Productivity and Economic Aspects of Some Groundwater Disposal Options for Irrigated Dairy Farms.

Matthew Bethune and Oliver Gyles
Institute of Sustainable Irrigated Agriculture, Tatura, May 2000

1. INTRODUCTION

High watertables have developed across much of the Murray Darling Basin from land clearing and irrigation. This can result in high rootzone salinity and reduced agricultural production in areas with limited sub-surface drainage. Groundwater pumping is often used to provide subsurface drainage and thus enable rootzone leaching. Pumping groundwater also provides an additional resource for irrigation in areas where groundwater salinity is low. This makes groundwater pumping with farm reuse a very popular salinity management option in areas with low groundwater salinity. However, farm reuse of saline groundwater results in high applied water salinity which can lead to secondary salinisation and reduced plant production. Management plans in the southern Murray Darling Basin recommend that farm reuse of pumped groundwater be restricted to areas where groundwater salinity is less than 5 dS/m. However, many areas are underlain by aquifers that are more saline than 5 dS/m. In addition, groundwater quality is expected to increase within the irrigated areas over time. This means that in the future farm reuse of groundwater will become limited due to high groundwater salinity.

Options currently recommended to farmers in the southern Murray Darling Basin for disposal of saline (>5 dS/m) groundwater include, salt export or disposal to an evaporation basin. However, there is potential for farm reuse of groundwater at salinities greater than 5 dS/m. Although small reductions in production may result from high irrigation water salinity. The cost of this reduced production may be less than the cost of salt export, or construction of an evaporation basin. The cost of salt management options needs to be investigated and compared to the production benefits.

The purpose of this study was to provide an evaluation of the potential for farm management of saline groundwater. This involved developing production response functions for a range of farm salt management options. These response functions were used to investigate farm scale economic aspects of farm management of saline groundwater. This study focussed at the farm scale. Therefore, costs and benefits at the regional scale may not be reflected in the analysis.

2. METHODOLOGY

The hypothetical farm

The hypothetical 100 hectare farm has a perennial pasture based production system and is located in a region where groundwater must be pumped to provide sub-surface drainage. Groundwater pumping lowers potentiometric pressure which enables leaching and lowers soil salinity in the plant rootzone.

Irrigation requirement
10ML/ha is taken as the annual irrigation requirement for well watered perennial pasture. This is consistent with district recommendations for maximum yield established at sites with low groundwater salinity. This irrigation supplements an estimated 480 mm rainfall, making total water use 14.8 ML/ha. It was assumed that twenty percent of total applied water was lost in runoff. The study farm is assumed to have a water right of 6.7ML/ha and the system allocation to be water right plus 50% sales allocation. Thus no transfer of water entitlement is required.

Irrigation costs
Given the assumed water right, an increase in irrigation intensity will incur additional costs for transfer of water entitlement and delivery of supply. The annualised cost of district surface supply system water "in the farm channel" is estimated at $62/ML (Gyles, 1999). Conversely, a reduction in irrigation intensity should similarly reduce production costs. No allowance is made for changes in irrigation labour requirement.

Groundwater pumping requirement
Drawdown in watertable is greatest near the groundwater pump. This means that less leaching is obtained at distance from the groundwater pump. A minimum pumped volume of 1 ML per hectare of the property is adopted to ensure that the whole farm receives some salinity control from the pump. This assumption that pumping 1ML of groundwater protects 1 ha of land is the current "rule of thumb" in the Shepparton Irrigation Region. The volume of groundwater pumped is set to equal the volume of water leaching below the rootzone if the volume of water leaching below the rootzone exceeds 1ML.

Other pasture management costs
It is assumed that there will be reduced fertiliser/pasture maintenance costs for the lower water use intensities. These reductions range from $10-100/ha depending on irrigation depth.

Water use efficiency of pasture based dairy production
Water use efficiency is assumed to be the average found by Armstrong et al, (1998). This is 867 litres of milk/ML of total water use (effective rainfall plus irrigation). No adjustment is made for variation in quality or utilisation of forage produced at different salinities or irrigation intensities.

Estimate of gross margins
Based on the assumed water use efficiency, a pasture based production gross margin of $157/ML total water use is derived by assuming a milk price of 27.1 cents/litre, and the pasture variable costs estimated by Knee (Armstrong et al., 1998), together with an allowance for shed, herd and repairs/maintenance costs. This estimate falls to $113/ML total water use for a milk price of 22 cents/litre.

Salt management options

A conceptual model of the groundwater and farm management system was developed to assess the impact on production of different farm salt management options. Equations describing the water and salt balance of this conceptual model were developed from the work of Prendergast (1993). These equations were found to provide good prediction of pasture yield from average annual irrigation water salinity (Prendergast, 1993). This approach assumes the system is in a steady state (refer to Prendergast (1993) for more detail). The production response to groundwater salinity and depth of irrigation was developed for the following salt management options:

Option 1 - Total conjunctive use

All pumped groundwater is mixed with channel supplies and used for irrigation on the farm. The volume of water resource available for irrigation is increased by the volume of pumped groundwater. Pasture production losses are accepted at high groundwater salinity where the salinity of the mixed groundwater and irrigation water exceeds 0.8 dS/m.

Yield response to irrigation

Crop yield due to water stress (Y_w) is calculated from actual evapotranspiration (ET_a), maximum evapotranspiration (ET_m) and a yield response factor (K_y) (eq 1, Doorenbos and Kassam 1979). Volume balance of water in the rootzone is assumed and ET_a is calculated from total water applied to the rootzone (W), minus the leaching volume (eq 2). ET_m is a function of potential ET (ET_o) and a crop factor (K_c). W is the sum of rainfall (R), irrigation (I) and groundwater (G) applied over the year minus runoff. The fraction of applied water lost in runoff (R_u) was assumed to be 0.2. In the case that W=ET_m, the fraction of runoff is increased to account for any surplus of applied water.

$$Y_w = 1 - K_y\left(1 - \frac{ET_a}{ET_m}\right) \qquad \text{eq 1}$$

$$\begin{aligned} ET_a &= (W - W.LF), \quad \mathrm{W - W.LF \le ET_m} \\ ET_a &= ET_m, \quad \mathrm{W - W.LF \ge ET_m} \end{aligned} \qquad \text{eq 2}$$

$$\begin{aligned} W &= (I + R + G)(1 - R_u), \quad ET_a < ET_m \\ \mathrm{W} &= \mathrm{ET_m}, \quad ET_a = ET_m \end{aligned} \qquad \text{eq 3}$$

$$ET_m = K_c.ET_o \qquad \text{eq 4}$$

LF = leaching fraction

Yield response to salinity

Crop yield due to salt stress (Y_s) is calculated as a function of average rootzone salinity (eq 5, Maas and Hoffman, 1977). A is the salinity threshold of the crop and B is the relative yield reduction per unit increase in average soil salinity (EC_{se}). EC_{se} is calculated using the empirical leaching equation of Rhoades (1974), with locally developed coefficients (eq 6) (Prendergast, 1993). The average salinity of applied water is calculated from the depth and salinity of channel supply water (I,C_I), groundwater (G,C_g) and rainfall (R,C_r) (eq 7).

$$Y_s = 1 - B(EC_{se} - A) \quad \mathrm{C_{se} > A} \qquad \text{eq 5}$$

A= salinity threshold of crop.

B = yield reduction per unit increase in soil salinity.

EC_{se}= average soil salinity

$$EC_{se} = 0.2 \cdot Cw(1+\frac{1}{LF}) \qquad \text{eq 6}$$

$$Cw = \frac{I.Ci + G.Cg + R.C_r}{I + G + R} \qquad \text{eq 7}$$

Combined stresses

When sufficient water is applied to prevent water stress, pasture yield is equal to Y_s. When the plant suffers from water stress, a linear program was used to solve the objective function (eq 7) by adjusting the parameter LF. A maximum value for LF was specified which relates to soil hydraulic properties.

$$Ys - Yw = 0 \qquad \text{eq 8}$$

Input parameters used in analysis.

Parameter	Value	Source
A	1.6	#1
B	9	#1
Kc	1	#2
ETo	1.2 m/yr	#3
R	0.48 m/yr	#5
Ky	1	#4
Ci	0.1 dS/m	
Cr	0	

#1 Mehanni AH and Repsis AP (1986) Perennial pasture production after irrigation with saline groundwater in the Goulburn Valley, Victoria. Aust J Exp Agric 26:319-324
#2 Doorenbos J and Pruit WO (1977) Crop water requirements. FAO Irrig Drain Paper 24, FAO Rome 1984.
#3 Twenty year average reference crop evapotranspiration (FAO-56) calculated using data from Bureau of Meteorology Climatic Station, Tatura, Victoria.
#4 Prendergast JB (1993) A model of crop yield response to irrigation water salinity: theory, testing and application. Irrig Sci 13:157-164.
#5. Effective rainfall

Option 2 - Complete salt export to river

Pumped groundwater is exported off-farm and the downstream impacts is increased river salinity. The salt load is calculated from the volume of pumped groundwater (100 ML) and C_g. The farm has no yield reduction due to salt stress and pasture yield is calculated using eq 1, assuming LF = 10%.

Option 3 - Total disposal to an evaporation basin

The area of perennial pasture is reduced to allow room for a sacrificial evaporative area. This sacrificial area could be an evaporation basin or a salt tolerant crop. It is assumed the disposal net evaporative capacity (evaporation minus rainfall) of the sacrificial area is 8 ML/ha. The basin area is calculated by dividing the disposal volume by the evaporative capacity of the area. No runoff from the sacrificial area is allowed. Surface supplies previously used on the disposal area are released for transfer to areas on or beyond the farm. Perennial pasture is only irrigated with low salinity channel water and groundwater pumping prevents salt stress. Therefore, pasture yield is calculated using eq 1.

Option 4 - Partial conjunctive use with reduced export to river

Groundwater use for irrigation is restricted to limit the impact of C_w on pasture productivity. The upper recommended limit for C_w in the Shepparton Irrigation Region Land and Water Salinity Management Plan (SIRLWSMP) is 0.8 dS/m. The volume that can be used for irrigation is calculated using eq 9. Surplus groundwater that cannot be safely reused is exported off farm. This partial reuse of the groundwater reduces the mass of salt exported. Downstream impacts result from increased river salinity as in the complete disposal to river option.

Option 5 - Partial conjunctive water use with farm sacrificial area

The area of conventional perennial pasture is reduced and part of the farm is used for disposal of groundwater surplus to the volume required for partial conjunctive use. The volume of groundwater that can be reused for irrigation (Gr) is calculated (eq 9), with I = 10 ML/ha and Cw =0.8 dS/m. Gr is subtracted from the total volume of pumped groundwater (100 ML) to give the volume of groundwater requiring disposal. Two options for farm disposal of groundwater are considered. Surface supplies previously used on the disposal area are released for transfer to areas on or beyond the farm.

$$G_r = \frac{I.C_i}{C_w(I+R)(C_w - C_g)} \qquad \text{eq 9}$$

Option 5a - Partial conjunctive water use with disposal to Bermuda grass

Surplus undiluted groundwater is used for irrigation of salt tolerant species. Bermuda grass (couch) is grown for utilisation in the dairy production system in this case. Effective rainfall contributes to production (beneficial use). Potential water use of Bermuda grass is assumed to be 12 ML/ha. Yield response to salinity is calculated using eq 5, with A = 6.9 dS/m and B = 6.2 dS/m (Fig 4). A higher LF is required due to the high salinity of water applied to the sacrificial area. To obtain a leaching fraction of 20% required an irrigation intensity of 10 ML/ha, combined with effective rainfall of 400 mm. This higher leaching fraction is required given the high irrigation water salinity. It is assumed that groundwater pumping allows higher leaching fractions under the sacrificial area. The size of the sacrificial area is calculated by dividing the disposal volume by 10 ML.

Option 5b - Partial conjunctive water use with disposal to evaporation basin

Surplus groundwater is evaporated in a basin constructed on the farm. The evaporative capacity of the basin is assumed to be 8 ML/ha. This is lower than for Bermuda grass as there is no benefit in supplying additional water to enable leaching and prevent salt accumulation under the basin.

Costs of groundwater and salt management options

Cost of groundwater pumping

As the assumed groundwater management policy is the same for all options, groundwater pumping costs are not included in this analysis. Nor is any allowance made for possible differences between options for delivery of groundwater to disposal points.

Cost of export to river

It is assumed that salt export results in increases in river salinity. The cost is calculated assuming that 6500 tonnes of salt results in 1 EC (0.001 dS/m) increase in river salinity at Morgan. The cost of a 1 EC increase is assumed to be $100,000.

Disposal to an evaporation basin

Perennial pasture production is lost on the disposal area. Basin construction cost is assumed to be $6250/ha. Capital cost amortised over 50 years. No additional operating and maintenance costs are assumed. The 4 ML/ha of effective rainfall evaporated in the basin is lost from the production system. Surface irrigation water supplies previously used on the disposal area are released for transfer to areas on or beyond the farm.

Disposal to Bermuda grass

Perennial pasture production is lost on the disposal area. The cost will be the product of the area used for disposal, by the difference in net cost of the salt tolerant forage per hectare relative to perennial pasture. Maximum potential production of Bermuda grass is assumed to be 70% that of perennial pasture (Kimbrough, 1998). The effectiveness of the utilisation of Bermuda grass dry matter by the dairy production system is assumed to be 70% of that for perennial pasture. The combined effect of these reductions is that the dairy productivity of Bermuda grass, in the base case low salinity situation, is assumed to be 49% of that for perennial pasture. The higher salinity tolerance of Bermuda grass will reduce this difference in more saline situations. Variable costs are assumed to be identical with those for perennial pasture in each situation. Surface supplies previously used on the disposal area are released for transfer to areas on or beyond the farm.

Definitions

Production in this study is defined as the area of the farm that has no yield declines due to salt and water stress.

Salt export refers to exporting of salt outside of farm boundaries. In this paper the impact of salt export on salinity in the Murray River is assessed.

3. RESULTS.

Groundwater pumping requirement

Increasing LF has a relatively large impacts on pasture yield when LF is small (Fig 1). Higher LF has a less pronounced affect on pasture yield. An ideal groundwater pumping rate (G) would capture all leaching below the rootzone and minimise yield reductions. Increasing C_g decreases the maximum yield achievable under groundwater reuse. This results from the impact of increasing C_g on C_w (Fig 2). Higher G also increases C_w and therefore potentially restricts the maximum achievable yield.

The slope of the relationship between C_w and C_g flattens with increasing irrigation intensity (Fig 2). This highlights one option for managing saline groundwaters is to purchase more low salinity supply water to allow greater dilution. This would allow complete farm reuse with reduced impact on farm production. However, maximum irrigation intensity needs to be limited to potential plant water use or excessive groundwater accessions and/or runoff will likely to occur.

By adopting a pumping target that enables a LF of 0.1 will ensure adequate leaching for the range of C_g considered in this study. Increasing G above this target may provide water resource benefits. However, the benefit of the additional water is offset by the increase in C_w and higher C_g. Therefore, it is assumed that it is not beneficial to provide LF greater that 0.1, as the focus in this study is on areas of higher groundwater salinity (>5 dS/m). The Shepparton Irrigation Region Land and Water Management Plan recommends 0.8 dS/m as the maximum salinity of water for irrigating pasture. A leaching fraction of 10 % is required to prevent yield reductions at this irrigation water salinity. This supports the current 'rule of thumb' in the Shepparton area that pumping 1 ML of groundwater protects 1 Ha of land.

Higher LF (and therefore G) is required if highly saline groundwater is used to irrigate a salt tolerant crop. Bermuda grass irrigated with 10 dS/m water could achieved 80 % of potential yield if a 20 % leaching fraction is obtained (Fig 4). It is assumed that higher leaching fluxes may be achieved under the sacrificial area at the expense of less leaching fluxes in the surrounding area. This should not have a large impact as the sacrificial area is small relative to the farm.

Production responses to management options

Option 1 - Total conjunctive water use

The threshold groundwater salinity at which pasture production declines as a result of high applied water salinity increases with decreasing irrigation intensity (Fig 3). This indicates that there is potential for farm reuse of saline groundwaters at low irrigation intensities and that farm reuse of groundwater may also have benefits in dryland areas.

The relationship between groundwater salinity, irrigation volume and yield indicates that there is considerable scope for reusing groundwater at salinities above 5 dS/m (Fig 3). The rate of drop in pasture yield with increasing groundwater salinity is not too great because of the dilution effect of both low salinity channel water and rainfall. Farm reuse of saline groundwater of salinity up to 15 dS/m would result in little production decline where low salinity irrigation water is applied at 4 ML/ha. Production benefits in such areas may be realised through groundwater pumping when compared to production losses resulting from no salinity control. The economic cost of implementing such a strategy needs to be assessed in relationship to the environmental and production benefits.

The production response for 0.1 dS/m groundwater salinity is analogous to that obtained from irrigation solely with low salinity surface channel supply.

Option 2 - Complete salt export to river

If there is no farm reuse of groundwater the mass of salt exported to maintain salinity control is considerably higher and increases linearly with groundwater salinity (Fig 6).

Option 3 - Total disposal to a farm sacrificial area

All pumped groundwater is disposed to a sacrificial area. For this case the size of the required sacrificial area does not change with groundwater salinity (Fig 5). Since the irrigation water salinity over the pasture on the rest of the farm is reduced, a lower leaching requirement is also required. In theory, this means a smaller volume of groundwater is required to be pumped and therefore a smaller sacrificial area. However, it is unlikely that groundwater pumping can provide uniform low leaching fractions to a large property. Therefore, the same pumped volume of groundwater is assumed.

Option 4 - Partial conjunctive use with reduced export to river

The mass of salt exported from a farm to allow salinity control through groundwater pumping will depend on groundwater salinity and volume of disposal required (Fig 7). Increasing the depth of irrigation increases the volume of groundwater that can be diluted to 0.8 dS/m and reused to irrigate pasture. This reduces the volume of groundwater and therefore mass of salt requiring disposal.

Option 5 - Partial conjunctive water use with farm sacrificial area

The size of the sacrificial area depends on the volume of groundwater requiring disposal. This volume requiring disposal can be reduced by reusing a part of the groundwater for irrigation of pasture, diluted to 0.8 dS/m. A smaller amount of groundwater would require disposal to the sacrificial area (Fig 5). The volume of groundwater that can be diluted to 0.8 dS/m depends on both groundwater salinity and the volume of low salinity irrigation water that can be used to dilute the groundwater (Fig 5). Increasing groundwater salinity requires a larger sacrificial area.

Impact of salt management options on gross margin

Irrigation intensity and groundwater salinity

The irrigation cost and fertiliser adjustments outlined above were used to estimate the gross margin given the productivity already estimated for the range of irrigation intensities and groundwater salinities shown in Fig 3. The change in gross margin relative to the base case ($2198/ha @ 1 m irrigation depth) is shown in Fig 7.

Introducing costs to the evaluation alters the analytical perspective from physical productivity to production economics. Optimum input levels are not necessarily those needed for maximum yield. The relationship between milk price and input costs must also be considered. Once the marginal increase in revenue falls below the cost of the additional inputs required, gross margin will fall even though production may still be rising. Thus Fig 8 indicates the optimum depth of irrigation is 1.0 m for systems using 7.5 and 10 dS/m groundwater even though Figure 5 shows production would rise with 1.2 m depth of irrigation. Similarly, costs of increased production exceed increased income beyond 0.8m and 0.6m depth of irrigation for the 15 and 20 dS/m systems respectively.

This relationship is sensitive to changes in factors affecting gross margin. For example, at a lower milk price of 22 cents/litre, the optimum depth of irrigation for production over the two lowest salinity groundwater categories would fall to 0.8m.

Option 1 - Total conjunctive water use

Reduced gross margins will result from lower plant productivity due to the impact of the increased salinity of irrigation as illustrated in Fig 7.

Assuming a direct relationship between pasture yield and milk production and that variable costs remain the same, a 10% reduction in pasture production will result in a fall in milk production of 1214 litres/ha, valued at $329.

Option 4 - Partial conjunctive use with reduced salt export to river

The modelling indicates that there is no significant improvement in pasture productivity with partial conjunctive use, except for systems underlain by 15 and 20 dS/m groundwater at high irrigation water use intensity (Fig 8). Reduced gross margins will result from lower plant productivity. There will also be distinct costs for the various options for disposal of surplus groundwater. This is calculated as in Option 2, although the volume for disposal is considerably reduced by partial conjunctive use.

Option 5 - Partial conjunctive use with reduced disposal to farm sacrificial area

As for Option 4, there is little improvement in pasture productivity with partial conjunctive use, except for systems underlain by 15 and 20 dS/m groundwater at high irrigation water use intensity An additional cost is that perennial pasture production is lost on the disposal area. The cost will be the product of the area used for disposal by the difference in net cost of the disposal activity per hectare relative to perennial pasture.

Option 5a. Partial conjunctive use with disposal to Bermuda grass

The relationship between gross margins derived from these assumptions and the productivity estimated by the modelling are shown in Fig 9. Gross margins are still rising with increasing irrigation intensity for all groundwater salinities at 1.4 m depth of irrigation. The potential for high leaching fractions resulting from irrigation with high salinity water imposes limits on the depth of irrigation.

Option 5b. Partial conjunctive use with disposal to evaporation basin

No production results from the evaporation basin area. The capital cost is assumed to be $6250/ha and disposal capacity 8 ML/ha.

Comparison of salt management options

A matrix of annualised costs and benefits for the range of groundwater disposal options is shown in Table 1. The estimates shown in Table 1 are for an irrigation depth of 1m and groundwater salinity of 20dS/m.

Table 2 sets out the total (net) annual cost for each option for the full range of groundwater salinities considered. The change in cost of disposal with groundwater salinity is shown in Fig 10. The cost of Total Evaporative Disposal is the same for all groundwater salinities and is estimated at $25,846 per annum. It is the most expensive option for all groundwater salinities except 20dS/m, where the estimated annual productivity loss for the Total Conjunctive Water Use (TCWU) option rises to $40,563.

Table 1: Matrix of costs and (benefits) for the range of disposal options.

OPTION		RIVER IMPACT	BASIN COST	REDUCED PRODUCTIVITY	CHANNEL WATER SAVING	REDUCED AREA PERENN PAST	GM FROM BERMUDA GRASS	TOTAL
Total river disposal		18462	0	0	0	0	0	18462
Total evaporation		0	3641	0	(5270)	27475	0	25846
Total Conjunctive Use		0	0	40653	0	0	0	40653
Partial Conjunctive use	River	8046	0	13188	0	0	0	21234
	Evaporation	0	1585	13188	(2295)	11963	0	24441
	Tolerant For	0	0	13188	(1836)	9570	(4295)	16628

Table 2 : Estimated annual cost of groundwater disposal options for a range of groundwater salinities

GROUNDWATER SALINITY (DS/M)	TOTAL EVAP	TOTAL RIVER	TOTAL CWU	CWU +RIV	CWU +EV	CWU +TOL
0.1	25846	92	0	0	0	0
1	25846	923	0	0	0	0
2	25846	1846	0	0	0	0
3	25846	2769	0	0	0	0
4	25846	3692	0	0	0	0
5	25846	4615	714	714	714	714
7.5	25846	6923	4744	4744	4744	4744
10	25846	9231	8331	8331	8331	8331
15	25846	13846	23438	16465	19304	14586
20	25846	18462	40653	21234	24441	16628

The lowest cost options at each groundwater salinity form the lower bound of the graph in Fig 10. Reference to Table 2 shows that there are several lowest cost options at low groundwater salinity. For 0.1 to 10 dS/m groundwater salinity, TCWU is the cheapest option though below 4 dS/m TCWU and Partial Conjunctive Water Use (PCWU) are equivalent as the irrigation salinity limit of the SIRLWSMP is not reached. Above 10 dS/m groundwater salinity, PCWU is cheaper than TCWU with the disposal of the surplus groundwater to salt tolerant pasture being the cheapest sub option. As for the options using total disposal of groundwater, evaporation is a more expensive option than outfall to the river.

4. DISCUSSION

Farm and regional perspectives for optimising sustainable salt management

There are industry issues and resource management constraints affecting the widespread adoption of options for conjunctive water use. While these were extensively considered during the preparation of Land and Water Management Plans, it is appropriate to incorporate both new insights from hydrological research and recent trends observed in aquifer pressure and salinity into reviews of sub-surface drainage programs.

For this purpose, a number of points would warrant further consideration.

Channel water availability relative to land resources

The average water right for the Goulburn-Murray irrigation region is approximately 3 ML/ha. There is a wide range in water entitlement and water use intensity across farms and enterprises in the region.

Table 3 shows that less than 10% of dairy farms have water rights greater than 6 ML/effective ha[1] (Farmanco *et al*, 1999).

TABLE 3: DISTRIBUTION OF WATER RIGHT INTENSITY ON DAIRY FARMS IN THE GOULBURN MURRAY IRRIGATION REGION (AFTER FARMANCO *ET AL* 1999)

WR/EFF HA	IRRIGATION DISTRICT			
	GOULBURN	MURRAY VALLEY	TORRUMBARRY	GMID
0-3	29%	31%	29%	30%
3-4	28%	35%	30%	29%
4-5	27%	23%	25%	25%
5-6	10%	6%	11%	10%
>6	5%	7%	6%	6%

Thus most dairy farms would need to purchase additional transferable water to operate at the irrigation intensity used for this case study. As water, rather than land, is the limiting resource for dairy production based on irrigated perennial pastures, there is an opportunity to consider the economic implications of the interaction of other forage production systems and different water use intensities with the regional hydrology. The case study farm evaluation needs to be carried out for a range of farms and enterprises before the options can be fully viewed in a regional perspective.

This wider range would also allow consideration of the impact of seasonal variations in water allocations on the relative merits of the different disposal options.

A regional integration of land and water resources with disposal options and crop productivity should significantly reduce the estimated cost of evaporative disposal, since this study assumed that land was limiting and perennial pasture production was lost by construction of a basin (see Table 1). In the regional context, the opportunity cost of land would more likely be simply the value of dryland production foregone plus the transaction costs of the transfer of resources.

[1] 1 ha perennial pasture = 1 effective ha and 1 ha annual pasture = 0.5 effective ha

Trends in aquifer salinity

Increasing aquifer salinity will reduce the potential for conjunctive water use. Practices which accelerate rising trends will impose costs on groundwater disposal options. The benefits of groundwater pumping for water resources, or exporting salt, must be offset by the cost of earlier losses in pasture productivity and/or adoption of more expensive disposal options (Gyles *et al*, 1994).

Channel water salinity

Increasing channel water salinity will reduce the potential for conjunctive water use. The external costs of disposal of public groundwater pump effluent to irrigation channels must be fully considered.

Availability of Salt Disposal Credits

It has been estimated [2] that there are only sufficient allocated salt disposal credits to continue the implementation of the SIRLWSMP until June 2001.

Changing enterprise composition within catchments

Disposal requirements will markedly increase as horticultural development continues. Given the scarcity of salt disposal credits, non-river disposal options will be required to handle the effluent produced by providing water table control to 2m depth for expanded permanent horticultural plantings.

Sodicity implications of increasing conjunctive use

The costs of managing any deleterious effects of increasing soil sodicity arising from conjunctive use would need to be included in a more comprehensive evaluation, particularly if large productivity impacts were to occur well into the future.

[2] Critchell S (2000) 'Allocation of Salt Credits' Draft discussion paper, CMSA, DNRE

5. SUMMARY AND RECOMMENDATIONS

The costs of groundwater pump effluent disposal options for a 100 hectare perennial pasture dairy farm in the SIR have been estimated and compared. On the basis of the assumptions used in this study, total conjunctive use with surface channel supplies is the cheapest disposal option for groundwater up to 10dS/m salinity. Given the restrictions on implementing river disposal, annualised savings are around $25,000 per 100 ha perennial pasture by using conjunctive water use rather than on-farm evaporative disposal for groundwater salinity up to 5 dS/m. Savings decrease at higher groundwater salinity as the productivity of forage production under conjunctive use declines. While total conjunctive use becomes more expensive than total evaporation above 15 dS/m, partial conjunctive use with disposal of excess groundwater to salt tolerant forage is approximately $9000 p.a. less expensive than total on-farm evaporation.

However, since the bounds of the study exaggerate the opportunity cost of the land required for construction of an evaporation basin, the relative merits of the on-farm disposal options should be evaluated using a modelling perspective integrating regional land and water resources with disposal options and crop type and productivity. The GIS based analytical tool "ASESS" model developed for MDBC-NRMS investigations and education project I 6040 (Gyles *et al*, 1999) would provide a regional spatial perspective for the analysis. This could be supplemented with sensitivity testing for changes in enterprise composition and the required standards of groundwater management due to trends in commodity prices, costs and water resource constraints using the inter-temporal model developed by Montecillo (Gyles and Montecillo, 1998). This work should substantially contribute to the strategic review of sub-surface programs by regional communities supported by resource management agencies.

6. REFERENCES

Anon (1989) *Shepparton irrigation region draft land and water salinity management plan*, Government of Victoria, Melbourne

Armstrong D, Knee J, Doyle P, Pritchard K and O Gyles (1998) *A survey of water-use efficiency on irrigated dairy farms in northern Victoria and southern New South Wales*. Department of Natural Resources and Environment, ISIA. Kyabram/Tatura.

Bethune M, Prendergast JB (1994) *Categorisation of aquifers being pumped to control salinity through conjunctive water use. Conf. Proc. "Water Down Under", Aust Inst of Engineers, Adelaide Nov. 1994, pp 649-652.*

Bethune M (2000) *Final report Project I-6053*, Murray-Darling Basin Commission, Canberra

Farmanco *et al*, (1999) *The Economic Impact of Proposed Bulk Water Entitlements on the Dairy Industry at the Farm and Regional Level*, in Consultancy report to United Dairy Farmers of Victoria, Goulburn Murray Water and Murray Dairy, Kyabram, Victoria.

Gyles O (1999) *Economic Aspects of Harvesting High Drain Flows in Irrigation Regions*, Proc. DNRE Ann. Econ. Conf., Rutherglen

Gyles OA and Montecillo OP (1999) *Linear Programming and Future Landuse Scenarios: An Irrigated Catchment Case Study*, 43rd Ann. Conf. Aust. Agric. Econ. Soc., Christchurch, NZ.

Gyles O, Morris M, Kularatne D, Abuzar M and S Rollings, (1999) *Targeting areas for beneficial structural adjustment in the southern Murray-Darling Basin*, NRMS project I 6040 final report, Murray Darling Basin Commission, Canberra

Gyles OA, Prendergast JB and MES Young (1994) *Optimal timing of resource protection: interactions of groundwater management with rootzone productivity and salt balance in the Shepparton region*. 38th Conf Aust. Soc. Agric. Econ., Wellington, NZ.

Kimbrough E L (1998) *Forage Bermuda grass*, Information Sheet 860 Extension Service of Mississippi State University, URL: http://ext.msstate.edu/pubs/is860.htm

Prendergast JB (1993). A model of crop yield response to irrigation water salinity: theory, testing and application. Irrig Sci 13:157-164.

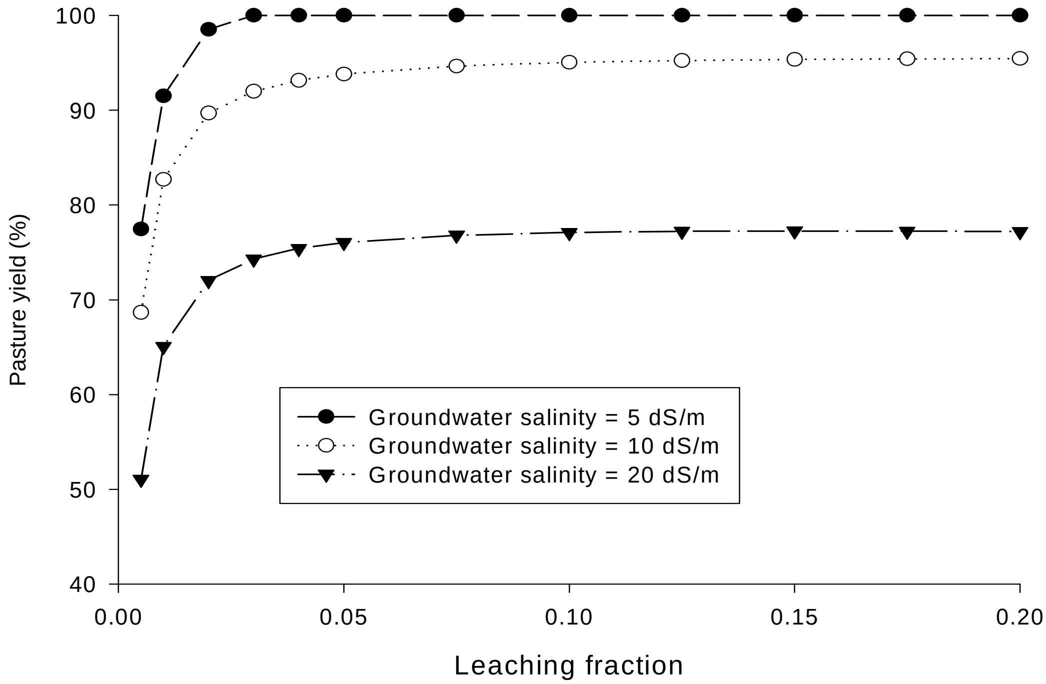


Fig 1. Relationship between pasture yield and leaching fraction for three groundwater water salinities. I=8 Ml/Ha.

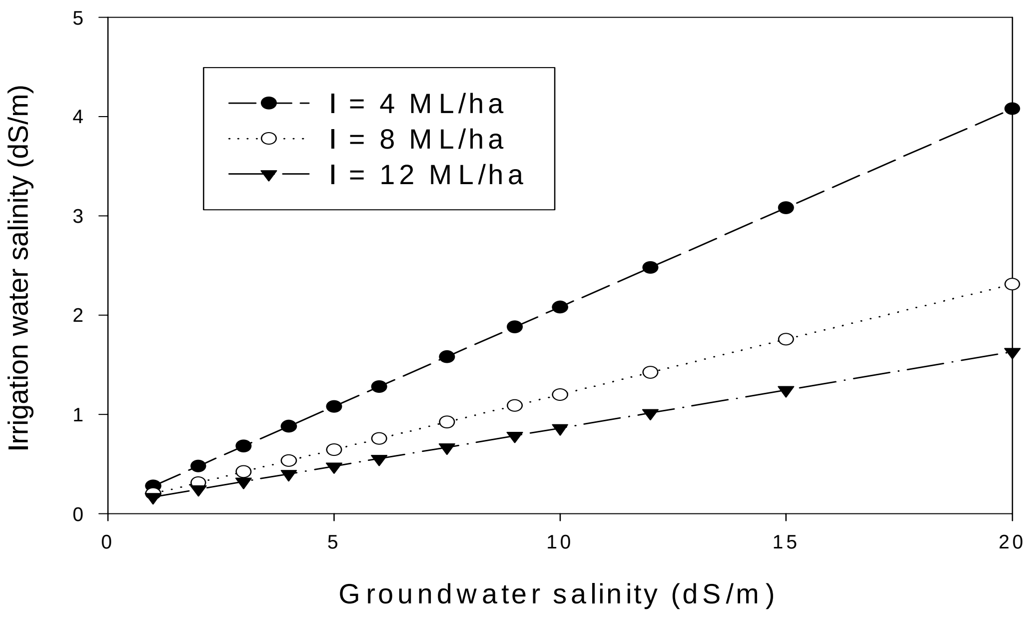


Fig 2. Relationship between irrigation water salinity, groundwater salinity and irrigation intensity (I). Irrigation water salinity not adjusted for rainfall. G=1Ml/ha.

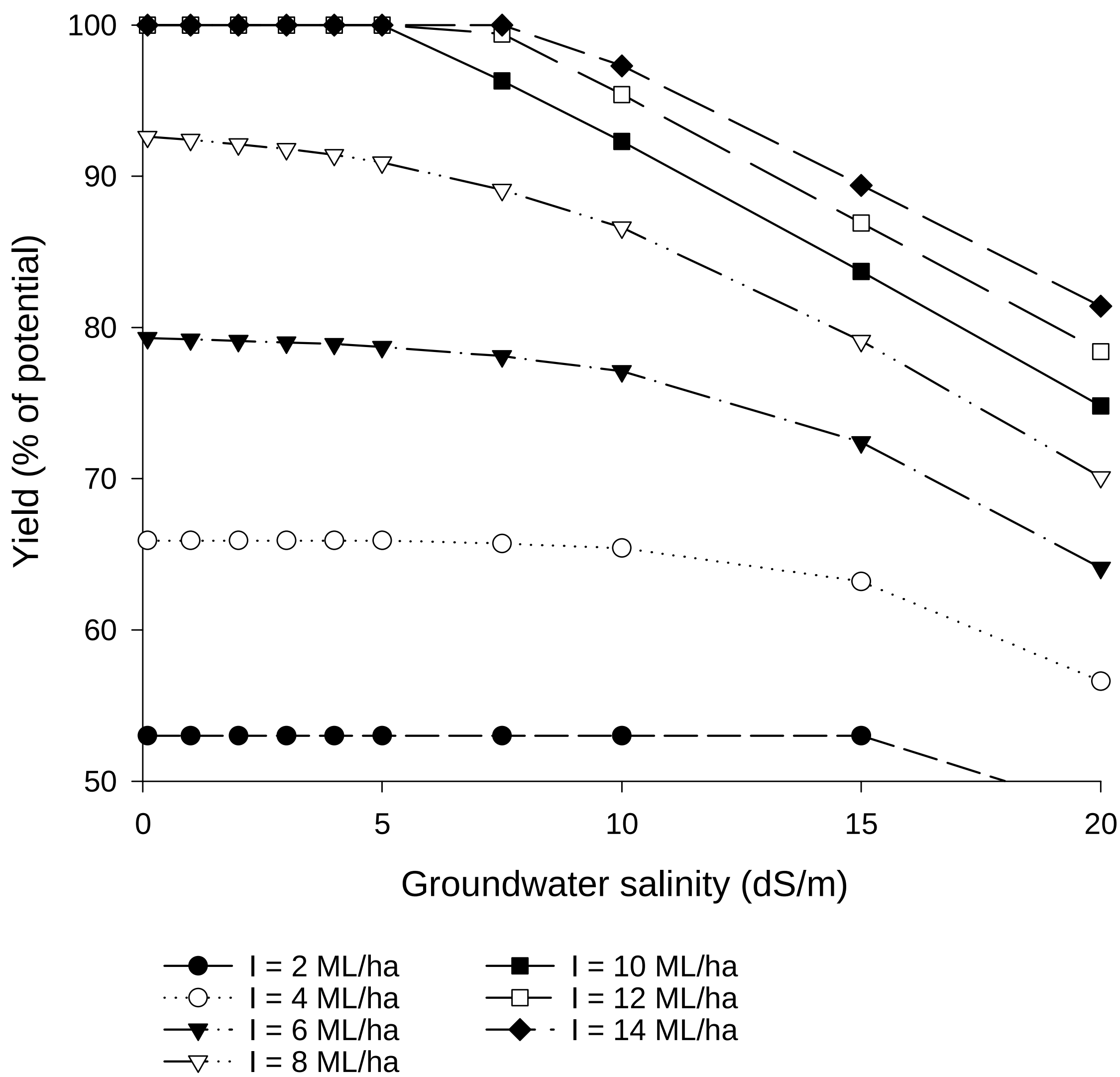


Fig 3. Relationship between relative pasture yield, groundwater salinity and irrigation intensities (I). LF=0.1.

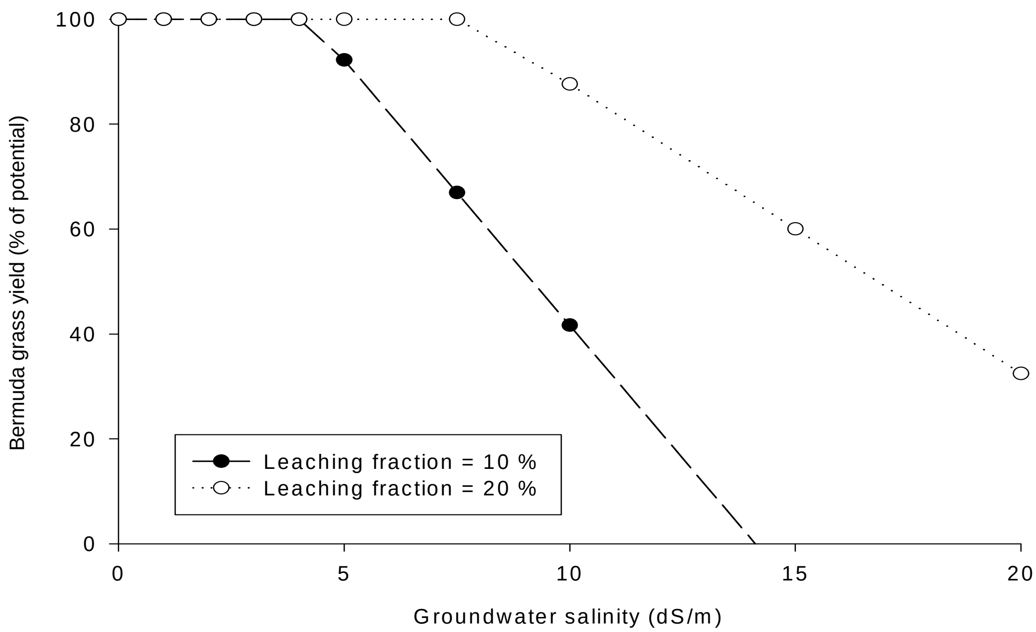


Fig 4. Impact of irrigation water salinity on bermuda grass (A=6.9 dS/m, B= 6.2 dS/m, I= 8 ML/ha).

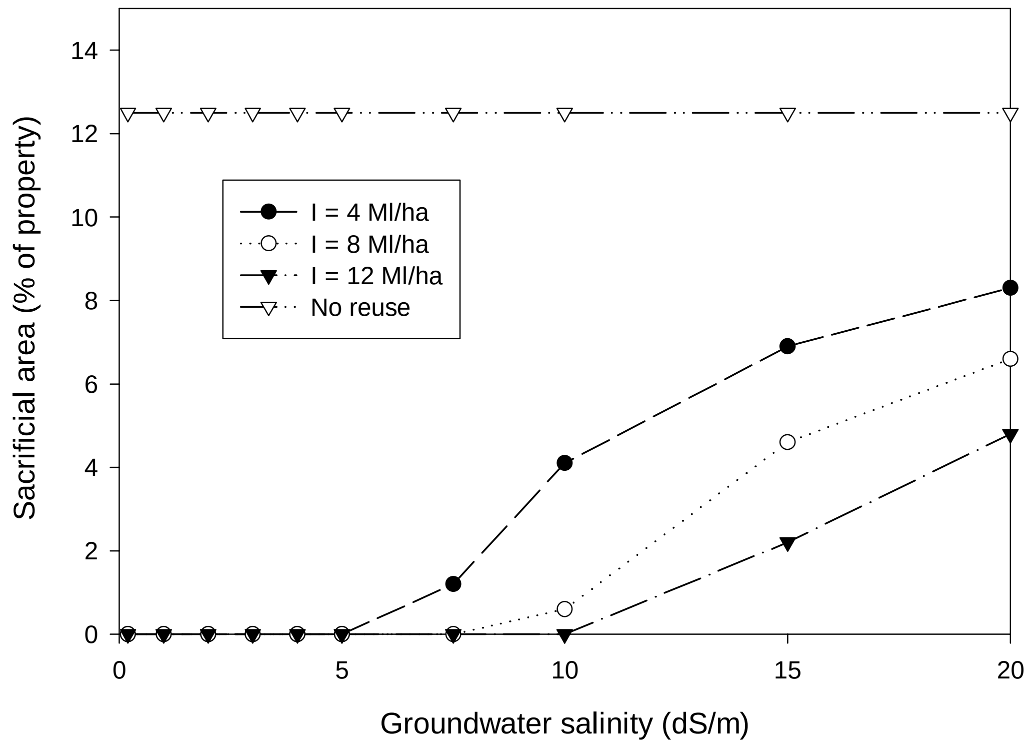


Fig 5.The size of sacrificial area required for different groundwater salinity and irrigation intensity (I).

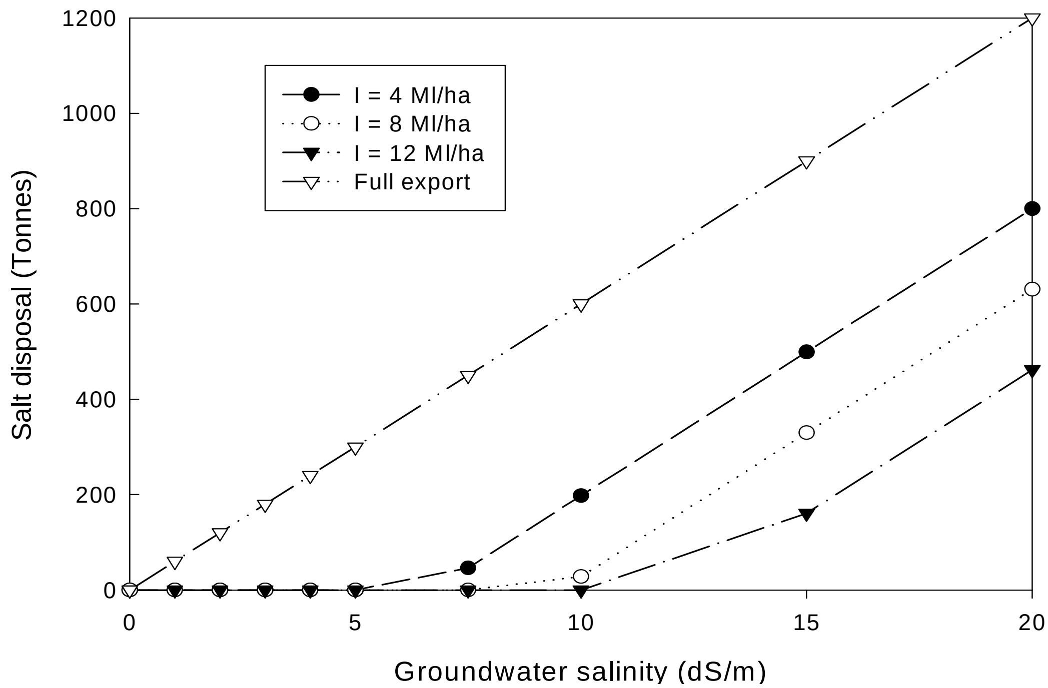


Fig 6. Requirements for salt disposal off farm to prevent irrigation water salinity exceeding 0.8 dS/m, as affected by irrigation intensities (I) and groundwater salinity. Full export occurs when there is no farm reuse of groundwater.

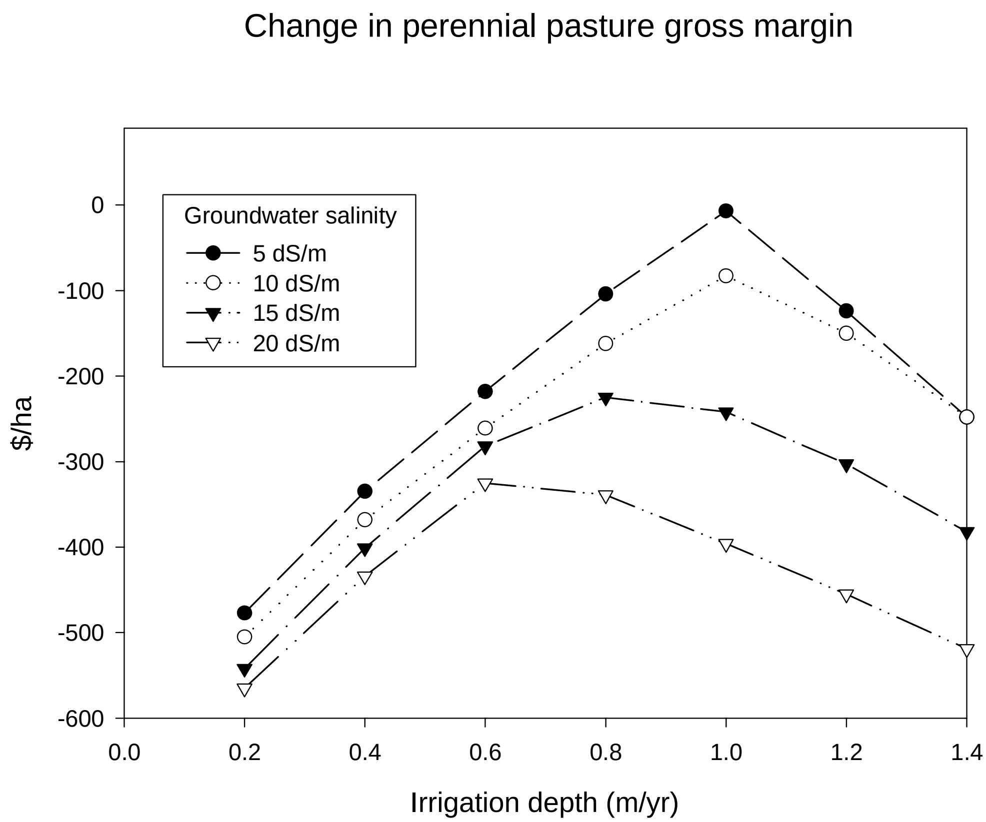


Figure 7. Change in gross margin relative to base case.

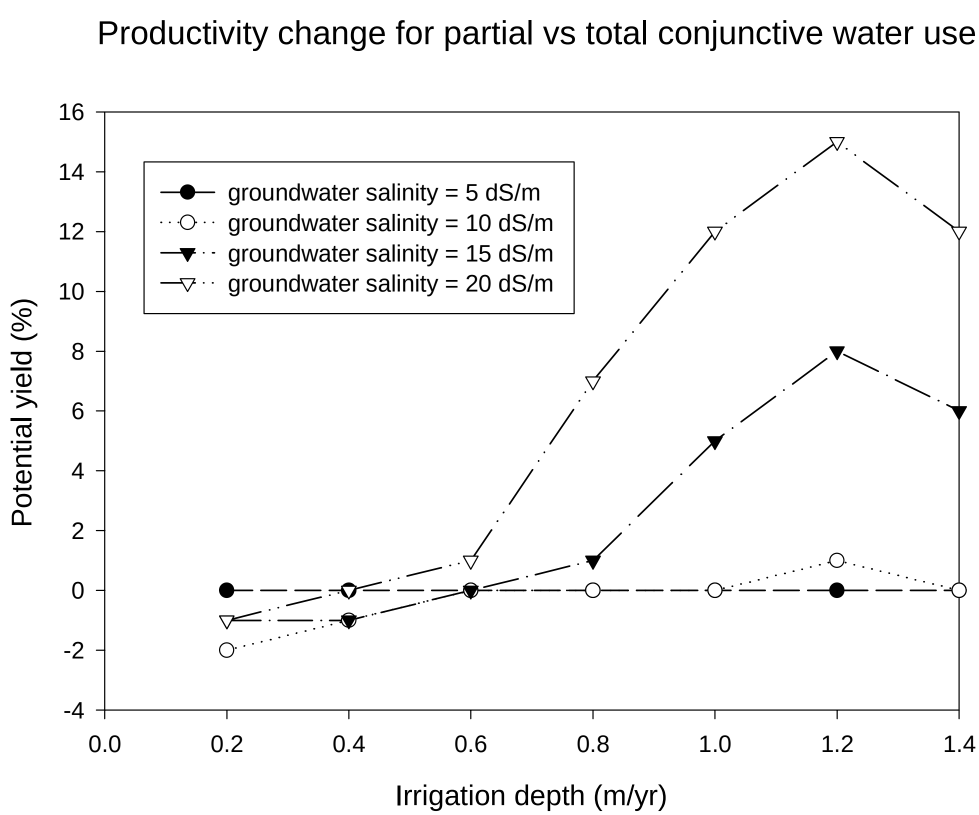


Figure 8 Change in productivity of perennial pasture: Partial vs total conjunctive use.

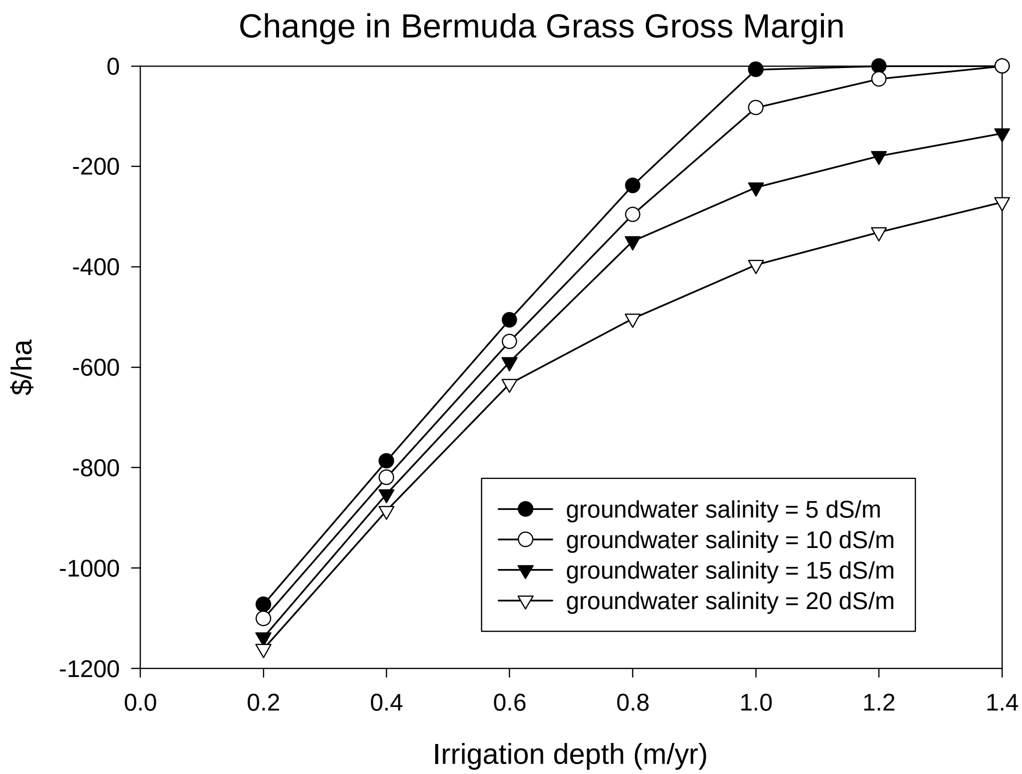


Figure 9: Change in Bermuda grass gross margin with irrigation depth and salinity.

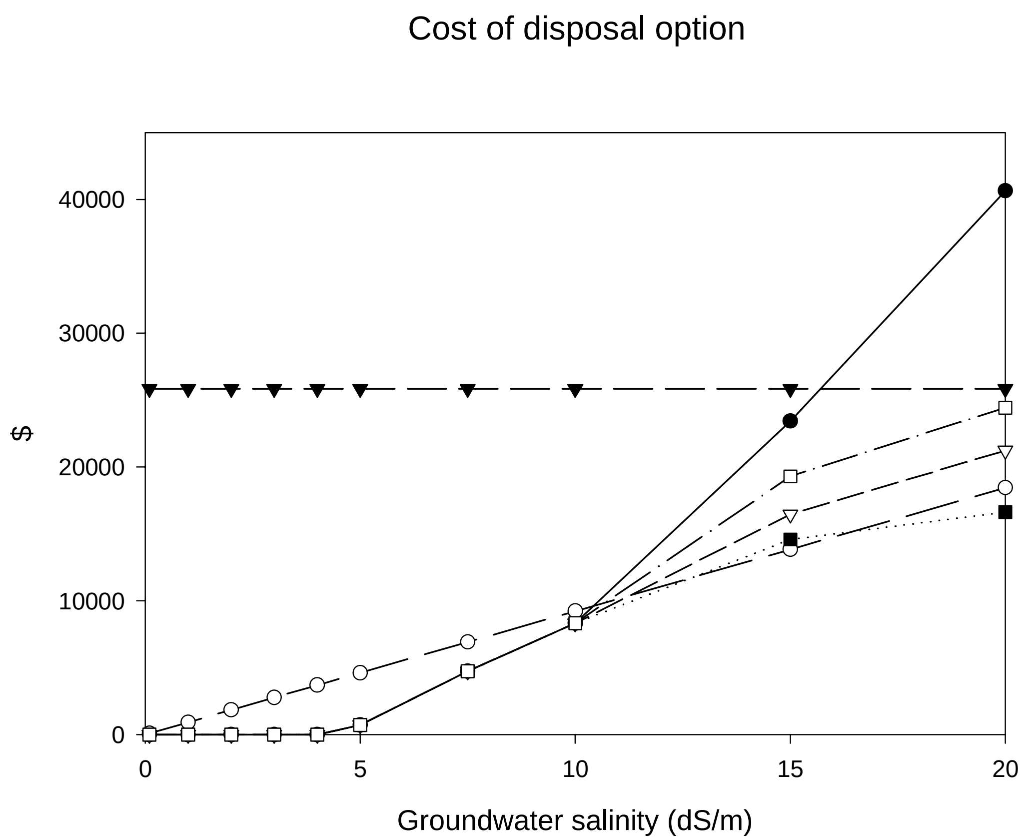
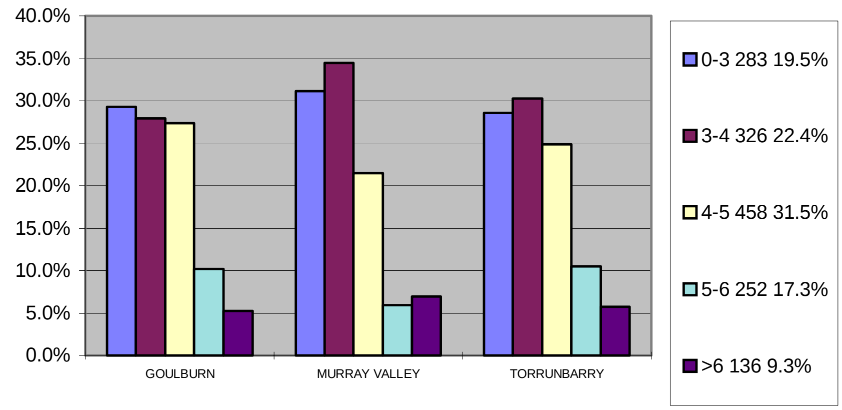


Figure 10: Change in cost with groundwater salinity for the range of disposal options (1 m depth of irrigation)



Dairy WR/Eff ha by District **(Source- GMW Culture data)**

Figure 11: Distribution of water right per effective hectare in the Goulburn-Murray irrigation region (after Gyles et al, 1999)