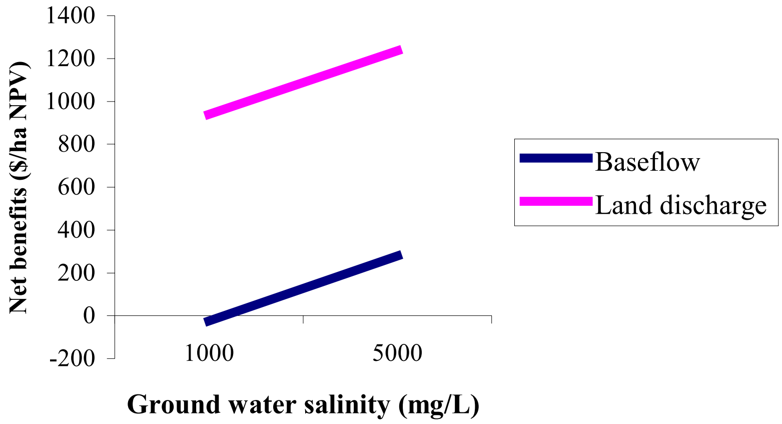
In setting up the simulation, the commercial returns from dryland pasture production and forestry were assumed to be equal. This was to focus the results on the cost of salinity and the benefits of salinity management. Net benefits are derived when the costs to agriculture from dryland and instream salinity are lower under forestry than the baseline scenario. The results of the analysis are presented as net benefits (NPV) per hectare of trees planted over a 100 year simulation period. A discount rate of 5 per cent was used for all the simulations presented.

Findings

Three sets of hydrological profiles were constructed to explore the importance of different hydrological parameters. The first set was used to compare a baseflow and a land discharge system under different levels of ground water salinity. In the second set the impact of different aquifer response times was explored. Lastly, the costs and benefits of reforestation on different soil types were examined. The results are shown in figures 1, 2 and 3.

A comparison of net benefits derived in a local baseflow system and a local land discharge system each with an equilibrium response time of 60 years on loam soils is shown in figure 1. Net benefits under both systems were higher as ground water salinity increased. This is because the costs avoided by establishing forestry, when compared with the baseline, are higher at higher ground water concentrations. The difference between the two net benefit curves reflects the fact that in a baseflow system all the salinity benefits and costs associated with reforestation are realised downstream in terms of changed surface water yields and salt concentrations. In a land discharge system, there are additional local benefits of mitigating the loss of productivity from dryland salinity. These are less than the loss in land value as a result of dryland salinity presented in table 1 because the benefits accrue over time. However, as ground water salinities increase, the benefits from reducing instream salinity become increasingly important.

Figure 1**. Land discharge and baseflow systems**
60 year equilibrium response time, loam soils



The net benefits from reforestation in a land discharge system with clay-loam soils in flow systems with different response times are shown in figure 2 (i) for the regional subcatchment and figure 2 (ii) for the local subcatchment. The land use change of the scale simulated leaves similar end of valley salt loads and surface water salt concentration after the systems reached equilibrium. It is the timing of the reduction in area salinised that is the main determinant of the benefit profile. In aquifers with longer response times, there are no salinity benefits from the reduction in recharge until several decades after the land use change. In contrast, the costs associated with reforestation such as reduced surface water yields and possibly a short term increase in stream salt concentration are often more immediate. In aquifers with shorter response times, benefits are derived much sooner and are therefore more likely to offset the costs.

Figure 2 (i). **Different equilbrium response times, regional subcatchment, loam soils**

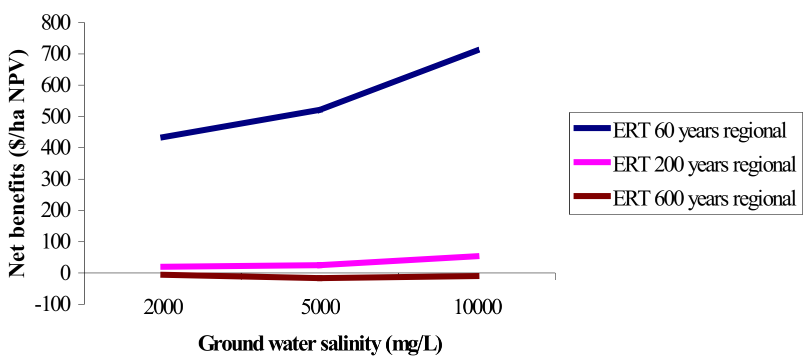
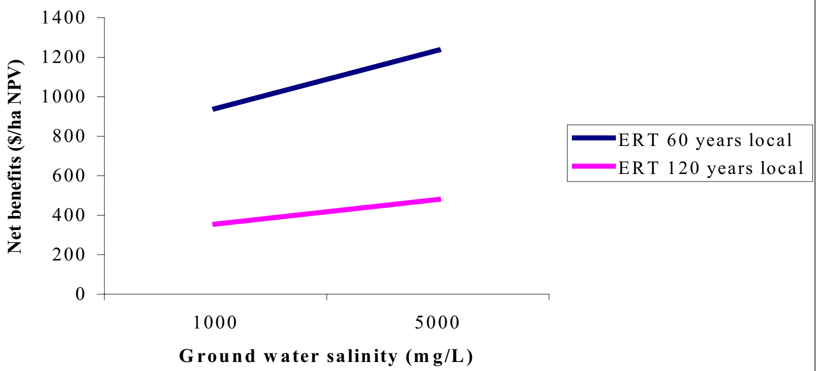
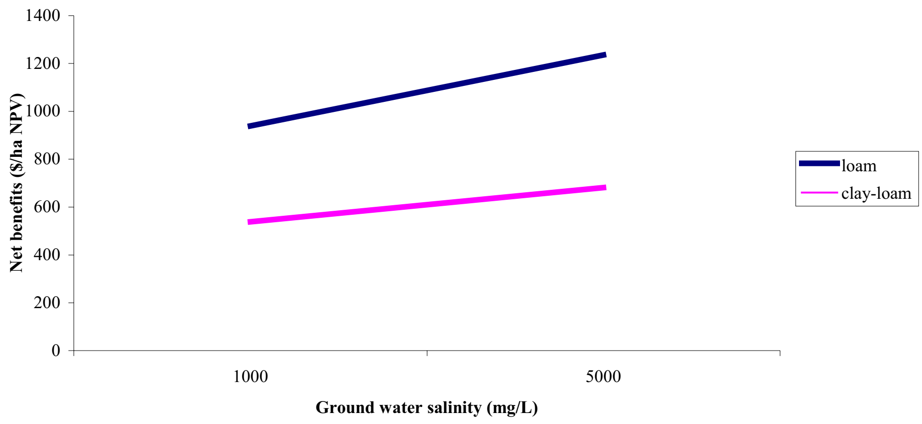


Figure 2 (ii). **Different equilibrium response times, local subcatchment, loam soils**



The final set of hydrological profiles focused on net benefits under forestry for two different soil types in a local land discharge system with an equilibrium response time of 60 years (figure 3). Recharge rates are lowest in clay soils and highest in loam soils. Correspondingly, runoff rates are highest for clay and lower for loam soils. The reduction in recharge under forestry in loam soils reduced the area of high water tables by around two thirds 100 years after forestation. In comparison with the heavier soils, the reduction in saline discharge to streams was larger and the loss of surface water yields was smaller, and generated a reduction in salinity concentration more quickly.

Figure 3. **Different soil types, 60 year equilibrium response time**



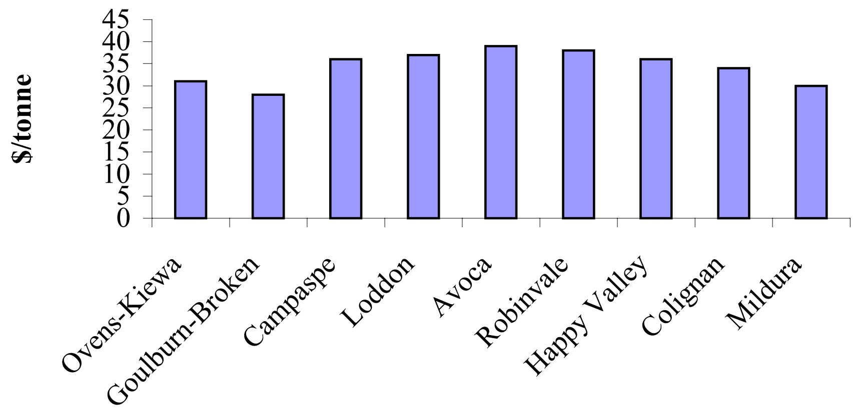
In the heavier soils, the area of high water tables was reduced by around one third after 100 years. Furthermore, the reduction in saline stream discharge was smaller and the loss of surface water flows was greater than for loam soils. Downstream salinity concentrations remained higher under reforestation for an extended period of time.

It can be broadly established that particular combinations of hydrological characteristics can lead to net benefits from revegetation and other land management changes. The distribution of these characteristics in the landscape will ultimately determine whether revegetation can be pursued as a cost effective option at a suitable scale to manage salinity. These areas may be small and dispersed widely through the landscape. The identification of such areas should be a key aspect of catchment based salinity management plans. For example, there may be opportunities for reforestation targeted to the localised outbreaks of dryland salinity in the lower landscapes and break of slope locations.

Discharge reductions

Simulations were undertaken in each catchment to determine the potential salinity benefits from reducing annual discharge into the main river. These benefits were analysed by simulating a ground water pumping scheme that reduced ground water discharge by between 2000 and 5000 ML a year, depending on the total amount of discharge available. This would be equivalent, for example, to building a salt interception scheme in the lower reaches of a catchment. Salinity benefits from reduced discharge accrue to downstream irrigators through reduced concentration of irrigation water. There are no benefits to the catchment where the action is undertaken from reducing discharge. Benefits are also derived for water users downstream of Morgan from improved water quality. The value of the salinity benefits to downstream catchments is shown in figure 4.

Figure 4. **Downstream salinity benefits per tonne reduction in end of valley salt discharge, per year, by catchment**



There are three main drivers underlying the results. First is the location of the catchment undertaking the action in the Murray River system. All other things being equal, the further upstream the catchment is in the system, the higher are the benefits from the action as more downstream users benefit.

Second, reducing discharge reduces the volume of both water and salt that flows into the main river. Therefore, the higher the ground water salinity in the catchment relative to the Murray River, the greater is the reduction in salt concentration for each tonne of salt removed. For regions that have high ground water salt concentrations, such as the Victorian Mallee, the salinity benefits of reduced discharge are relatively high, despite their downstream location.

Third, salt is being re-deposited from rivers into the landscape in some regions. This can occur through seepage into regional aquifers and evaporation on flood plains. As the latter tends to be mobilised into the river system during flood events, it has little impact on water quality. This will to some extent dissipate the downstream benefits of reduced discharge.

The results provide a measure of the downstream return to meeting an end of valley load reduction or target. While the upper catchments in the Murray system have relatively low ground water salinity, the returns are high given their location upstream of major horticultural areas. Returns are also high within the horticultural areas of the Victorian Mallee due to the high levels of ground water salinity. However, with fewer and fewer assets downstream, benefits decline as you move closer to the South Australian border.

Engineering interventions to reduce discharge have two distinct advantages over salinity management options designed to reduce recharge such as land use change. First, reductions in discharge generate benefits almost immediately and second, the impact of engineering options is likely to be more certain than those associated with land use change.

Improving irrigation efficiency

Irrigation has substantially increased the amount of water entering ground water systems, leading to rising water tables. As water tables rise, there is an increase in mobilised salt that is discharged into the Murray River. As a result, a substantial proportion of the salt load in the Murray River comes from return ground water flows from irrigation. Improved irrigation efficiency may decrease the amount of ground water leakage, thereby decreasing the amount of saline ground water being transported to the river system.

However, improvements in irrigation efficiency affect the pattern of surface runoff, irrigation drainage and ground water discharge that, in turn, alters the composition of return flows from irrigation. Return flows consist of surface runoff from flood irrigation, irrigation drainage and ground water discharge from irrigation areas that reach the Murray River system.

Return flows and externalities

Reflecting the large volume of water that is diverted from the Murray River and its tributaries in the upstream irrigation areas in Victoria and relatively low rates of irrigation efficiency, return flows form a substantial part of water available for downstream users. In the simulation experiments presented below, the cap on diversions was maintained resulting in a reduction in allocation for downstream irrigators due to losses in return flows. As a result, external effects on downstream users were a combination of changes in water volume and quality. External benefits or costs can arise if the quality and quantity of return flows to the Murray River change, thus impacting on those users not directly engaged in improving efficiency. The impacts of efficiency changes on return flows are dependent on the agronomic and hydrological characteristics of each irrigation area and as a result, may produce external benefits or costs that vary continuously along the Murray River system.

The main water quality issue in the Murray River system has been increasing river salinity. The extent to which return flows affect salt concentrations in the Murray River depends on several factors, including ground water recharge rates and the salinity of the ground water underlying irrigation areas. The volume of water entering the ground water system is higher in areas with low rates of irrigation efficiency. Increased ground water recharge has led to rising water tables and increased ground water discharge and saline irrigation drainage. The volume of salt transported to the river depends to a large extent on the salinity of the ground water. The salinity of ground water discharge in the Murray River and its tributaries is relatively low in the upland catchments. Ground water salinity levels tend to increase moving downstream and reach levels approaching seawater in low-lying regions of South Australia.

Volumetric effects as a result of changes in return flows may occur, for example, if an improvement in irrigation efficiency through, for example, paddock landforming and leveling for flood irrigation systems reduce the surface water runoff component of return flows.

Simulations of improved in irrigation efficiency were conducted for several major irrigation areas on the Murray River system to examine the qualitative and volumetric changes in return flows. The internal and external costs or benefits of changes in irrigation practices are compared to the baseline scenario. Internal (or direct) impacts are those that occur within the irrigation areas where the action is undertaken whereas external (or indirect) impacts are those that affect water users downstream of the areas where the action is undertaken. The capital costs of improving irrigation efficiency are not included in this analysis. Summary data for the irrigation areas under consideration are listed in table 2.

Irrigation efficiency was increased by 5 per cent in the irrigation areas listed in table 2. Irrigation efficiency is defined here as the proportion of irrigation water extracted from the river that is returned to the atmosphere as evapotranspiration. In areas such as western Victoria, irrigation efficiency can approach 75 to 80 per cent for horticulture. In areas where there is widespread use of flood irrigation on pasture, irrigation efficiency is of the order of 50 per cent.

Table 2: **Summary data for the irrigation areas studied**

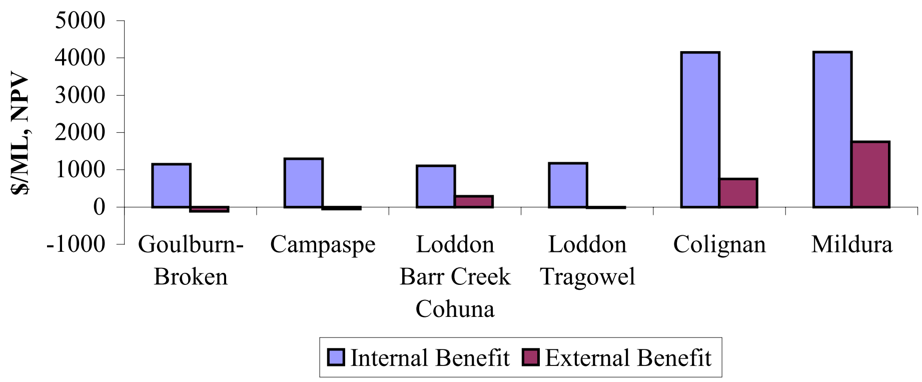
Irrigation area	**Main irrigated activities**	**Water allocation**		**ET[a] fraction**	**Recharge fraction[b]**	**Ground water salinity**
		Murray GL	**Tributary** GL	%	%	mg/L
Goulburn–Broken	Pasture, cropping, horticulture	320	853	65	50	1 000
Campaspe	Pasture, cropping	207	75	50	60	5 000
Loddon Barr Creek	Pasture, cropping	163	0	65	75	20 000
Loddon Cohuna	Pasture, cropping	275	0	65	75	3 000
Loddon Tragowel	Pasture, cropping	455	0	55	75	9 725
Colignan	Horticulture	59	0	80	100	10 000
Mildura	Horticulture	188	0	80	100	25 000

a the percentage of irrigation subject to evaporation and transpiration. *b* the percentage of excess water, irrigation water and precipitation less evapotranspiration, that enters the ground water system.

With, for example, a 5 per cent increase in irrigation efficiency, a 5 percent reduction in application rates will achieve the same crop yield. It was assumed that irrigators retain all the water savings and use those savings to expand irrigated production in the region the water is saved. Hence, the reduction in surface water run-off, drainage and ground water recharge will be less than 5 per cent. The internal and external costs and benefits were calculated over a 50 year time period.

Internal benefits from increased irrigation efficiency are derived from an increase in agricultural revenue stemming from the increased availability of irrigation water and reduced extent of high water tables. The internal and external benefits associated with undertaking improvements in irrigation efficiency are shown for each irrigation area in figure 5.

Figure 5. **Internal and external benefits of improving water use efficiency**



The external costs and benefits of improved irrigation efficiency are a combination of qualitative and quantitative changes in return flows. The impacts of undertaking improvements in efficiency are highly dependent on the characteristics of the irrigation area where the action is undertaken and as a result, there is considerable variation in the external benefits and costs.

External salinity benefits derived from an improvement in the quality of water are a result of the reduction in saline ground water discharge, thereby reducing the volume of salt load that is transported to the river system. The extent to which a reduction in salt loads and concentration is achieved depends on, among other things, the volume of the reduction in recharge and the underlying ground water salinity. As a result of the improvement in water quality, agricultural yields and revenue increase. The main driver of the benefit profile is the response time of the ground water aquifer (the time it takes for a change in recharge to be reflected in a change in saline discharge) with ground water aquifers with short response times generating water quality benefits sooner. External benefits are only derived as a result of improvements in irrigation efficiency in the lower Victorian catchments of the Murray River system where ground water salt concentrations are high and ground water response times are short relative to those in the upper reaches of the system.

Offsetting the water quality benefits is a reduction in the volume of return flows. Volumetric changes in return flows may occur as a result of reductions in the volume of ground water discharge, irrigation drainage and/or surface water runoff. Improving irrigation efficiency generates external costs in the upper catchments as they are characterised by large volumes of surface water runoff and low ground water salt concentrations. Return flows from these regions dilute the salt concentration of the Murray River. The improvement in efficiency reduces the surface water runoff component of return flows thereby imposing costs downstream as water quality is reduced.

In the simulations undertaken for this analysis, the cap on the volume of water that can be diverted for irrigation is maintained. A decline in irrigation return flows as a result of improved irrigation efficiency in an upstream region will therefore lead to a reduction in water entitlements for downstream users that had previously accessed those flows.

Concluding remarks

Within the current understanding of the hydrological processes that have generated the problem of dryland and instream salinity, there are several general factors to consider when prioritising investments in salinity management. In terms of revegetation to reduce recharge there are three key issues. First, revegetation imposes a tradeoff as it leads to reductions in both surface water yield and ground water discharge. This tradeoff is more pronounced in high rainfall areas and is less favorable on steeply sloped and heavy soils. Targeting revegetation to areas with an existing or emerging high water table problem is more likely to be cost effective than targeting base flow systems that discharge directly into streams. Third, the timing of benefits in slow responding ground water systems is unlikely to offset the immediate costs incurred as a result of reduced surface water yields.

While the salinity audit of the Murray Darling Basin, released in 1999, did not point to irrigation as a major source of increased river salinity, changes to irrigation practices are an important mitigation option. Reduction in irrigation recharge can have an almost immediate effect on saline discharge to rivers due to the fact that the lateral distances are short and the soil profile is often already pressurised.

Finally, the salinity benefits of actions such as revegetation, increased irrigation efficiency and ground water discharge pumping all are highly dependent on the underlying level of ground water salinity. In the upland catchments of Victoria, ground water salinity is generally low, reducing the benefits of most salinity management options. In the low catchments of eastern Victoria, ground water salinities are considerably higher and there is likely to be greater benefits from salinity mitigation.

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Background

Stephen Beare is the research director of ABARE’s Agriculture and Natural Resources Directorate. The Directorate is responsible for economic policy research covering land and water management, fisheries, bio-security and food safety.

Dr Beare’s major research interest is in mathematical models in which economic analyses are integrated into biophysical systems. This work has been directed to examining issues such as water policy, salinity mitigation options and disease management.

Dr Beare holds a PhD and a master’s degree in economics from Oregon State University and a bachelor of science degree from the University of California.