CRC FOR CATCHMENT HYDROLOGY
CSIRO LAND AND WATER
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ON-FARM AND COMMUNITY SCALE SALT DISPOSAL BASINS ON THE RIVERINE PLAIN

EFFECTS OF BASINS ON THE FINANCIAL VIABILITY OF SUBSURFACE DRAINAGE FOR GRAPEVINES AND CITRUS IN THE MIA

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Foreword

To limit salinity increases in the River Murray, there are pressures to minimise salt leaving irrigated catchments of the Murray-Darling Basin. Part of this strategy is to store drainage disposal water in the irrigation areas themselves and use disposal basins. Unfortunately, there are no existing guidelines for siting, design and management of such disposal basins. The CRC for Catchment Hydrology and CSIRO Land and Water, with support from the Murray-Darling Basin Commission have embarked on a project with the overall objective of producing such guidelines for the Riverine Plain of the Murray Basin. This report is one of several reports being produced in this project to support the guidelines. It deals with the topic of financial viability of horticultural developments in the MIA with the inclusion of drainage and on-farm disposal basins. The report shows that the financial viability is sensitive to the property area, efficiency of irrigation, value of the crop and the sensitivity to waterlogging and salinity. This has ramifications for how disposal basins should be introduced into irrigation areas.

Glen Walker

Leader, Salinity Program

Summary

Horizontal subsurface drainage (tile drainage) has been successfully used for protecting perennial horticulture against waterlogging in the semi arid irrigation areas of the Riverine Plain. On-farm saline disposal basins in conjunction with subsurface drainage systems have been used in the Murrumbidgee Irrigation Area (MIA) since 1988, as a method of diverting saline subsurface drainage water away from fresh surface waters (Wu *et al.* 1999). The use of saline disposal basins as part of the subsurface drainage system has proved to be an effective strategy for on-farm management of saline subsurface drainage water in the MIA.

This report examines the financial viability of a subsurface drainage system with saline disposal basin. Analysing the trade off between varying basin size for watertable control in high rainfall years against the loss of cropping area every year, thereby achieving a balance between optimum basin size and maximising returns from crops.

Subsurface drainage with a saline disposal basin was found to be an effective strategy in controlling waterlogging and therefore improving crop yields. The benefits of waterlogging control to crops in the farm area were higher than the loss due to giving an area to a saline disposal basin. However, the unrestricted disposal of subsurface drainage to surface systems was most attractive in terms of income.

The income and cost differences between a "no drainage scenario" and drainage with a saline disposal basin for a new vineyard indicated that the subsurface drainage with a saline disposal basin has about 39% higher returns per ha than the no drainage situation.

An alternative to subsurface drainage may be to have a highly controlled irrigation system such as drip irrigation. If it is assumed that with suitable site selection and management the drip irrigated vineyard will not require drainage, then this is a more financially attractive option than subsurface drainage with or without a basin under furrow irrigation. There needs to be serious consideration of this option if investment in a highly controlled irrigation system is a better alternative to installation of subsurface drainage. It was also found that subsurface drainage with a basin under drip was equally viable to subsurface drainage with a basin under furrow irrigation, when the basin area used for drip was about half that of furrow.

The financial performance of a subsurface drainage system is better with larger farms because of economies of scale associated with farm size. A significant saving on account of reduced cost of production by choosing an appropriate farm is possible e.g. total cost per ha on a 100ha farm is about 35% less than the cost per ha on a 20ha farm.

Small farm sizes below 20ha in new vineyards (10ha in existing vines) and below 10ha in new and existing citrus orchards should consider other options, such as draining into a larger community basin or draining into surface drainage systems.

Crop price and yield has a considerable effect on the financial attractiveness of a drainage system. The subsurface drainage systems with a saline disposal basin are better suited to crops that have high yields and prices and crops that are more sensitive to waterlogging.

Drainage without a basin was found to be financially more attractive than using a basin, even when the land for the disposal basin was given a zero value. Increasing land value decreased the financial attractiveness of using a saline drainage disposal basin. However, the use of basins with vineyards was still financially viable when land was valued at $5000/ha.

Irrigation management is a key factor in deciding the financial attractiveness of a drainage system. With poor irrigation management, the system with unrestricted drainage water disposal did not experience any increase in watertable and hence no yield decline. Where drainage was restricted with a disposal basin, the resulting higher watertable resulted in about a 4% decline in average yield and about 5% decline in net cash flow, the Benefit Cost Ratio (BCR) declined by 2% and Net Present Value (NPV) by 9%. A considerable saving is possible with better irrigation management due to less water use and therefore less drainage and hence a smaller basin area.

Subsurface drainage with a saline disposal basin has greater economic potential for adoption on existing plantings. The income with existing vineyards increased by more than 20% whereas total costs were 13% less than for a new development. The profitability of drainage with disposal was more than doubled for existing vineyards.

Financial analysis of citrus, which is more sensitive to waterlogging than grapes, indicated that the drainage disposal systems with a basin are more attractive with more waterlogging sensitive crops.

Considerable yield improvements for grapes were found as a result of increasing basin size. The yield with a basin area that was 10% of the drained area was quite close to potential yield, and hence can be said to be the physically optimal area. However, this may not be financially optimal as this increase in yield may not outweigh the increase in cost and the lost production from land used for saline disposal basin.

A 5% basin area had the highest NPV and BCR followed by a 7.5% basin area, which indicated that for grapevines an optimal area would be between 5 and 7.5% of drained area. Smaller areas incurred excessive waterlogging losses and larger areas had too large an annual penalty in loss of cropped area. However, a reasonably steady annual NCF is achieved with a 7.5% basin area in new vineyards.

The optimisation of output indicated that a basin area between 5 and 7.5% of drained area would be optimal. In existing vineyards, the marginal returns are greater than the marginal cost up to an average yield of about 18t per ha which corresponds to a saline disposal basin area of about 8%. A basin area of 5% was not optimal as the profits were increasing. Therefore, for the MIA, a subsurface drainage system with a saline disposal basin area of about 7.5% is financially most attractive in new and existing vineyards. In citrus however, a basin area of about 12.5% of farm area would be financially optimal.

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Glossary of Definitions

Basin area %: The basin area % is the percentage of the drained area that is allocated to a saline disposal basin.

Benefit Cost Ratio (BCR): Is the ratio of total discounted benefits to total discounted costs. If discounted benefits exceed discounted costs, the ratio exceeds 1.0. All systems with ratio greater than one are financially desirable and the system with highest value is the most financially desirable

Break Even Time (BET): Is the period in years for a system's cumulative cash flow to become positive. This represents the time period required for a system to pay for all its' debts and after this period net positive gains start accruing.

Cash Flow Budget: A cash flow budget is a technique used to show future costs and returns associated with a project over a period of time. These are the basis for deciding whether or not to undertake a project, for obtaining finance and for monitoring its performance once it commences. These are used primarily to evaluate an investment.

Net Cash Flow (NCF): This is the net of total annual income after paying for total annual costs before overhead costs, taxes and discounting. Annual net cash flows over the life of an enterprise are used to see when the investment begins to earn a positive cash flow. This measure also allows cash flow trends to be seen i.e. whether cash flows are increasing, decreasing or remaining steady over time.

Net Present Value (NPV): Is the net gain or difference obtained after subtracting the total discounted cost of an enterprise from the total discounted benefit over the expected life of an enterprise. A scenario with a positive NPV provides a net gain and so is desirable, that with the highest NPV is most desirable. A negative value shows the system is financially unattractive.

Marginal Cost: Marginal cost is defined as the change in total cost per unit increase in output. It is the cost of producing an additional unit of output. That is:

$$MC = \eth TC / \eth Y$$

Where

MC is the marginal cost

ðTC is the change in total cost

ðY is the change in output

Marginal Revenue: Marginal revenue is the change in total revenue per unit increase in output

Algebraically, MR can be written as:

$$MR = \partial TR / \partial Y$$

Where

MR is the marginal revenue

∂TR is the change in total revenue

∂Y is the change in output

Production Function: A production function describes the rate at which resources are transformed into products or it specifys quantities and qualities of resources needed to produce a particular product.

Algebraically, a Production Function can be written as:

$$Y = f(X_1, X_2, X_3, \ldots\ldots, X_n)$$

Where

Y is the output

Xi (i=1…n) are the resources

Purely competitive market: A market is said to be purely competitive, if it fulfils the following conditions:

1. A large number of buyers and sellers
2. Homogeneous product i.e. agricultural products of a given type are similar in appearance and quality.
3. Buyers do not prefer the product of one farmer to the product of a second, as a result individual farmers are unable to create a unique demand.
4. Market price is given i.e. where a farmer can not influence the market price of his product
5. Where businesses are free to enter into or cease production as they please
6. Where prices are free to vary

Total Cost: These are the sum of total variable and total fixed costs

Algebraically, TC can be written:

$$TC = TFC + TVC = TFC + P_x X$$

Where

TC is the total cost

TFC is the total fixed cost

TVC is the total variable cost

P_x is the price of resource X

Total Revenue/ Total Value Product: Is the value of output in dollar terms and is called Total revenue when expressed as a function of output and Total Value Product when expressed as a function of input. That is,

$$P_y . Y = P_y . f(X)$$

The first is called Total Revenue and the second is the Total Value Product.

1. Introduction

High watertables leading to crop waterlogging and soil salinisation are commonplace in irrigated regions of south eastern Australia. These problems have been addressed by installation of subsurface drainage in the form of horizontal pipe drains.

Horizontal subsurface drainage (often known as tile drainage) has been successfully used for protecting perennial horticulture against waterlogging in the semi arid irrigation areas of the Riverine Plain. These subsurface drainage systems are effective in protecting crops but the disposal of the drainage water, which is usually highly saline, into surface water systems has had negative effects on down stream water users. To reduce these effects on–farm saline disposal basins, in conjunction with the subsurface drainage systems, have been used in the Murrumbidgee Irrigation Area (MIA) since 1988 as a method of diverting saline subsurface drainage water away from non-saline surface waters (Wu, *et al.*, 1999).

Diversion reduces the adverse effect of reduced water quality on down stream water users, but creates an additional cost burden upon farmers installing subsurface drainage. Evidence gathered so far indicates that saline disposal basins can be an effective way of handling drainage water. However one of the most important concerns about the use of saline disposal basins is the cost involved in the siting, design and construction (Singh and Christen, 1999). Since subsurface drainage is an expensive operation, this type of drainage is generally suited to high value crops such as grapevines and citrus.

This analysis studies the economic viability of subsurface drainage systems considering the saline disposal basin as part of the whole drainage system, rather than as a separate entity. The financial effect of a subsurface drainage system will vary with physical and financial factors such as farm size, crop price and yield, irrigation efficiency, choice of crop and its sensitivity to waterlogging, and also the basin area needed to store the drainage water. Thus, it is important to assess the impact of these factors on the financial attractiveness of subsurface drainage/ disposal systems.

This paper examines the financial desirability of a subsurface drainage system with a saline disposal basin, whilst analysing the trade off between varying basin size for watertable control in high rainfall years, against the loss of cropping area every year, thereby achieving a balance between optimum basin size and maximising returns from the crop.

2. Objectives

The specific objectives of this study are to:

1. Analyse the impact of using a saline disposal basin on farm income
2. Determine the physical and economic conditions for successful use of on-farm saline disposal basins
3. Determine the most financially attractive basin area
4. Analyse the overall farm economic conditions for long term financial viability with a subsurface drainage/ disposal system

3. Methodology

The use of on-farm saline disposal basins can be considered as part of Land and Water Management Plans (L&WMPs) to reduce the salt load leaving irrigation areas. Thus, with the installation of subsurface drainage, a saline disposal basin would have to be installed to hold the drainage water, rather than discharging into the surface drainage system. Therefore, while considering the cost and benefits associated with saline disposal basins, the drainage system needs to be included as part of an integrated system. This reflects the reality that in many present situations, where a drainage system produces saline water, there must be a basin to receive the water, as off site disposal is no longer possible. However, it is necessary to compare the impact of using a saline disposal basin on farm income, against drainage without a basin, and a situation without drainage, to analyse the financial feasibility of using such a system in horticultural developments.

3.1 Waterlogging and Yield Response Functions

Determining waterlogging

To gain a better understanding of the underlying hydraulic relationships between farm and basin, and to optimise the design of the basin to minimise the basin area whilst controlling waterlogging, a water balance model called BASINMAN has been developed by Wu *et al.*, 1999. The BASINMAN model was used to analyse the effect of saline disposal basin size on waterlogging in the farm.

The BASINMAN models were for a typical horticultural soil of the MIA, Hanwood loam, using 35 years (1962-1997) of weather data from CSIRO Griffith. The model used an open water evaporation pan coefficient of 1. The farm and basin domain was run as a closed system with no groundwater inflows or outflows. The model outputs daily watertable levels that were analysed to determine yield losses due to waterlogging.

Yield response functions were developed for grapevines and for use with the daily watertable depths generated by the BASINMAN model. This yield data was then used in developing cash flow budgets for financial analysis of the subsurface drainage basin system.

The yield response function for grapevines was developed from the work of Stevens and Prior (1994). They conducted plot trials where various durations of waterlogging (0,1,3,5 and 7 days) were imposed in a two-week irrigation cycle. These results were interpreted as that a one day period of waterlogging caused a 15% reduction in growth for that day, a two day period of waterlogging resulted in a 29% reduction in vine growth on the second day and, for a three day or longer period of waterlogging vine, growth was reduced by a maximum of 45%. The recovery in growth rate of vines after waterlogging was interpreted as being instantaneous after a one or two day waterlogging event; however after three or more days of waterlogging the stress was severe enough to reduce growth for the following eleven days. It was assumed that the recovery in growth over that period would be linear. If a waterlogging event occurred during a recovery period, it was assumed that the growth would again be reduced by 45% and the recovery process reinitiated.

In the field it was assumed that a watertable within 0.9m of the soil surface would cause waterlogging stress. This was on the basis of field observations in several vineyards in the MIA that there are few roots below 0.9m depth. Based on this, the effect of waterlogging on growth was computed for each day of the growing season. The average growth rate was then computed for the whole season. Since a reduction in growth does not necessarily equate to the same reduction in yield, it was assumed that the yield loss would only be 60% of the growth reduction. This was on the basis that waterlogging stress would have a similar effect to soil salinity stress, and that with soil salinity stress yield loss in grapevines is about 60% of the growth reduction, Mass and Hoffman (1977).

To initialise the grape yield loss function for the MIA, conditions the BASINMAN model was run with unrestricted drainage to determine the typical level of waterlogging in the area as the base level for the NSW Agriculture reported grape yields used in the financial analysis. This base level of waterlogging was then deducted from calculated waterlogging yield losses.

The yield response function for citrus was developed from the work of Minessy *et al.* (1970). They conducted measurements on the growth and yield of Washington navel oranges under varying drainage conditions in a single orchard. The growth in the orchard was split into five levels with about 500 trees for each level of vigour. The watertable was monitored at four points for each level of vigour, the key watertable reading taken as the depth to watertable seven days after irrigation. For the five levels of vigour the seasonal average watertable depth varied between 0.5 and 1.7m, Figure 1.

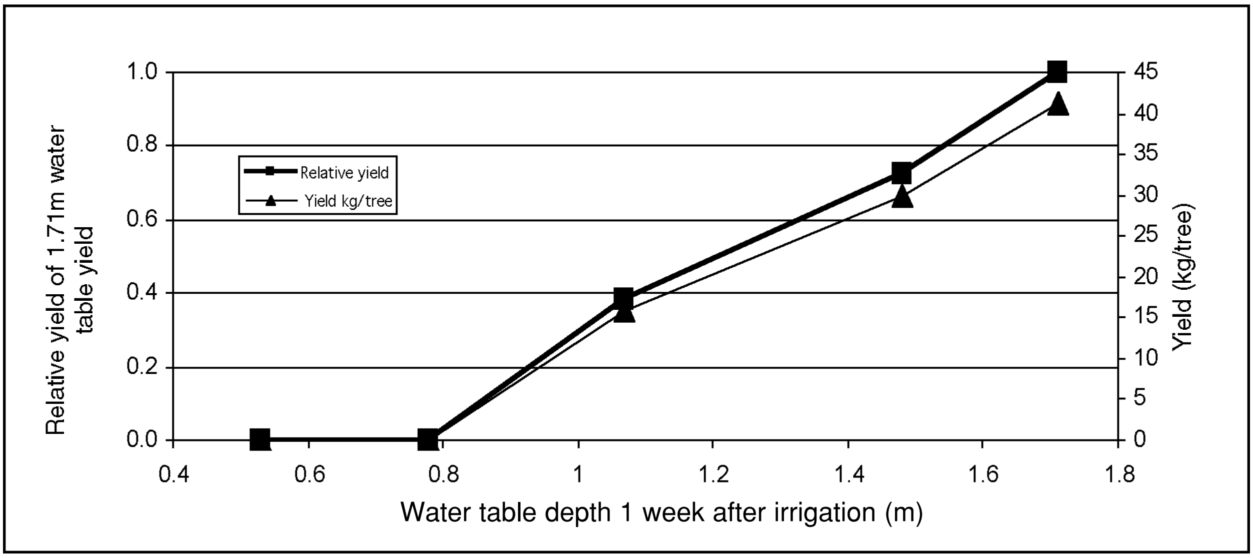

Figure 1.Yield as a function of watertable depth for Washington navel oranges

The yield results and watertable readings from this paper were used to develop a linear relationship between yield and depth to watertable. This relative yield function was developed assuming that the yield of the trees with watertables at 1.7m deep was unaffected by waterlogging.

The BASINMAN output was interrogated for the watertable depth seven days after each irrigation. The average of these depths was then used to calculate the yield loss. To initialise the citrus yield loss function for the MIA conditions, the BASINMAN model was run in unrestricted drainage mode to determine the typical level of waterlogging in the area as the base level for the NSW Agriculture reported citrus yields used in the financial analysis. This base level of waterlogging was then deducted from calculated waterlogging yield losses.

Yield losses due to salinity

The above yield response functions do not take into account the effect of salinity on yield. This is due to BASINMAN not including any solute transport.

The effects of salinity in most of the scenario modelling in this report are likely to be minimal as waterlogging is being controlled; this will also result in effective salinty control. The onsett of waterlogging will have the initial impact on yield reduction, and this will lead to undesirable conditions before salinity effects become apparent. This is especially the case for citrus which is extremely sensitive to waterlogging. Citrus yield will decline very quickly due to waterlogging and become uneconomic before salinity effects become apparent. Grapevines are less sensitive to waterlogging and thus salinity effects will be more important than for citrus. However, only when modelling scenarios where there is no drainage and the watertable is high is it likely that salinity will have a large effect on yield. This occurs in the initial analysis where drainage with, and without, a basin is compared to an undrained situation. In this case, the work of West and Taylor (1984) showing that vine growth is halved when waterlogging occurs in saline conditions was incorporated into the yield loss function. Thus, when analysing situations with no drainage, it was assumed that the predicted yield losses due to waterlogging would be doubled due to salinity effects. This is on the basis that most of the shallow groundwater in the MIA is saline.

3.2 Yield Schedule

A 25 year budget was constructed with an expected harvest area and yield schedule for each year of production, allowing total yield to be calculated for a 40ha farm of new horticultural development. The analysis was undertaken for Shiraz winegrapess and Washington navel oranges. The yields for existing plantings were also developed, the yield schedule for each year is presented in Table 1.

Table 1. Potential yield schedule for new and existing plantings of vines and citrus

Yield (tonnes/ha)				
Vines* (Shiraz)			Citrus (Navels)	
Year	New	Existing	New**	Existing
1	0.0	18.31	0	42.09
2	1.0	18.31	0	41.25
3	3.66	18.31	0	43.08
4	7.32	18.31	5.47	44.91
5	11.0	18.31	14.10	46.74
6	13.73	18.31	19.18	46.69
7	17.39	18.31	26.25	52.64
8	18.31	18.31	31.60	55.59
9	18.31	18.31	42.23	58.54
10	18.31	18.31	40.01	61.5
11	18.31	18.31	42.09	61.5
12	18.31	18.31	41.25	61.5
15	18.31	18.31	46.74	61.5
18	18.31	18.31	49.69	61.5
20	18.31	18.31	61.5	61.5
25	18.31	18.31	61.5	61.5

Source: *Moll and Christen (1996)
** Farm Budget handbook, NSW Agriculture (1997),
Note: 11th year yield of new citrus (with a positive Net Cash Flow) was assumed as the 1st year yield of existing citrus.

3.3 Financial Evaluation

The financial evaluation of the desirability of a subsurface drainage basin system was carried out using a spreadsheet model, incorporating the waterlogging and resulting yields with different basin areas, and the saline disposal basin cost and subsurface drainage costs in a 25 years Cash Flow Budget. This timeframe was assumed to be long enough for the development to achieve a steady state cash flow. The cash flow budget allows the annual net cash flow to be calculated, and a cumulative balance for each year to be determined. Total yearly benefits and costs were discounted using a rate of 8%, which is assumed to be equal to a farmers opportunity cost of capital (i.e. The expected rate of return from the farmers' most attractive alternative use of capital). Income and costs from crops using different subsurface drainage/disposal systems were estimated to determine and compare the impact of using a saline disposal basin on farm income.

The effect of inflation is not considered in the analysis, based on the assumption that it affects both input and output prices equally. However, this may not be valid as input prices tend to increase faster than output prices.

The financial attractiveness of each system was determined using common financial evaluation criteria such as Net Present Value (NPV), Benefit Cost Ratio (BCR), Break-Even Time (BET) and annual Net Cash Flow (NCF).

3.4 Analysis of Physical and Economic Factors Affecting Saline Disposal Basin Viability

Financial analysis of the impact of various physical and economic factors on different subsurface drainage/disposal systems was carried out to identify and quantify the impact of the key factors for successful and financially attractive subsurface drainage-disposal systems. For this analysis, two subsurface drainage-disposal situations namely; Drainage with No Basin (DNB) and Drainage With Basin (DWB) were used for a new vineyard development. This comparison was undertaken to examine the impact of policy change on farm financial viability of changes from the status quo situation of DNB, where drainage water is diposed of to the surface drainage network to a situation where a saline disposal basin is required (DWB). For this analysis, a basin area of 7.5% of the total farm area (40ha) was used. The selection of this area was on the basis of analyses using the BASINMAN model, which suggested that about 7.5% basin area is able to control waterlogging in vines effectively (Wu *et al.*, 1999). The important factors considered for the analysis are presented in Table 2.

Table 2. Variables considered in economic analysis

Factors	Range	Default value
Farm size (ha)	10,20,40,60,80,100	40
Change in price of crop	–40%,-20%,0%,+20%,+40%	$700/ tonne
Change in average yield of crop	-40%,-20%,0%,+20%,+40%	ND=11.32 t/ha DNB=15.35 t/ha DWB=15.04 t/ha
Irrigation efficiency	Efficient: 110% of ET-R Inefficient: 120% of ET-R	Efficient
Development type	New, Existing	New
Crop choice (waterlogging sensitivity)	Vines (less sensitive), Citrus (more sensitive)	-
Basin area (%)	2.5,5,7.5,10 in vines and citrus and 12.5 in citrus	7.5
Land value ($/ha)	0, 1000, 2000, 3000, 4000, 5000	5000
Discount rate (%)	4, 8, 10	8

This analysis does not include the downstream costs of the DNB option, as the analysis being financial considers only the tangible on-farm cost and benefits. Moreover, to ensure that result of the comparison analysis between DNB and DWB remains unaffected, the downstream benefit accruing due to saline disposal basin is also not included in the analysis.

The alternative to these two conditions (DWB, DNB) is not to have any drainage (ND). This was included in order to assess whether the impositon of saline diposal basins would result in farms choosing not to undertake subsurface drainage.

3.5 Optimising Basin Area

The trade off between different basin sizes for watertable control is the resulting yield improvement in high rainfall years against the loss of cropping area in every year. This was analysed using different financial criteria by achieving a balance between the best basin size and maximising returns from the crop. The range of basin sizes considered is also given in Table 2.

A test of significance (t-test assuming unequal variance) was used to analyse if increasing basin size has any significant improvement in crop yields and annual Net Cash Flow (NCF). Standard Deviation of the mean of annual NCF was calculated to measure the extent of variability between different subsurface drainage with basin scenarios.

The optimisation of the most financially attractive basin area is done by determining the most profitable level of output using the principle of marginal returns (Doll and Orazem, 1984), and then relating the optimum output level with the corresponding basin area (for details on method of optimisation see Appendix 1).

3.6 Sensitivity Analysis

The sensitivity analysis of the financial attractiveness of the subsurface drainage system with the best basin area to factors such as price, yield, irrigation management, farm size and crop was carried out to analyse the overall economic conditions for the long term viability of the subsurface drainage/disposal system.

The sensitivity analysis of subsurface drainage-disposal systems under different scenarios was carried out using @ RISK© a program that allows variation in variables, in this case farm size, market price and yield to be taken into account and enables rapid sensitivity tests to be carried out.

3.7 Data Used

The information relating to winegrapes and citrus were obtained from various published sources and agencies. The information on average grape prices was taken from the Winegrapes Marketing Board Annual Report (1997).

The detailed information on costs of vineyard development, including the cost of machinery/equipment, land preparation, trellising, vine establishment and maintenance, irrigation system installation and operational cost (Riverina Twin Furrow in this case), chemicals, harvesting and subsurface drainage were obtained from Moll and Christen (1996). The detailed information on the income and costs of vineyard development is presented in Appendix 2A and 2B.

For citrus, the estimates on various costs and prices involved in the establishment of a citrus orchard were obtained from the Farm Budget Handbook, NSW Agriculture (1997).

The information on costs of siting, design and construction of saline disposal basin were obtained from Singh and Christen (1999). Apart from these construction costs of a saline disposal basin, a land value equivalent to \$5000/ha of saline disposal basin was considered for new vines and citrus analysis, while for existing horticultural development net income per ha was considered as a proxy of production foregone from the basin area. The detailed information on siting, design and construction of saline disposal basins is presented in Appendix 2C.

4. Results and Discussion

This section is divided into five sub sections:

4.1 Physical and economic impacts of using a saline disposal basin

4.2 Analysis of physical and economic factors affecting the successful use of subsurface drainage with a saline disposal basin

4.3 Determining the financially optimal basin area

4.4 Scenario analysis of the optimum basin area

4.5 Sensitivity analysis of the optimum basin area to variations in physical and economic factors

4.1 Physical and Economic Impact of Using a Saline Disposal Basin

This analysis was conducted for a new 40ha vineyard with three scenarios: subsurface drainage with a 7.5% basin area (DWB), subsurface drainage without a basin (DNB), and no subsurface drainage (ND).

4.1.1 Crop yields

Crop yield represents the relationship between crop growth and watertable depth with the different systems. The relative yield in Table 3 indicates that waterlogging (and salinity ND) has considerable impact on crop yield.

Table 3.Relative yields of grapevines under different drainage/disposal systems

Subsurface drainage/disposal system	Relative yields*
Potential average yield (t/ha) (MIA Average)	15.35
No Drainage (ND)	0.74
Drainage with No Basin (DNB)	1.00
Drainage With Basin (DWB)	0.98

** relative yield is the fraction of potential average yields*

No reduction in yields was observed when draining without a basin (DNB), where there is no restriction on the disposal of drainage. Any excess water is rapidly drained from the profile by the subsurface drains and disposed of to the surface drains. The yield was lowest when there was no drainage (ND), where there was no control over rising watertables and soil salinisation. Considerable control of watertables was achieved when draining with a basin. Figure 2 shows the trend in annual average yield over a period of 25 years.

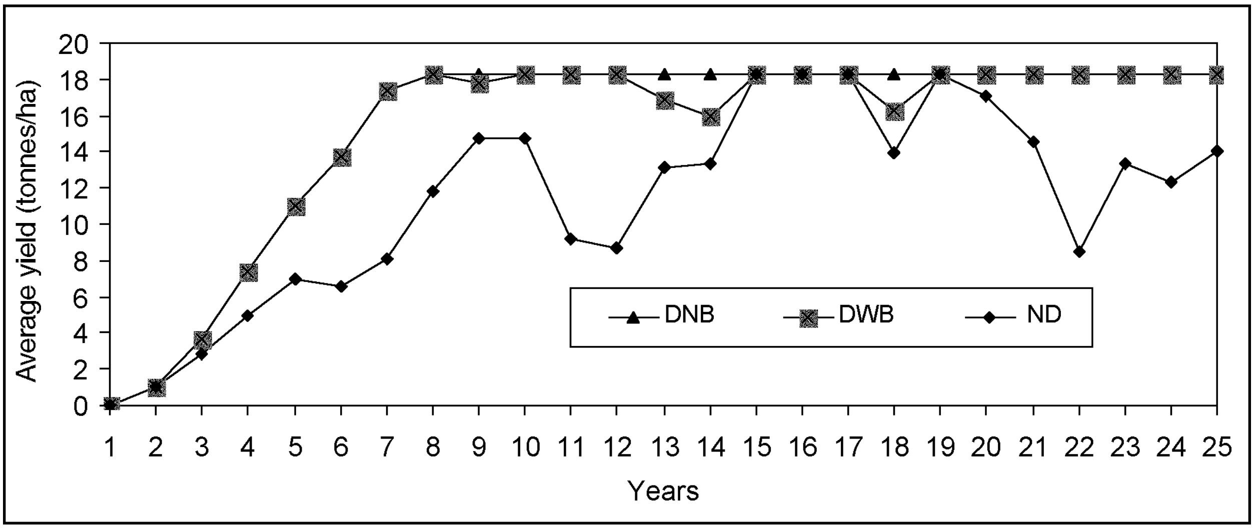

Figure 2. Average yield for a new vineyard with different drainage-disposal schemes

4.1.2 Income and costs

Income was highest with the DNB system followed by DWB and was lowest in the ND situation, Figure 3.

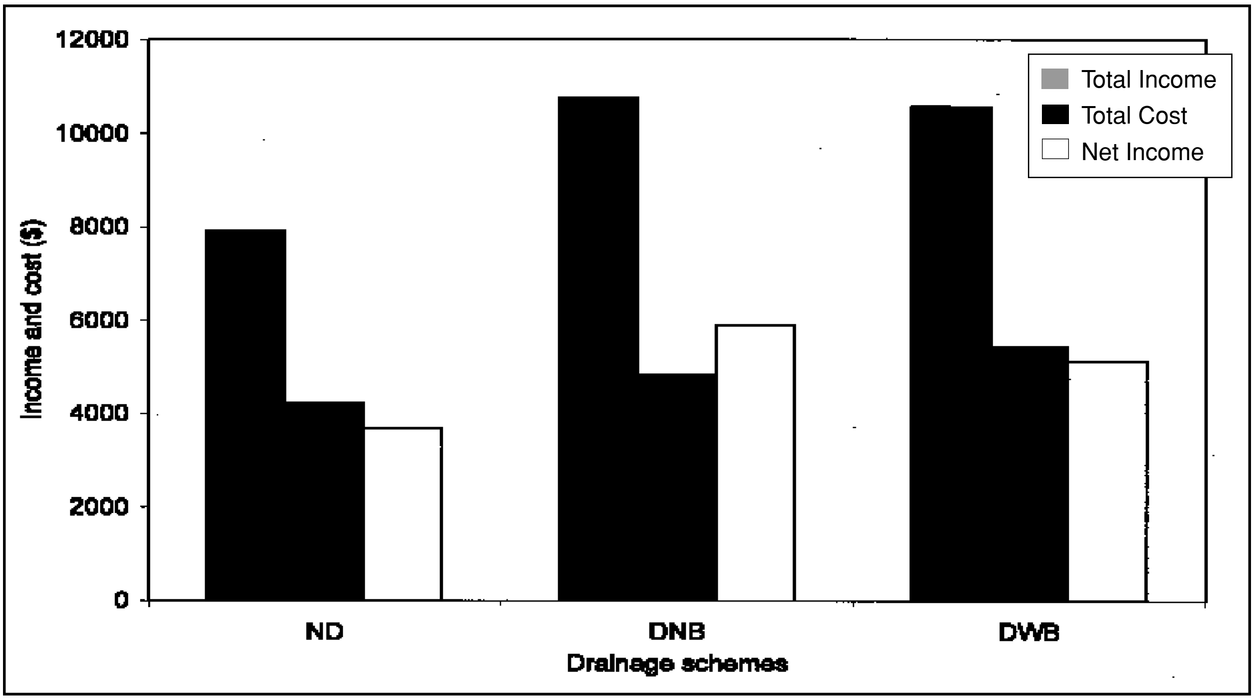

Figure 3. Income and costs for a new vineyard with different drainage-disposal schemes

In the DWB situation, the benefits of yield improvement due to watertable control outweighed the losses due to foregone production from land given to the basin area. The important components responsible for increased costs in DWB were cost of production, that is a function of crop yield and area, overhead expenses, saline disposal basin and subsurface drainage cost (Table 4).

Table 4.Effect of drainage/disposal systems on crop income and costs per ha per year

Items	Drainage/disposal systems		
	ND	DNB	DWB
Area of crop planted (ha)	40	40	37
Average yield (t)	11.32	15.35	15.09
Income (yield x price) $/ha	**7,924**	**10,745**	**10,563**
Fixed cost	1,027	1,027	1,055
Variable cost	1,936	2,246	2,263
Overheads	1,276	1,307	1,411
Subsurface drainage cost	0	257	257
Saline disposal basin cost	0	0	474
Total cost $/ha	**4,239**	**4,837**	**5,460**
Net income $/ha	**3,685**	**5,908**	**5,103**

The net income from crop production was highest in the DNB situation, followed by DWB and ND situations.

The magnitude of cost and income differences under different subsurface drainage/disposal systems is shown in Table 5.

Table 5.Income and cost difference for a new vineyard under different drainage/disposal systems

Difference between	Cultivated area (ha)	Yield (t/ha)	Cost ($/ha)	Net Income ($/ha)	Gross income ($)
NDand DNB	0 (0.0)	+4.03 (35.6)	+598 (14.1)	+2,223 (60.3)	+11,2840 (30.2)
ND and DWB	-3 (7.5)	+3.77 (33.3)	+1,221 (28.8)	+1,418 (38.5)	-73,871 (23.3)
DNB and DWB	-3 (7.5)	-0.26 (1.7)	+623 (12.9)	-805 (13.6)	-38,969 (9.1)

Figures in parentheses are the percentage change

The DNB situation was the most attractive in terms of net income where the returns were about 60% higher than the ND situation. This shows that losses due to waterlogging and soil salinisation under the ND situation are much higher than the cost of installing a subsurface drainage system, which is the reason most horticultural developments are drained. However, unrestricted disposal of subsurface drainage water in surface waters may no longer be an option in the future; a saline disposal basin may have to be constructed to store drainage water. The income and cost differences between ND and DWB indicated that the subsurface drainage system with a saline disposal basin is still a financially attractive proposition, as the returns are about 39% higher per ha than for ND. This is due to large cost increases (about 29%) for lost production from the land used for saline disposal basin and additional cost of saline disposal basin construction.

4.1.3 Financial analysis of drainage options for a new vineyard

The long term financial viability of any system is expressed by the performance of financial indicators, given that the assumed costs and yields do not change over time. Table 6 shows the performance of different subsurface drainage systems in terms of various financial indicators.

Table 6.Financial performance of drainage/disposal systems for a new vineyard

Evaluation criteria	Subsurface drainage/ disposal systems		
	ND	DNB	DWB
NPV ($000's)	542	1,338	899
BCR	1.25	1.54	1.35
BET (years)	10	8	8
NCF ($/ha)	3,690	5,908	5,103

The results shows that all the systems are financially attractive in the long run, as indicated by a Benefit-Cost Ratio (BCR) greater than 1 and a Net Present Value (NPV) greater than zero, a short Break Even Time (BET) and a positive average Net Cash Flow (NCF). The subsurface drainage system without a basin is the most financially attractive, followed by drainage with a basin and then no drainage. That drainage with a basin is more financially attractive than no drainage in the long run is due to the yield differential between the two systems being much higher then the cost differential.

The fluctuation in yield reflects the fluctuation in watertable due to variations in rainfall and thus crop yield. These fluctuations can have a significant impact on the financial attractiveness of a particular system, Figure 4.

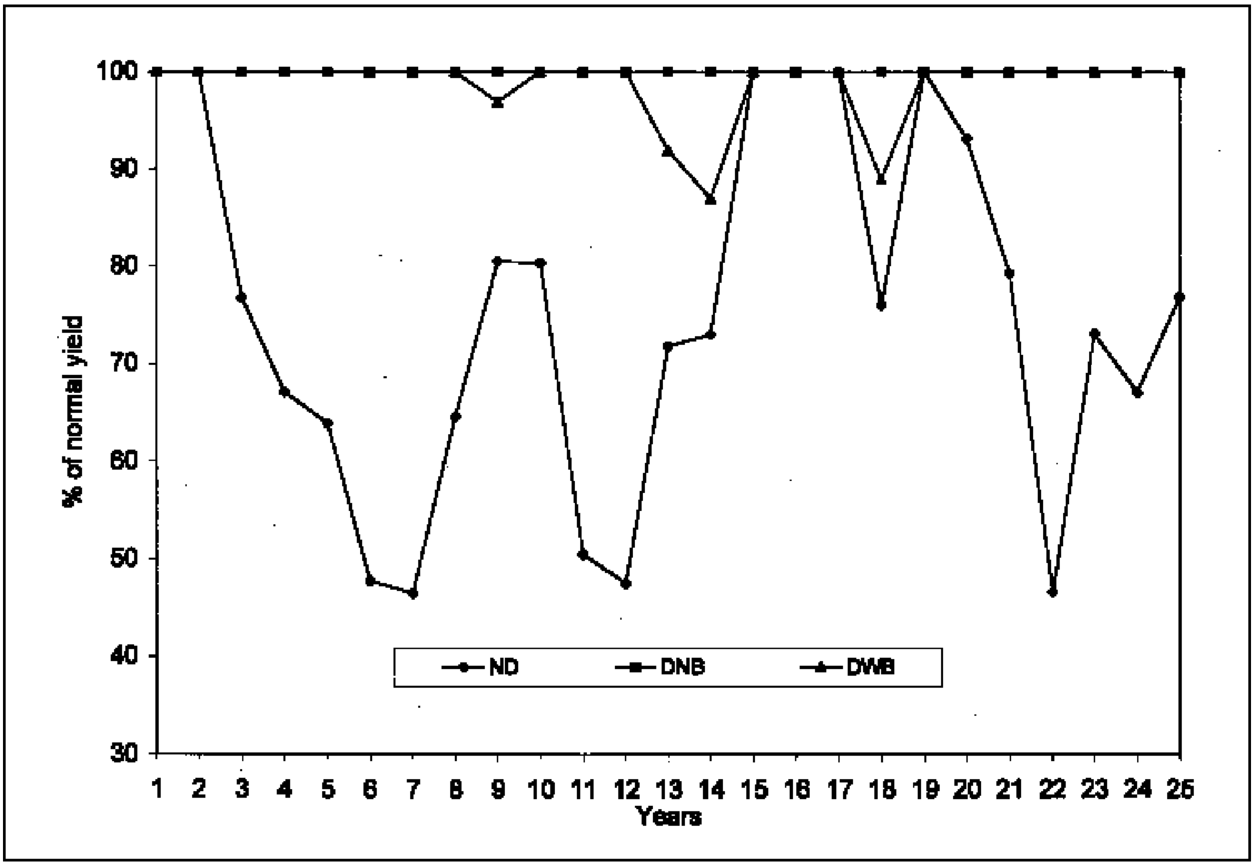

Figure 4. Relative yield for a new vineyard with different drainage-disposal schemes

The fluctuations in yield and hence annual net returns (NCF) were highest with ND, more stable with DWB and most stable under unrestricted drainage disposal (DNB), Figure 5.

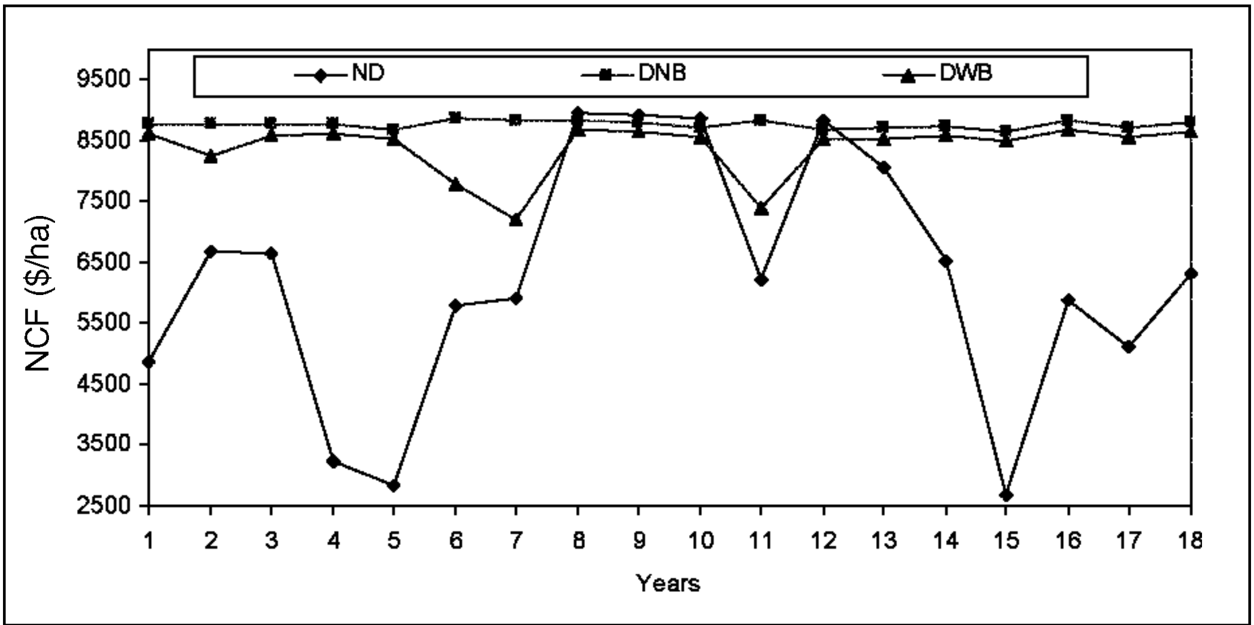

Figure 5. Annual Net Cash Flow for a new vineyard with different drainage-disposal schemes

The extent of variability in the annual Net Cash Flow (NCF) between different subsurface drainage/disposal systems can be shown as the Standard Deviation of the means of the annual NCF, Table 7.

Table 7.Standard deviation of NCF between different drainage-disposal systems in a new vineyard

Drainage/disposal systems	Standard Deviation ($/ha)
ND	2,012
DNB	63
DWB	443

For DNB there is very little variation in NCF, the standard deviation is only $63/ha, providing a very stable income. There is increased variation for DWB, as there are times when the basin is not large enough (7.5%) to control waterlogging completely. This tends to occur in periods of low evaporation and high rainfall. However, DWB has a much smaller standard deviation in annual NCF than ND, the stability of income with DWB is probably adequate for planning and investment.

4.1.4 Alternative irrigation methods

When considering subsurface drainage and the use of a saline disposal basin, it may be possible that using a highly controlled irrigation system (such as drip) may provide a long-term alternative to subsurface drainage. In this analysis, DWB was compared to the installation of a drip irrigation system, using costs from Moll and Christen (1996). It was assumed that with suitable site selection and management the drip irrigated vineyard would not require drainage; however, for comparison, a situation where the drip irrigation system had subsurface drainage and a disposal basin was also included. This was a 3% basin area as compared to 7.5% basin for furrow irrigation, Table 8.

Table 8.Financial viability of controlled irrigation compared to subsurface drainage

Evaluation criteria	Irrigation and subsurface drainage/disposal system			
	Furrow		Drip	
	DNB	DWB	ND	DWB
Total Cost ($/ha)	5,700	6,600	4,100	7,200
BCR	1.54	1.35	1.63	1.43
NPV ($000's)	1,338	899	1,451	1,088

Drip irrigation without drainage is the most attractive option, but this relies on the assumption that drip irrigation requires no subsurface drainage, and requires careful site selection to avoid groundwater inflows from outside the farm. However, drip irrigation is still viable when combined with a subsurface drainage system and a basin about half the area required with furrow irrigation. This option has a financial performance slightly better than that of furrow irrigation with drainage and a basin.

These results do not include any additional benefits that may accrue from the use of drip irrigation in terms of improved wine grape quality.

4.2 Analysis of Physical and Economic Factors Affecting the Successful Use of Subsurface Drainage With a Saline Disposal Basin

Analysis was carried out to examine the financial performance of various subsurface drainage systems in order to identify crucial factors for successful use of a subsurface drainage system with a saline disposal basin. The financial attractiveness was examined by considering the following factors:

4.2.1 Farm size

4.2.2 Crop price

4.2.3 Crop yield

4.2.4 Land value

4.2.5 Basin depth

4.2.6 Irrigation efficiency

4.2.7 New and existing horticultural development

4.2.8 Crop sensitivity to waterlogging

For the above analyses a 40ha vineyard is used, other parameters are given in Table 2.

4.2.1 Farm size

Farm size has a considerable impact on the financial attractiveness of a drainage system for a new development, Table 9.

Table 9 Financial performance of drainage/disposal systems for different farm sizes

Evaluation criteria	Systems	Farm size (ha)					
		10	20	40	60	80	100
BC Ratio	DNB	0.82	1.2	1.54	1.71	1.81	1.87
	DWB	0.73	1.05	1.35	1.49	1.58	1.63
NPV ($000's)	DNB	-205	312	1,338	2,365	3,391	4,416
	DWB	-327	83	899	1,709	2,524	3,340
BET (Years)	DNB	16	10	8	7	7	7
	DWB	22	11	8	8	7	7
Annual NCF ($/ha)	DNB	1,737	4,525	5,908	6,372	6,603	6,740
	DWB	504	3,574	5,103	5,609	5,864	6,018

The analysis shows that the financial attractiveness of all the subsurface drainage systems improves considerably with increasing farm size, however the rate of increase declines as farm size increases. The main reason behind such a trend could be that, with increasing farm size, all the capital assets created are fully utilised, and due to greater economies of scale associated with larger farm size results in greater financial performance of the farm enterprise. It can be seen from Table 10 that a subsurface drainage system, with or without a basin, becomes financially unattractive for farms less than 20ha. For farms less than 20ha, every unit decrease in farm size decreases the profitability of the system by about 4% for DNB, and by about 8% for DWB. Every unit increase in farm size between 20 and 40ha increases the profitability of DNB by 1.7% and 1.5% for DWB. Above 40ha, this rate declines to about 0.9% for DNB and 0.7% for DWB, Figure 6.

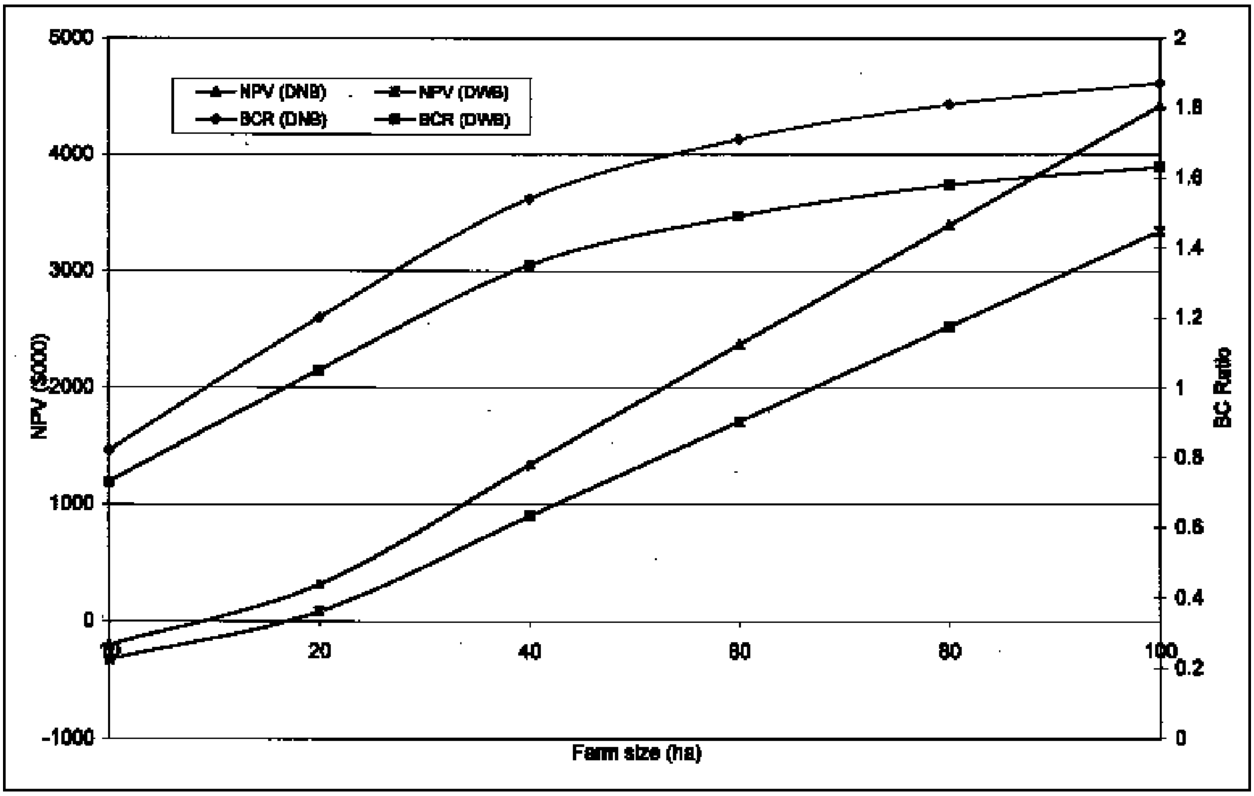

Figure 6.Effect of farm size on financial attractiveness of drainage-disposal schemes

Drainage/disposal is financially more attractive in larger farms as the per unit cost decreases with the size of farm. Table 10 shows the pattern of income and cost changes with different farm sizes having subsurface drainage with a saline disposal basin (DWB).

Table 10.Effect of farm size on farm income and cost per ha for a new vineyard (DWB)

Income and cost ($/ha)	**Farm size (ha)**					
	10	20	40	60	80	100
Area of crop planted (ha)	9.25	18.5	37	55.5	74	92.5
Basin area (ha)	0.75	1.5	3	4.5	6	7.5
Average yield (t/ha)	15.09	15.09	15.09	15.09	15.09	15.09
Total income per ha	**10,563**	**10,563**	**10,563**	**10,563**	**10,563**	**10,563**
Costs per ha Machinery and Equipment	1,536	768	383	256	192	153
Trellising	228	228	228	228	228	228
Vine establishment	127	127	127	127	127	127
Vine maintenance	317	317	317	317	317	317
Crop production	2,263	2,263	2,263	2,263	2,263	2,263
Overheads	4,716	2,506	1,411	1,049	867	758
Subsurface drainage costs	331	282	257	249	245	243
Saline disposal basin	549	503	474	468	462	458
Total cost per ha	**10,067**	**6,994**	**5,460**	**4,957**	**4,701**	**4,547**
Net income	**496**	**3,569**	**5,103**	**5,606**	**5,862**	**6,016**

The cost of capital assets and overhead expenses on a 20ha farm constituted about 47% of the total cost, which reduced to about 20% when the farm size increased to 100ha. Therefore, it is important to consider the farm size before opting for a subsurface drainage/disposal system. For a small farm it may be necessary to consider other options, such as draining in to a community basin and paying a fee on per ML of drainage water or discharging into surface waters and paying a penalty.

4.2.2 Crop price

Table 11 shows that crop price has a considerable impact on the financial attractiveness of a subsurface drainage system. The profitability of drainage with no basin changes at a rate of 1.6% per unit change in price; the rate of change for DWB was about 1.4%. The DNB scenario becomes unattractive when about a 40% decline in crop price occurs, whereas the DWB scenario becomes marginal with only a 20% decrease in crop price.

Table 11.Effect of crop price on financial attractiveness (farm size and yield constant)

Financial criteria	Drainage system	% change in price (base price $700/tonne)				
		-40	-20	0	+20	+40
BC Ratio	DNB	0.92	1.23	1.54	1.86	2.17
	DWB	0.81	1.08	1.35	1.62	1.90
NPV ($000)	DNB	-193	574	1,338	2,103	2,866
	DWB	-500	202	899	1,595	2,291
BET (years)	DNB	13	9	8	7	6
	DWB	17	11	8	7	7
Annual NCF ($/ha)	DNB	1,595	3,754	5,908	8,066	10,220
	DWB	855	2984	5103	7223	9343

4.2.3 Crop yield

The subsurface drainage systems were less sensitive to change in yield than change in price. This is because price changes have an impact on gross income only, whereas a yield change affects both income and costs. Table 12 shows that DNB can sustain a yield loss of up to 40%, whereas DWB becomes financially unattractive when the yield decline is slightly more than 20%.

Table 12.Crop yield effects on the financial attractiveness of drainage/disposal systems

Financial criteria	Drainage System	% change in average yield				
		-40	-20	0	+20	+40
BC ratio	DNB	1.00	1.28	1.54	1.79	2.03
	DWB	0.86	1.12	1.35	1.58	1.79
NPV ($000)	DNB	-8	673	1,338	2,013	2,687
	DWB	-331	293	899	1,513	2,127
BET (years)	DNB	12	9	8	7	6
	DWB	15	10	8	7	7
Annual NCF ($/ha)	DNB	2,097	4,025	5,908	7,821	9,732
	DWB	1,319	3,232	5,103	6,983	8,862

The cost of crop production increases with increase in yield, due to increases in costs of crop harvesting and levies associated with marketing. Table 13 shows the effects of yield change on crops' income and cost.

Table 13 Financial attractiveness of drainage/disposal systems under changed crop yield of new vines

Income and cost ($/ha)	% change yield (base yield = 15.09 t/ha)				
	-40	-20	0	+20	+40
Average yield (t/ha)	9.05	12.10	15.09	18.11	21.11
Total income	6,335	8,470	10,563	12,677	14,777
Costs					
Total crop production cost	4,285	4,507	4,729	4,963	5,184
Subsurface drainage cost	257	257	257	257	257
Saline disposal basin cost	474	474	474	474	474
Total cost per ha	5,016	5,238	5,460	5,694	5,915
Net income per ha	1,319	3,232	5,103	6,983	8,862

The rate of increase in income is higher than the rate of change in cost. This shows that the higher the crop yields, the more attractive will be the installation of a subsurface drainage basin system. The subsurface drainage system with basin is financially attractive over a wide range of yield levels, which is due to the crop price. This scenario is a new vineyard development; the DWB system is expected to generate higher returns under existing vines due to higher yields and less capital cost, as establishment costs are not incurred.

4.2.4 Land value

A sensitivity analysis of a 40ha new vineyard with a 7.5% saline disposal basin was undertaken by varying the land value from zero to $5000/ha, Table 14.

Table 14.Effect of land value on financial viability of drainage disposal systems

Land value ($/ha)	NPV ($000's)	BCR
0	1,070	1.45
1,000	1,036	1.43
2,000	1,002	1.41
3,000	967	1.39
4,000	933	1.37
5,000	899	1.35

The NPV and BCR decrease as the cost of land increases. However, the DWB option remains financially viable even at a land value of $5000/ha.

To examine the financial advantages of the DNB scenario, a simple analysis was undertaken by assuming a cost per ha to the farm for drainage disposal. This found that the DNB scenario comes into parity with DWB scenario when the farm incurs a drainage cost of about $300/ha, when the land for a saline disposal basin has zero value. Whereas, when the cost of land for saline disposal basin to the farm is $5000/ha, the equivalent drainage charge in the DNB scenario is about $500/ha.

4.2.5 Basin depth

Basins function on the basis of evaporation, which relies upon the area of water surface; however increasing the bank height and hence storage volume may be useful in critical periods e.g. high rainfall. To investigate the benefits of increasing bank height, a range of bank heights from 0.7 to 1.5m were modeled for impacts on costs and yields, Table 15.

Table 15.Effect of bank height on the financial viability of a subsurface drainage disposal system

Bank height (m)	NPV ($000's)	BCR	BET (yrs)	NCF ($/ha)
0.7	905	1.35	8	5,113
0.9	901	1.35	8	5,107
1.1	886	1.35	8	5,100
1.3	890	1.35	9	5,092
1.5	883	1.34	9	5,083

The financial viability of subsurface drainage with a saline disposal basin decreases with increase in bank height. The long term modeling showed that there was only a 1% increase in grape yield by increasing bank height from 0.7 to 1.5m. This is because saline disposal basins function by evaporation, not storage. In this scenario, with a 7.5% basin area, only 1mm of drainage from the farm will raise the water level in the basin 13mm. This means that bank height has little effect on the long-term capacity of a basin to take drainage water.

4.2.6 Irrigation efficiency

The cost of subsurface drainage/disposal systems is largely determined by the amount of water a system handles. Under inefficient irrigation management (applying more water than needed, here taken as 120% of evapotranspiration), there are several consequences; increased cost of water, more recharge to ground water and consequent rise in watertable and crop yield decline, which impacts on the financial viability of a basin, Table 16.

Table 16.Effect of irrigation efficiency on the financial attractiveness of drainage/ disposal

Criteria	DNB		DWB	
	Efficient (110% of ET-R)	Inefficient (120% of ET-R)	Efficient (110% of ET-R)	Inefficient (120% of ET-R)
Average yield (t/ha)	15.35	15.35	15.09	14.70
BCR	1.54	1.54	1.35	1.32
NPV ($000's)	1,338	1,333	899	820
BET (years)	8	8	8	9
Annual NCF ($/ha)	5,908	5,899	5,103	4,853
Costs ($/ha)				
Fixed cost	1,027	1,027	1,055	1,055
Crop production expenses	2,246	2,257	2,263	2,243
Overhead expenses	1,307	1,307	1,411	1,411
Subsurface drainage cost	257	257	257	257
Saline disposal basin cost	0	0	474	474
Total cost ($/ha)	**4,837**	**4,848**	**5,460**	**5,440**

The results show that where there is unrestricted disposal of drainage water (DNB) there is no increase in watertables and so no yield decline. Any rise in watertable is controlled by the subsurface drains and pumped into the surface system. The cost of additional pumping of drainage water was assumed to be negligible and is not included in the present analysis. However, the additional cost of irrigation water is considered in the crop production cost.

For the subsurface drainage system with a 7.5% basin (DWB), the rising watertable resulted in about a 4% decline in average yield and about 5% decline in net cash flow. The BCR value declined by about 2%. The Net Present Value declined by about 9% and the development required an additional year for cost recovery, which means additional interest to be paid on the cumulative deficit. These effects would be more marked in a more waterlogging sensitive crop such as citrus. In this analysis the comparison was between irrigation at 110 and 120% greater than ET-R, a relatively small difference. The starting point of irrigation efficiency on flood irrigated farms is often low (>120%), however design and economic analysis at very low levels of irrigation efficiency is unrealistic. This is because farmers will adjust their irrigation practices to meet the drainage constraint of an evaporation basin. Thus analysis at levels of irrigation at 110 to 120% of ET-R for the long term is more acceptable.

4.2.7 New or existing horticultural developments

Whether the drainage-disposal system is installed in a new or existing horticultural development has an impact on the profitability of any subsurface drainage system. Table 17 shows that the financial attractiveness of DWB is greater in existing developments. The income under existing developments increases by more than 20%, whereas total cost was about 13% less than for a new horticultural development. The profitability of drainage disposal was more than double for existing developments, which strengthens the scope for adopting subsurface drainage with basin as an effective strategy for controlling watertable and improving crop yields on existing vines which do not have a drainage system already installed.

Table 17 Financial attractiveness of drainage/ disposal system for new and existing plantings

Criteria	Planting	
	New	Existing
Average yield (t/ha)	15.09	18.13
Total income ($/ha)	10,563	12,691
BC Ratio	1.35	2.54
NPV ($000's)	899	3,038
BET (years)	8	0
Annual NCF ($/ha)	5,103	7,888
Costs ($/ha)		
Fixed cost	1,055	514
Crop production expenses	2,263	2,373
Overhead expenses	1,411	1,121
Subsurface drainage cost	257	257
Saline disposal basin cost	474	485
Total cost ($/ha)	**5,460**	**4,750**

4.2.8 Crop sensitivity to waterlogging

The analysis was also conducted for citrus, a more waterlogging sensitive crop than grapevines, Table 18.

Table 18.Financial attractiveness of drainage/disposal system for citrus

Criteria	Developmental phase			
	New citrus		Existing citrus	
	DNB	DWB	DNB	DWB
Average yield (t/ha)	36	32	52	46
Total income ($/ha)	10,800	9,537	15,636	13,935
Total cost ($/ha)	6,489	6,741	9,130	9,286
BC Ratio	1.32	1.08	1.80	1.58
NPV ($000's)	797	201	2,773	1,908
BET (years)	10	13	0	0
NCF ($/ha)	4,311	2,795	6,506	4,649

The financial criteria indicate that DNB is a viable proposition for both new and existing citrus plantings. However, DWB makes a new citrus planting quite marginal. It should be noted that, under the scenarios modeled here, citrus without any drainage was completely unviable. DWB, was viable for existing plantings which indicates that citrus enterprises may be able to afford to use evaporation basins in situations where the crop and farm has been established.

4.3 Optimising basin area

To choose the most financially attractive basin area a number of physical, financial and economic indicators for different basin areas were analysed for a new vineyard.

4.3.1 Waterlogging and crop yield

The relative yield and waterlogging control under different drainage systems are given in Table 19 and Figure 7.

Table 19.Effect of drainage systems on crop yield and watertable control in new vines

Saline disposal basin area (% of farm area)	Average yield (t/ha)	% of potential yield*	% of time when basin is empty
2.5	13.9	91	14
5	14.7	96	18
7.5	15.1	98	38
10	15.3	99	46

** potential average yield for MIA taken as 15.4 t/ha*

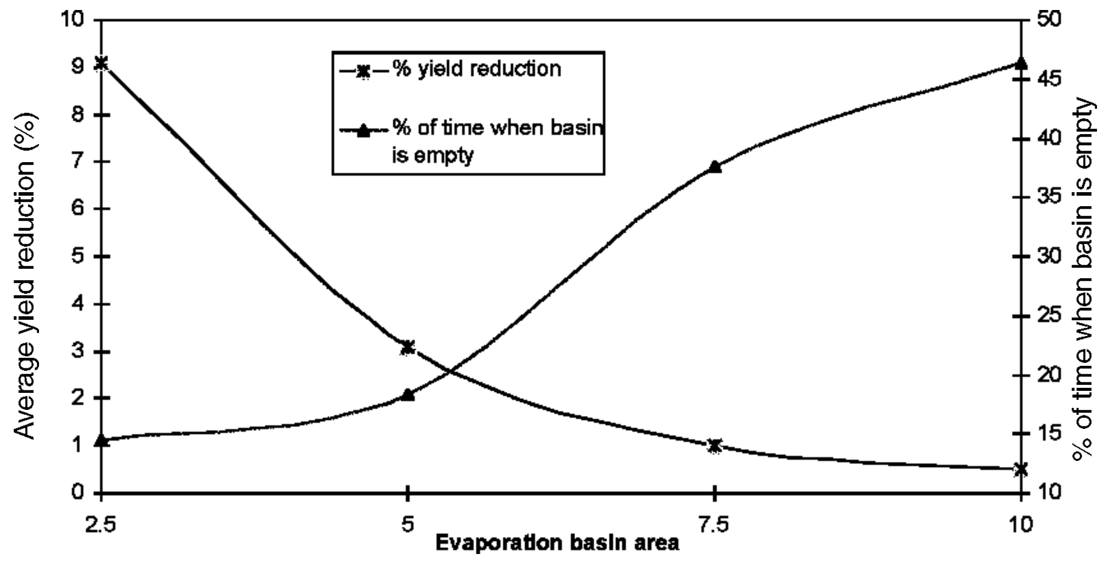

Figure 7. Waterlogging and yield relationship for vineyard with subsurface drainage and saline drainage disposal basin

There is a considerable improvement in crop yield as a result of increasing basin size. A yield increase of about 5% was achieved when basin size was increased from 2.5 to 5% of the farm area; the increase in yield with further increases in basin size to 7.5 and 10% was 2% and 1%, respectively. The yield under a 10% basin area was quite close to potential yield and hence can be said to be the physically optimal area. However, this may not be financially optimal, as this increase in yield may not outweigh the increase in costs and lost production from land used for the saline disposal basin. The optimal basin area is where the benefits due to reduced waterlogging are not outweighed by the loss in production due to the basin area. This means that basin should not be too large as this is not cost effective. A simple measure of this is the percentage of time when the basin is empty. The improvement in waterlogging was not great up to a 5% basin size, however, when the basin size was increased to 7.5% waterlogging reduced considerably; however, the percentage of time when the basin was empty doubled. This analysis of the purely physical data indicates that the best basin area may be between 5 and 7.5% for a new vineyard in the MIA.

4.3.2 Net Present Value, Benefit Cost ratio and Break Even Time

For the four basin areas, the results from Table 20 and Figure 8 show that a 5% basin area has the highest Net Present Value followed by a 7.5% basin area. This indicates that for grapevines an optimal basin area in the MIA would be between 5 and 7.5% of drained area. Smaller areas would incur excessive waterlogging losses and larger areas had too large an annual penalty in loss of cropped area.

Table 20.Financial attractiveness of drainage with different saline disposal basin areas

Criteria	Basin area (% of farm area)			
	2.5	5	7.5	10
NPV ($000's)	853	968	899	807
BC Ratio	1.35	1.38	1.35	1.31
BET (years)	9	8	8	9

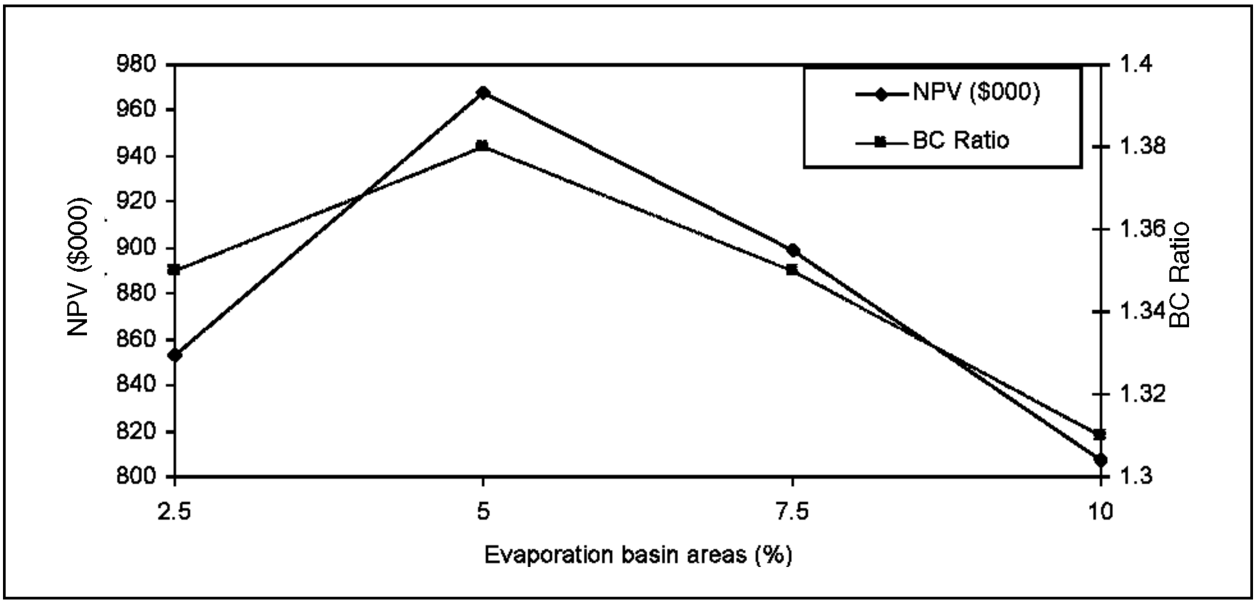

Figure 8.Basin area and financial attractiveness of a new vineyard

The Benefit Cost Ratios also indicate that the subsurface drainage system with 5% basin area is the financially most attractive, the 2.5 and 7.5 % basin areas had the same (lower) BC Ratio. A comparison between 2.5 and 7.5% basin areas showed the additional cost of lost production from a 7.5% basin area is compensated for by an improvement in the crop yield. The 7.5% area is also more attractive than a 2.5% area in terms of higher NPV and lower BET.

A comparison between drainage without a basin and with different basin areas, Figure 9, shows that the 5 and 7.5% areas are closest to the no basin situation. This trend also supports 5 to 7.5% basin areas as being the most financially attractive.

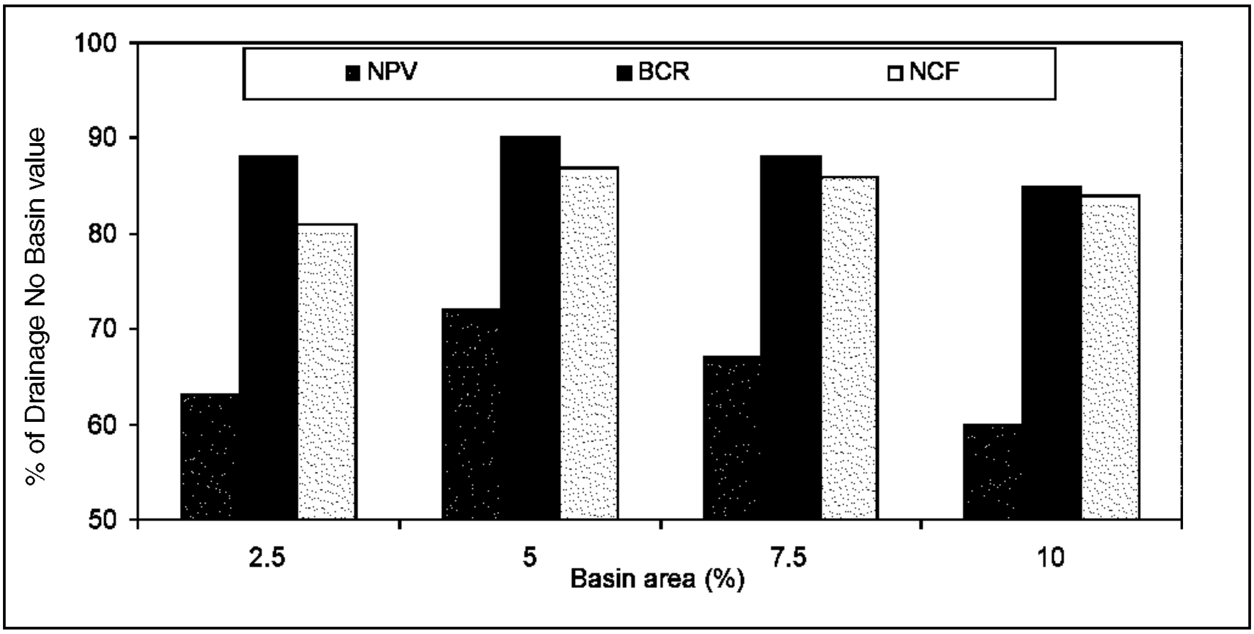

Figure 9 Comparison of DWB against DNB for various basin areas

4.3.3 Annual Net Cash Flow

Annual net cash flow (ANCF) analysis for the four different basin areas is shown in Table 21.

Table 21.Effect of basin size on annual cash flow for new vines

Basin area (%)	Annual Net Cash Flow ($/ha)	
	Mean	Standard Deviation
2.5	4,807	683
5	5,125	545
7.5	5,103	442
10	4,970	240

The drainage system with a basin area of 5 and 7.5% had the highest average ANCF indicating the most attractive basin sizes. The difference between the means of these two sizes was only 0.4%. Net Cash Flows in Figure 10 show that a 5% basin area had large variations up to 50%, due to yield depression in wet years.

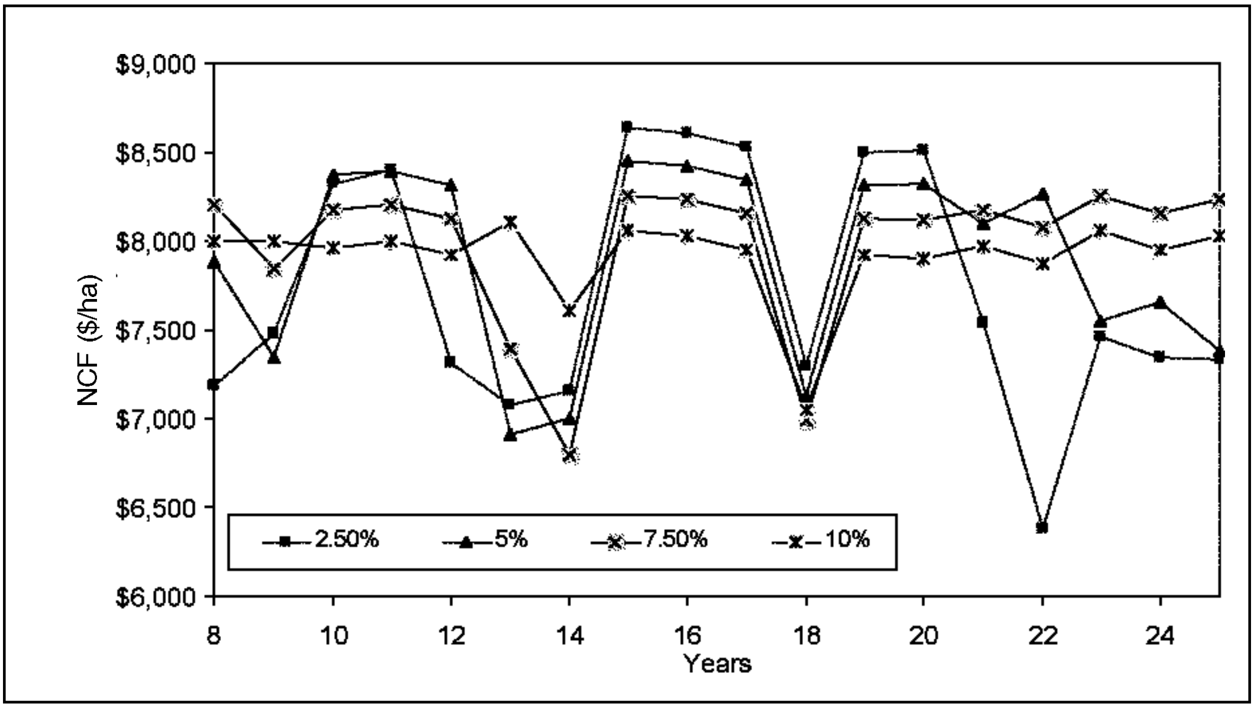

Figure 10.Annual net cash flow for different basin areas

These fluctuations were considerably reduced when basin size was increased to 7.5%. However, a steady ANCF is only achieved with a 10% basin area, as indicated by the lowest standard deviation, but there was still a dramatic reduction in ANCF for one year. Figure 11 shows that a 7.5% basin area gives reasonably steady state annual Net Cash Flow for a new vineyard development; this would be most financially attractive in the long run.

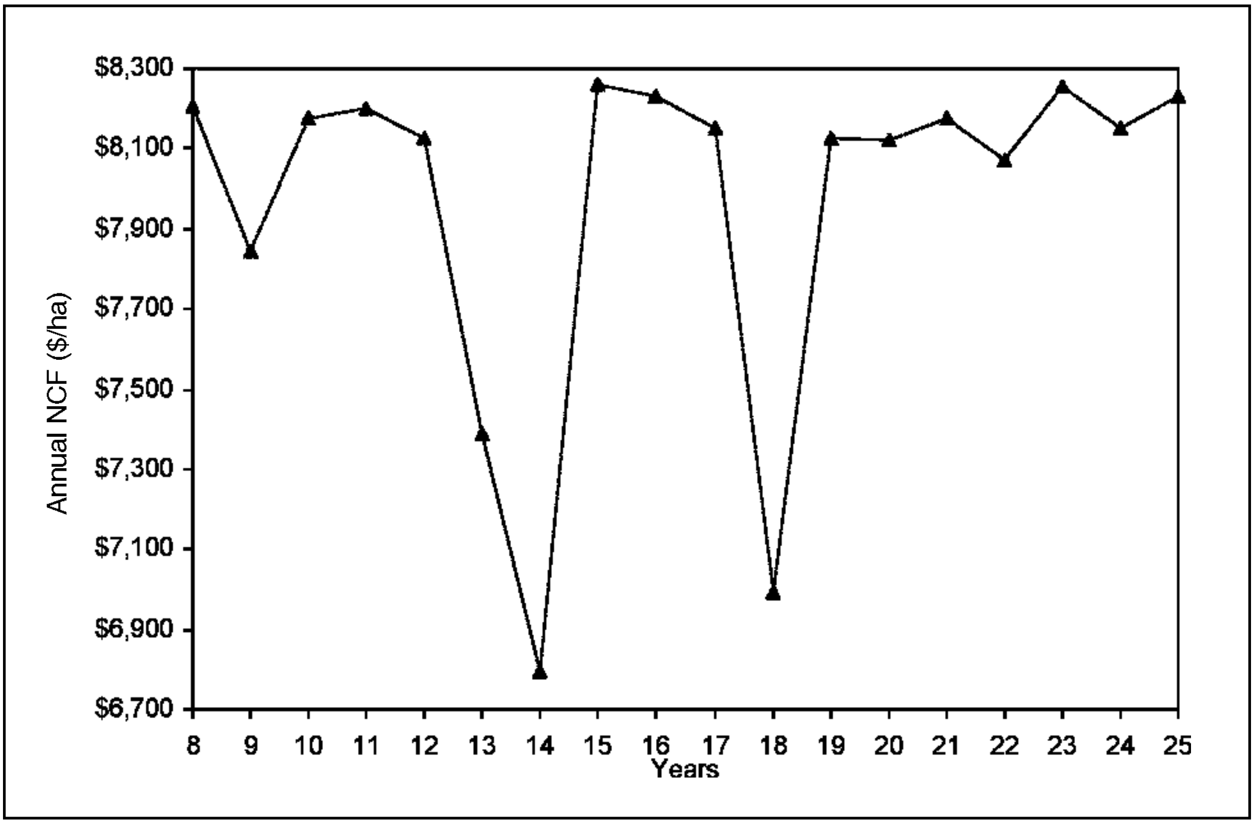

Figure 11.Annual net cash flow for a new vineyard with 7.5% basin area

4.3.4 Marginal costs and returns

The optimal basin area may be determined using the principle of marginal returns (Doll and Orazem, 1984). This principle states that the investment should be increased up to the point where every additional increase in income per unit increase in output (MR/output price) is equal to or greater than every additional increase in cost (MC) per unit increase in output.

Table 22 shows that, when the basin size increases from 2.5 to 5%, the additional returns are more than double the cost, but when the basin size is further increased to 7.5% the marginal cost becomes higher than the marginal returns (price of output). This shows that increasing basin area beyond 7.5% would add more to the cost than to the revenue. On the basis of this analysis, a basin area between 5 to 7.5% of the drained area would be optimal.

Table 22.Marginal costs and returns for different basin areas in new vineyard

Basin area (%)	Average yield (t/ha)	Total Revenue ($/ha)	Total cost ($/ha)	Profit (TR-TC) ($/ha)	MC* (dTR/dy) ($/t)
2.5	13.9	9,758	4,951	4,807	0
5	14.8	10,346	5,221	5,125	321
7.5	15.1	10,563	5,460	5,103	770
10	15.3	10,675	5,706	4,969	1,537

**marginal return (Py) is $700/t*

Figure 12 shows that the economic optimum yield in a new vineyard is about 15t per ha. This optimum yield corresponds to the average yield obtained from about a 7.5% saline disposal basin area.

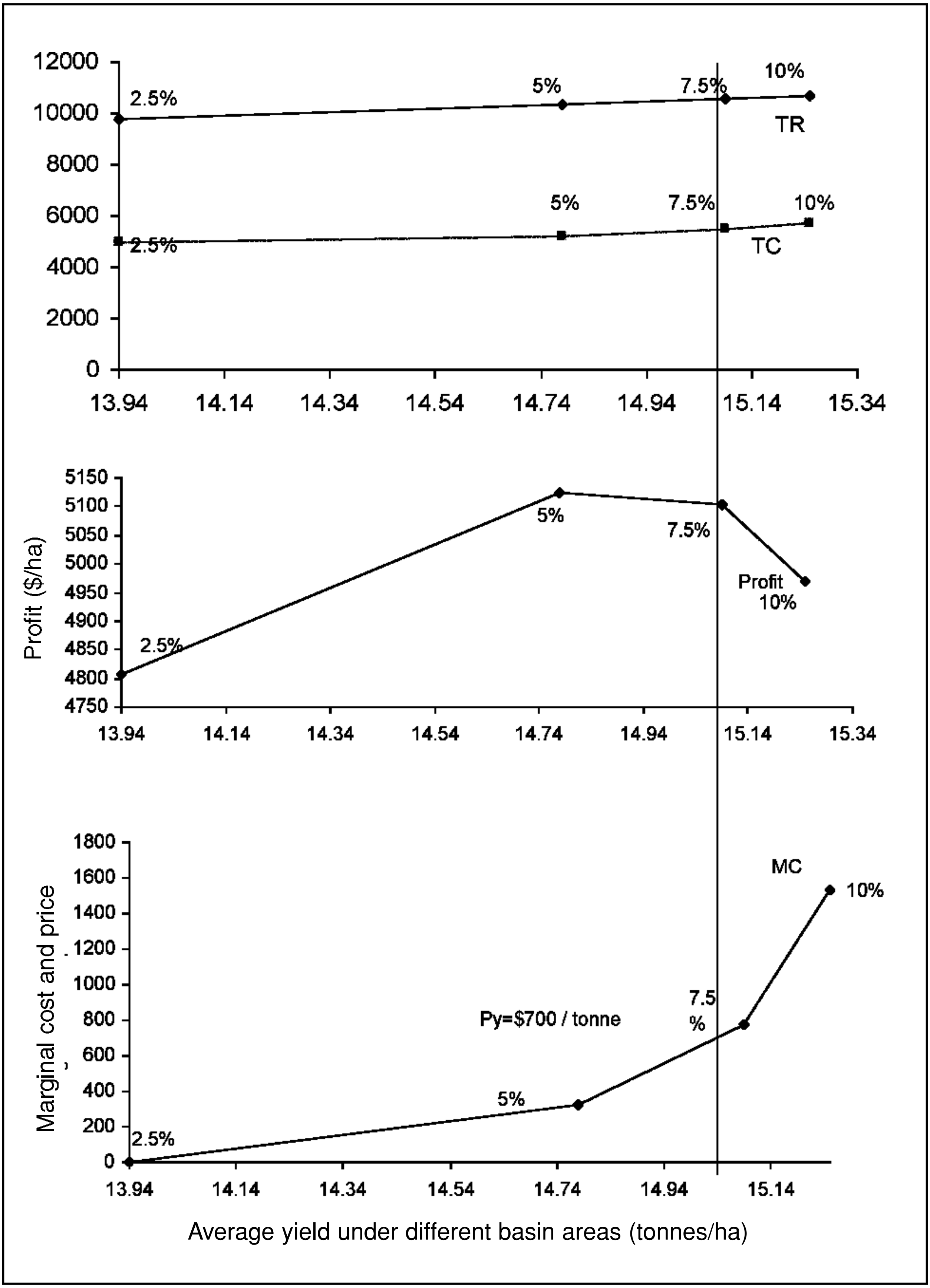

Figure 12.Optimum basin area for new vineyard

4.4 Scenario analysis - existing plantings, citrus

The financial attractiveness of a drainage system with a particular basin area may vary according to changes in various factors such as stage of crop development i.e. new versus existing horticultural developments and crop choice i.e. less sensitive versus more sensitive to waterlogging. Therefore it is important to determine whether the results from previous sections (indicating that a 7.5% basin area is optimal) remain valid when the farm/development conditions are changed.

4.4.1 Crop development

The performance of various physical and financial criteria shows that a drainage/disposal system is more financially attractive in an existing vineyard situation, Table 23.

Table 23.Financial attractiveness of the best basin area in existing vines

Income and cost	Basin area (% of farm area)			
	2.5	5	7.5	10
Average yield (t/ha)	16.7	17.7	18.0	18.2
Total income	11,683	12,411	12,635	12,754
Total cost ($/ha)	4,441	4,591	4,751	4,991
NPV ($000's)	2,946	3,152	3,038	2,886
BCR	2.55	2.64	2.54	2.43
Annual NCF ($/ha)	7,242	7,820*	7,884	7,763

** significantly different at 5% probability from value of immediately lower basin area*

Crop yields were significantly improved when the basin area was increased from 5 to 7.5% with an existing farm size of 40ha. The other financial criteria indicated that the profitability was approximately double for existing vines than for a new vineyard development. The 5% basin area is the most financially attractive in terms of highest BCR and NPV. However, the average yield is significantly higher with a 7.5% basin area, and highest with a 10% basin area (but not significantly different from the 7.5% basin area). The NCF was highest with a 7.5% basin area, but not significantly different from a 5% basin area.

The fluctuations in the annual NCF in Figure 13 show that with a 7.5% basin area, the fluctuations are reduced considerably as compared to a 5% basin area. None of the basin areas could control the fluctuations fully, although a 10% basin area has the most stable annual NCF. It can therefore be concluded that basin areas of 5 to 7.5% are also financially viable for an existing vineyard in the MIA.

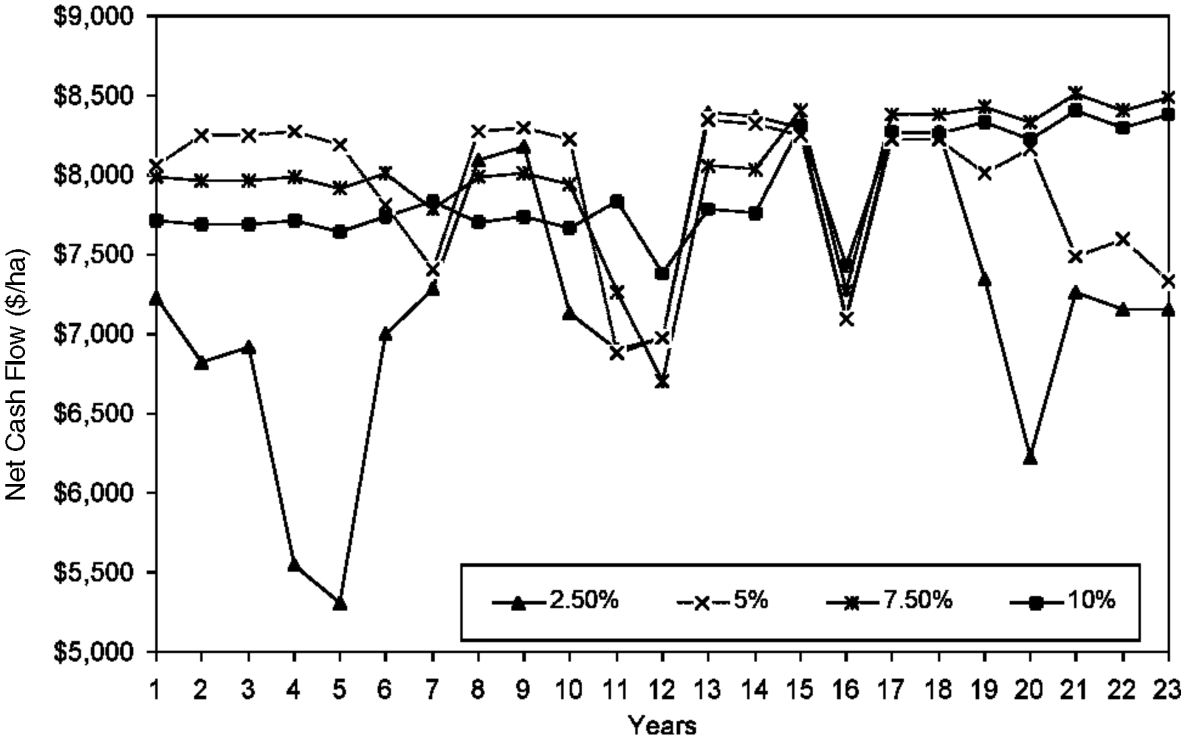

Figure 13.Annual net cash flow for an existing vineyard with different basin areas

Table 24 shows that the marginal cost equates to the marginal revenue (Py) when the basin area is more than 7.5%, but less than 10.

Table 24 Marginal costs and returns for an existing vineyard with different basin areas

Basin area (%)	Average yield (t/ha)	Total Revenue ($/ha)	Total Cost ($/ha)	Profit (TR-TC) ($/ha)	MC ($\partial TR/\partial Y$) ($/ha)	MR (P_y) ($/t)
2.5	16.7	11,683	441	7,242	0	700
5	17.7	12,411	4,591	7,820	144	700
7.5	18.0	12,635	4,751	7,884	500	700
10	18.2	12,754	4,991	7,763	1,411	700

Figure 14 shows that the marginal returns are greater than the marginal cost up to an average yield of about 18.1t per ha, which corresponds to a disposal basin area of about 8% of farm area. A basin area of 5% is not optimal as the profits are increasing. Therefore a disposal basin area of 7.5% of farm area would be optimal in an existing vineyard development, the same result as for a new vineyard.

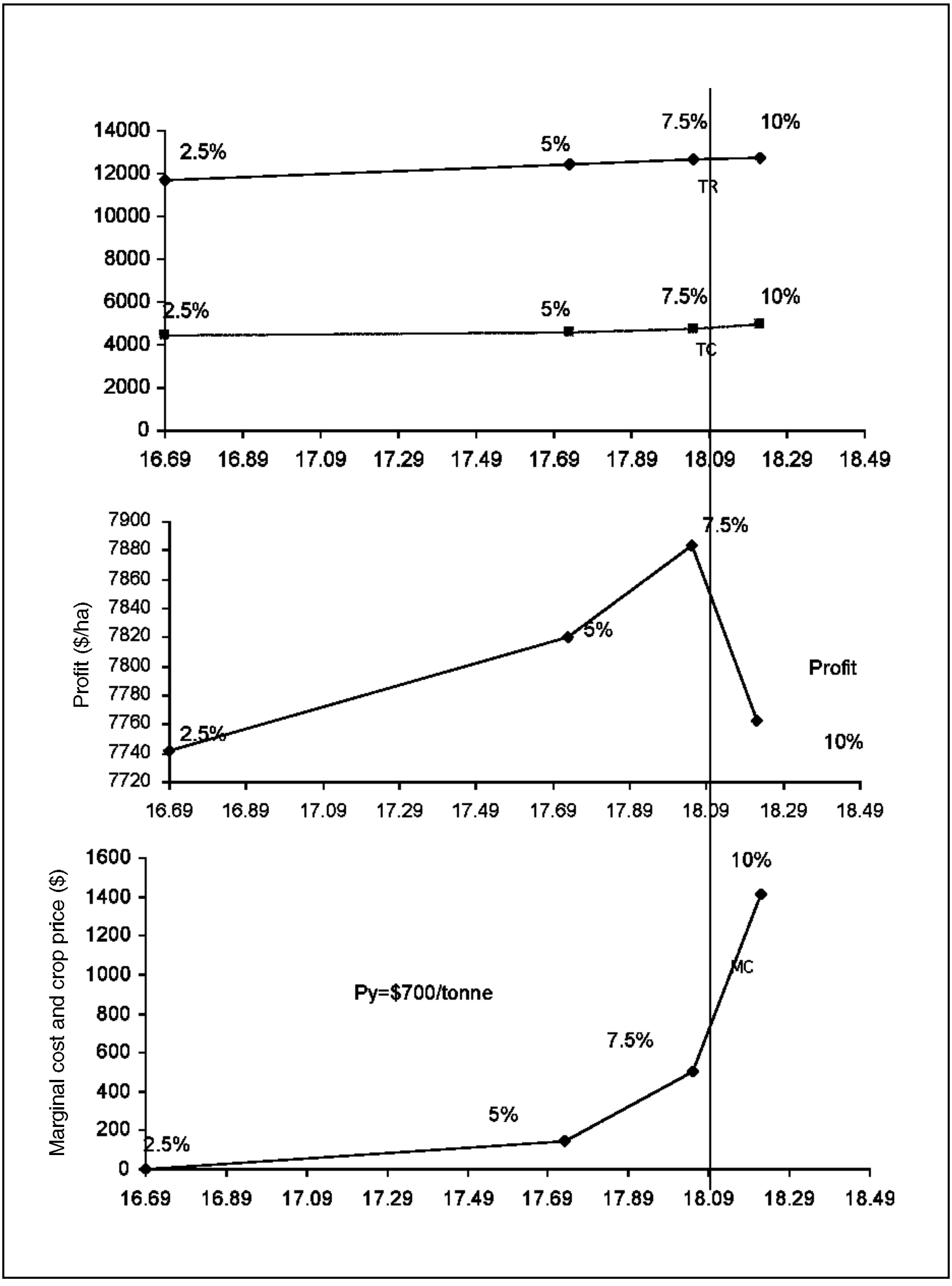

Figure 14.Optimum basin area for existing vineyard

4.4.2 Crop choice

The analysis of subsurface drainage systems with different basin areas in citrus (a more waterlogging sensitive than grapevines) showed that subsurface drainage has a significant impact on crop yields (Table 25).

Table 25.Financial attractiveness of drainage with basin in new and existing citrus

Financial Indications	Planting	Basin area (% of farm area)				
		2.5	5	7.5	10	12.5
Average yield (t/ha)	New	4.4	9.2	31.8	34.8	35.6
	Existing	8.3	15.9	46.4*	50.4*	51.4
NPV ($000's)	New	-1,846	-1,503	201	342	301
	Existing	-1,655	-766	1,908	2,062	1,978
BCR	New	0.17	0.34	1.08	1.13	1.12
	Existing	0.43	0.74	1.58	1.61	1.58
BET (years)	New	25	25	13	12	12
	Existing	25	25	0	0	0
Annual NCF ($/ha)	New	-4,314	-3,180	2,795*	3,359	3,362
	Existing	-5,470	-3,383	4,649*	5,345	5,335

*significantly different at 5% probability levels from value of lower basin area

The yield improvements were significant when the basin size was increased from 5 to 7.5% of farm area. The yields were highest with a 12.5% basin area in both new as well as existing developments. The systems were financially unattractive with a basin area below 5% for both new and existing citrus. The profitability of each basin size shows that in citrus a 10% basin area is financially most attractive having the highest NPV, BCR and lowest Break Even Time.

The fluctuation in the annual NCF in new and existing citrus (Figures 15 and 16) shows that the annual NCF for a 10 and 12.5% basin area remained higher than a basin area of 7.5% with both types of citrus development. The fluctuations in the annual NCF were well controlled with these basin areas.

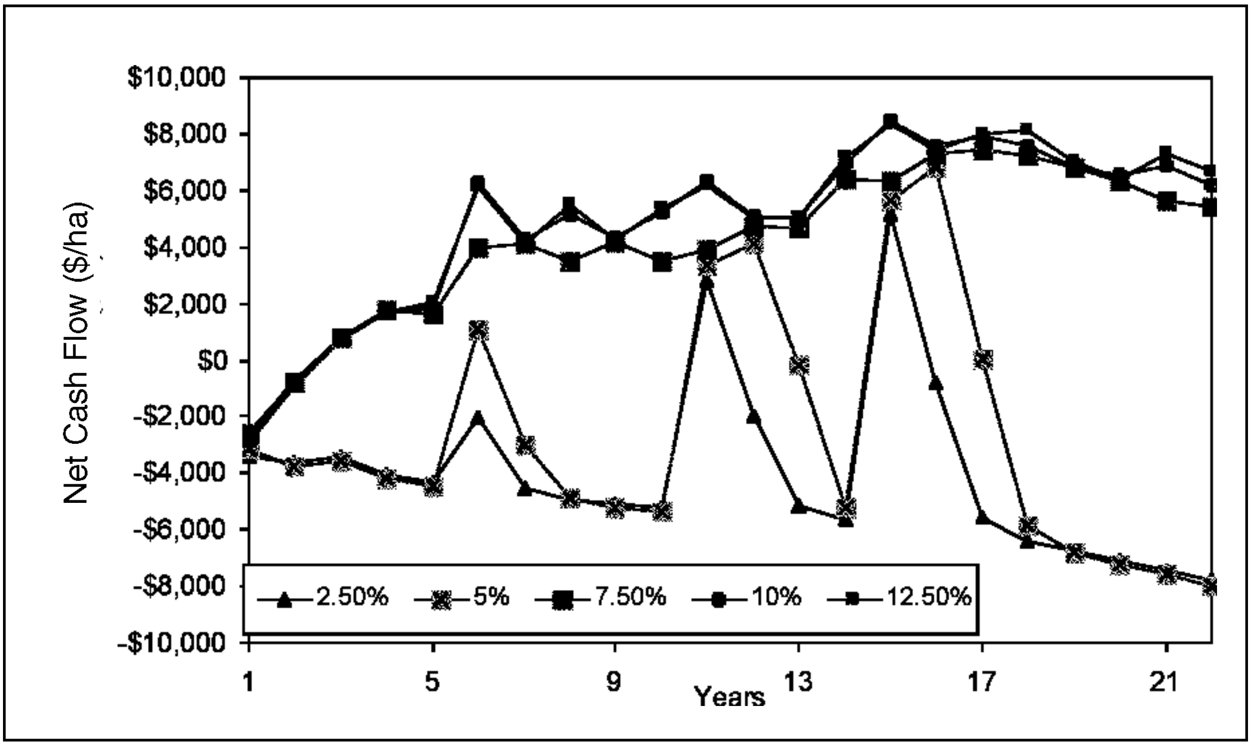

Figure 15.Annual net cash flow for a new citrus planting with different basin areas

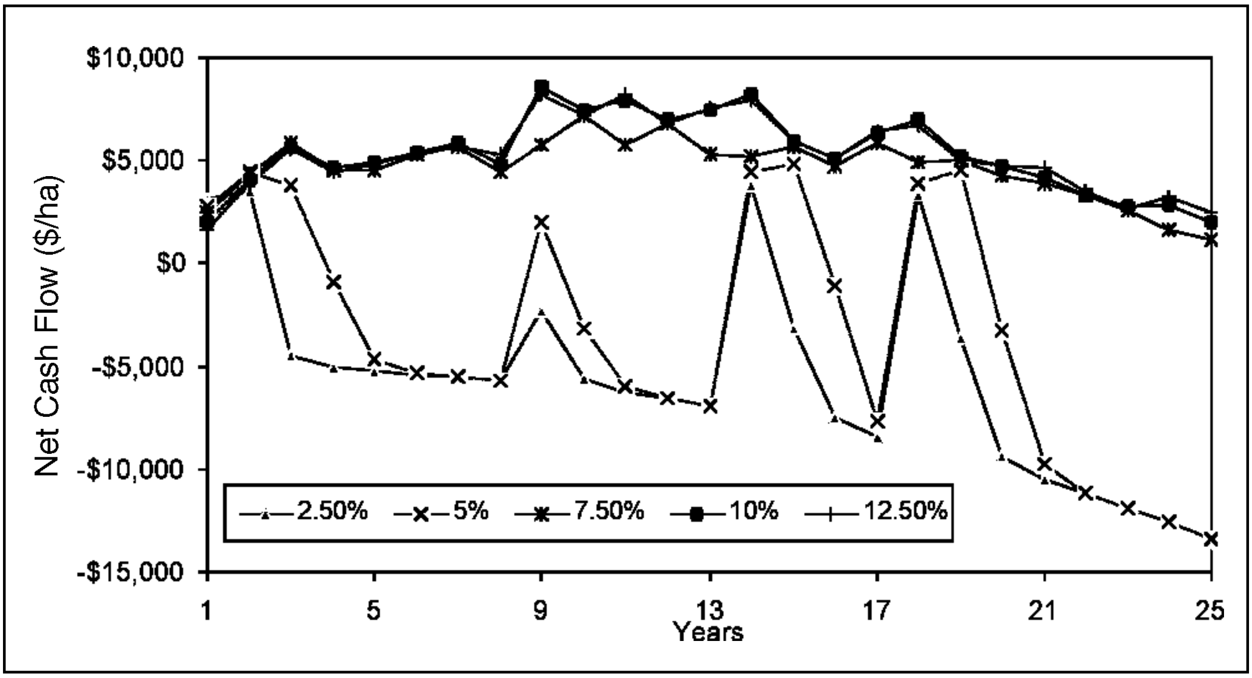

Figure 16.Annual net cash flow for an existing citrus planting with different basin areas

The optimisation results of basin area by the marginal costs and returns in Table 26 shows that in both new as well as existing citrus, the marginal cost equates to the marginal revenue at a basin area of about 12.5%.

Table 26.Marginal costs and returns for citrus

Basin area (% of drained area)	Average yield (t/ha)	Total Revenue ($/ha)	Total Cost ($/ha)	Profit (TR-TC) ($/ha)	MC ($\partial TR/\partial Y$) ($/t)
New citrus					
2.5	4.4	1,323	5,637	-4,314	0
5	9.2	2,748	5,928	-3,180	61
7.5	31.8	9,537	6,742	2,795	35
10	34.8	10,449	7,090	3,359	114
12.5	35.6	10,680	7,318	3,362	296
Existing citrus					
2.5	8.3	2,481	7,951	-5,470	0
5	15.9	4,764	8,150	-3,383	26
7.5	46.4	13,935	9,286	4,649	37
10	50.4	15,135	9,790	5,345	126
12.5	51.4	15,420	10,085	5,335	310

**marginal return (Py) is $300/t*

Figures 17 and 18 show that for new citrus the optimal yield is about 35t/ha, which corresponds to a basin area of 12.5%. In existing citrus the optimal yield is about 51t/ha, which again corresponds to a saline disposal basin area of 12.5%. Thus it can be seen that for citrus, which is a more waterlogging sensitive crop, the optimal basin area by marginal returns analysis is larger (12.5%) than for grapevines (7.5%).

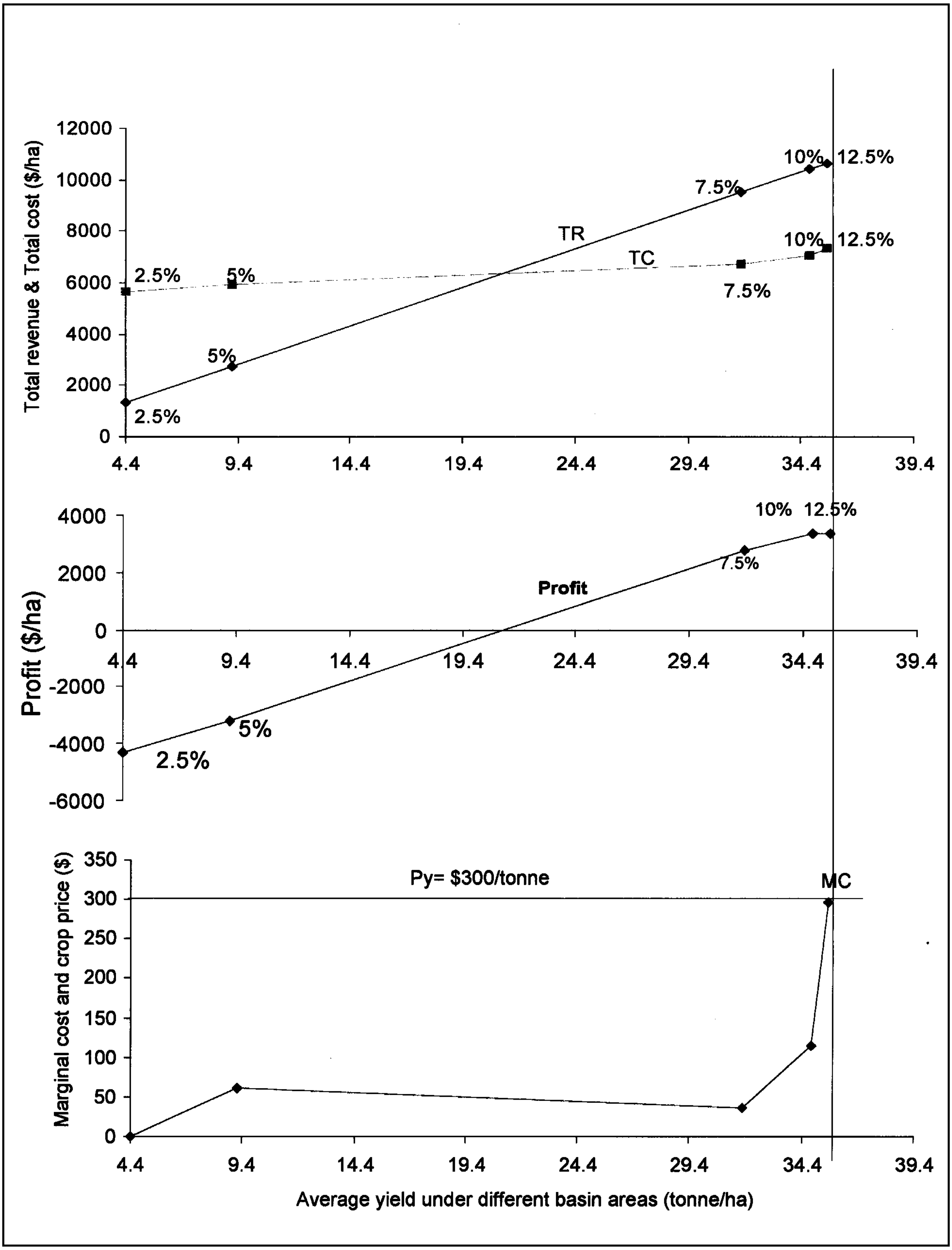

Figure 17.Optimum basin area for new citrus orchards

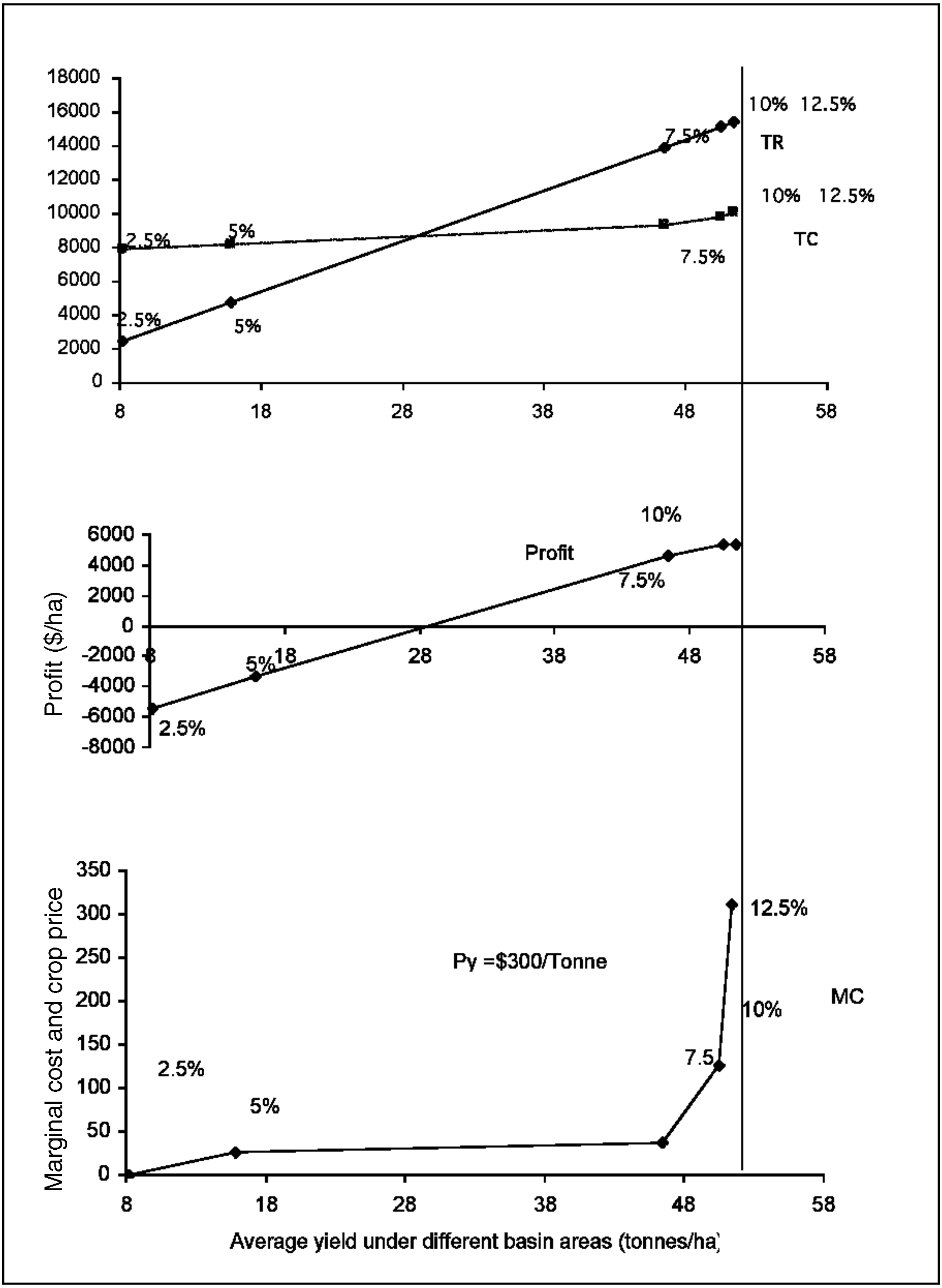

Figure 18.Optimum basin area for existing citrus orchard

4.5 Sensitivity Analysis of the Best Basin Area

The likely financial attractiveness of a drainage system with the best basin area is subject to changes in farm size, irrigation efficiency, crop yield and price. Analysis was undertaken to determine at what point a deviation in these factors would cause the farm to become unfinancial (Table 27).

Table 27.Critical values for important factors before BCR falls below 1

Factors	Vines		Citrus	
	New	Existing	New	Existing
Optimal basin area (%)	7.5	7.5	12.5	12.5
Farm size (ha)	18	6	5	1
Crop yield (% decline)	30	50	10	45
Crop price (% decline)	20	60	10	35

The results shows that the existing vines and citrus are able to sustain a greater degree of decline in the factors considered here, when compared to new developments. The overall conditions for the financial viability of the optimum basin area in vines and citrus with respect to different factors is analysed below.

4.5.1 Farm size

A minimum of about 20ha farm size in new vineyards and about 10ha for existing vineyards and new citrus orchards would be required for the financial viability of the subsurface drainage with optimum basin area (Figure 19).

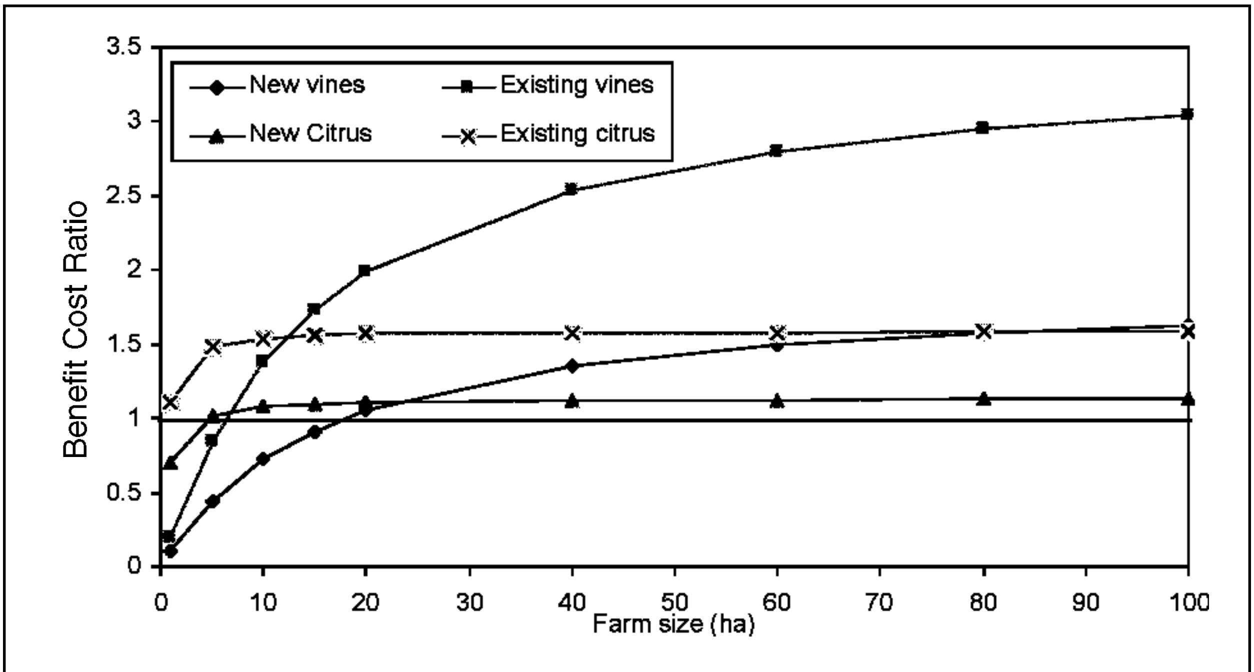

Figure 19. Change in Benefit Cost Ratio with farm size

The BCR for a vineyard subsurface drainage system with a saline disposal basin of 7.5% increases sharply with increase in farm size initially, and stabilises at farms greater than 60ha. For citrus, there are only changes when farm sizes are less than 10ha, otherwise there is little change. Thus it would appear that vineyards are more sensitive to changes in farm size than citrus orchards.

The greater sensitivity of vines to farm size is due to the fact that, as farm size increases, the capital assets available become utilised to their full capacity. Also, due to better crop prices, higher returns start accruing with a reduction in the per unit cost of fixed capital assets. For citrus, the cost component is greater due to a higher cost of production and larger basin area. Also as the crop prices are lower, these costs are less likely to be compensated for by increases in farm size alone.

4.5.2 Crop yield

A drainage system with basin is more sensitive to changes in crop yield in new developments (Table 27). Drainage/disposal in new citrus becomes unattractive with only a small decrease (10%) in crop yield, whilst in new vines the system can sustain a 30% decline in yield. The greater sensitivity of new citrus to yield change is because the crop is less remunerative, the high initial cost of establishment and maintenance, and the extended time before tree maturity. Existing plantings of both vines and citrus can sustain about a 50% yield decline because of their higher yield coupled with lower cost of maintenance.

The financial attractiveness of the optimum basin system, over a range of average yield changes, shows that the profitability of the system increases with increase in yield in all the crops, the increase being more prominent in existing vines (Figure 20). The increase in yield also results in higher costs of production, but the increase in returns is higher than the increase in cost. These differences are likely to be more prominent with higher crop prices.

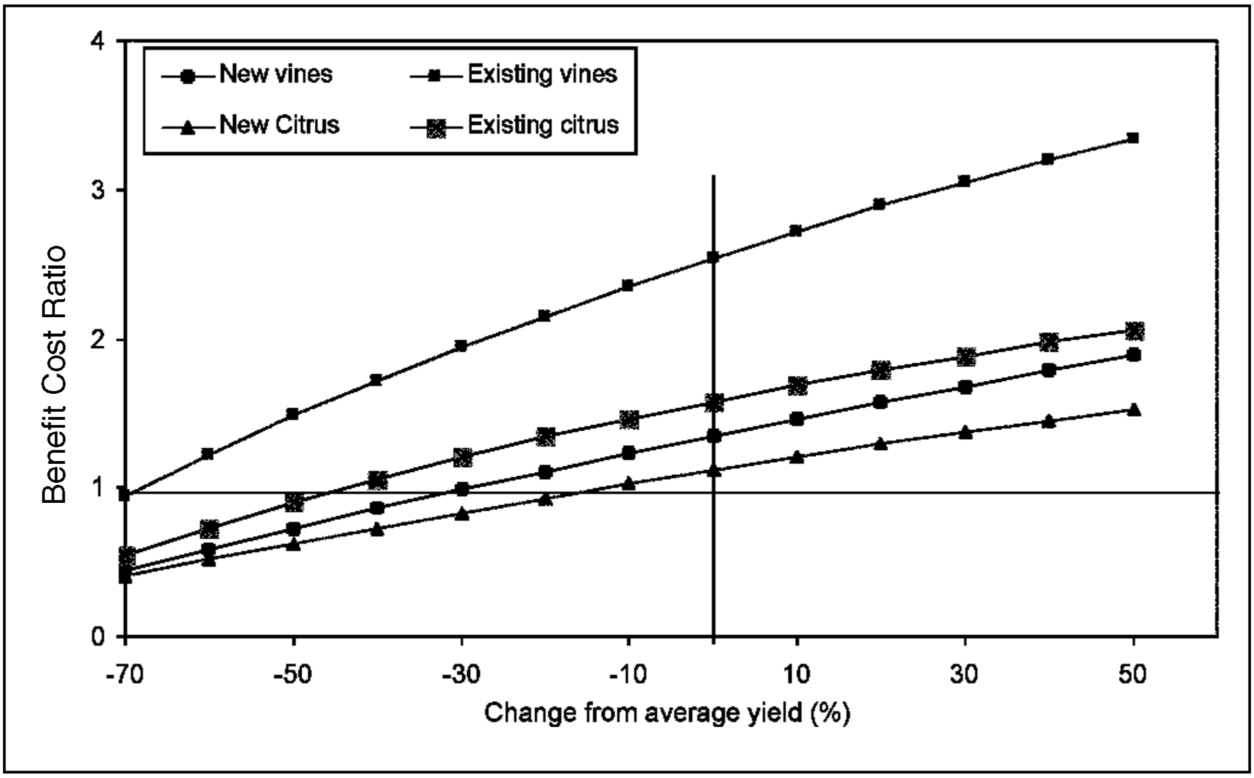

Figure 20. Change in Benefit Cost Ratio with yield

4.5.3 Crop price

The effect of crop prices on the financial attractiveness of a drainage system with a basin in citrus and vines were quite similar to that of changes in crop yields, Table 27. New vineyards can sustain a price cut of up to 30% whilst, in new citrus orchards, drainage-disposal becomes unattractive with only a small decline (about 10%) in average price. In the case of existing vines, the system is attractive up to a 60% decline in prices, and in existing citrus up to about a 35% reduction.

The results in Figure 21 show that the rate of increase or decline in the profitability of the system is higher with change in prices than in crop yields. The higher sensitivity of the system to price change is due to the fact that changes in price only affect the total returns from the crop and the cost remains unaffected; changes in average yield affect both cost as well as returns from crops.

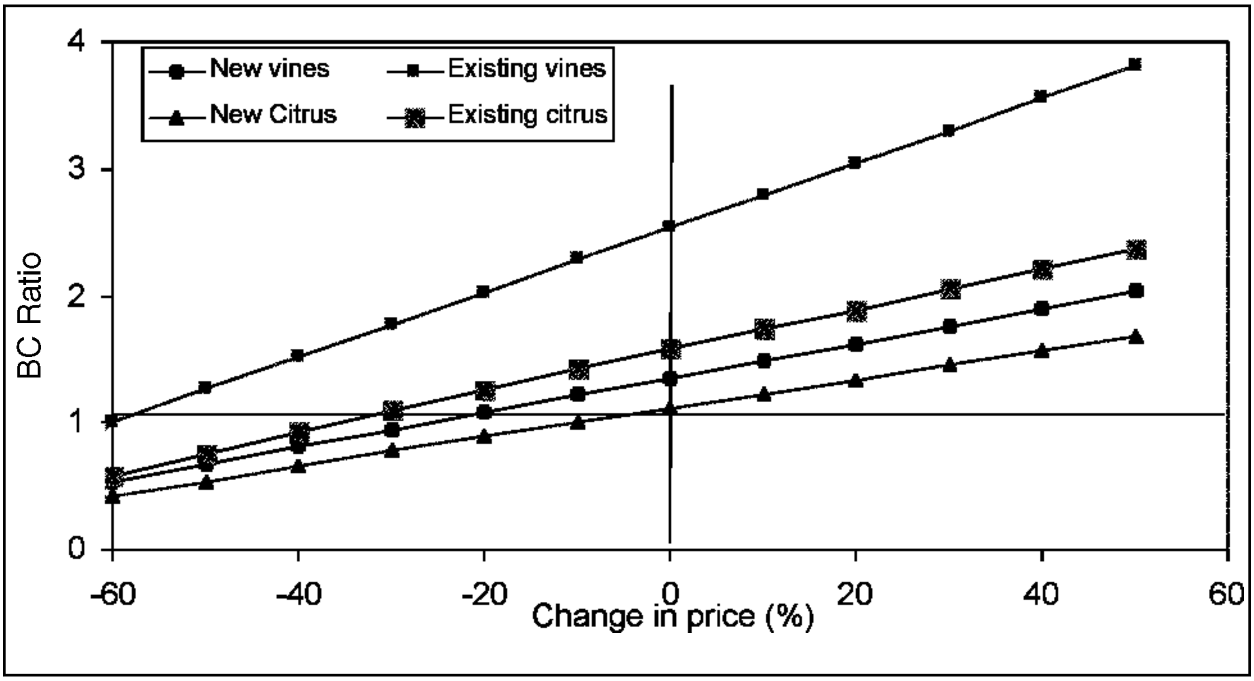

Figure 21. Change in Benefit Cost Ratio with crop price change

4.5.4 Irrigation efficiency

The impact of poor irrigation management is not very large in vineyards, as a drainage system with basin was still financially attractive under poor irrigation management (Table 28).

Table 28.Benefit cost ratios for poor irrigation efficiency, 120% of ET-R.

Factor	Vines		Citrus	
	New	Existing	New	Existing
Basin area (%)	7.5	7.5	12.5	12.5
Benefit Cost Ratio	1.30	2.5	0.30	0.60

Irrigation management in citrus has a severe adverse impact on the subsurface drainage systems viability. Therefore, irrigation efficiency is a key factor in deciding the financial viability of any drainage-disposal system in citrus.

The effect of irrigation management can be judged by comparing the effect of optimum basin size on improving crop yield under efficient and inefficient irrigation management (Figure 22).

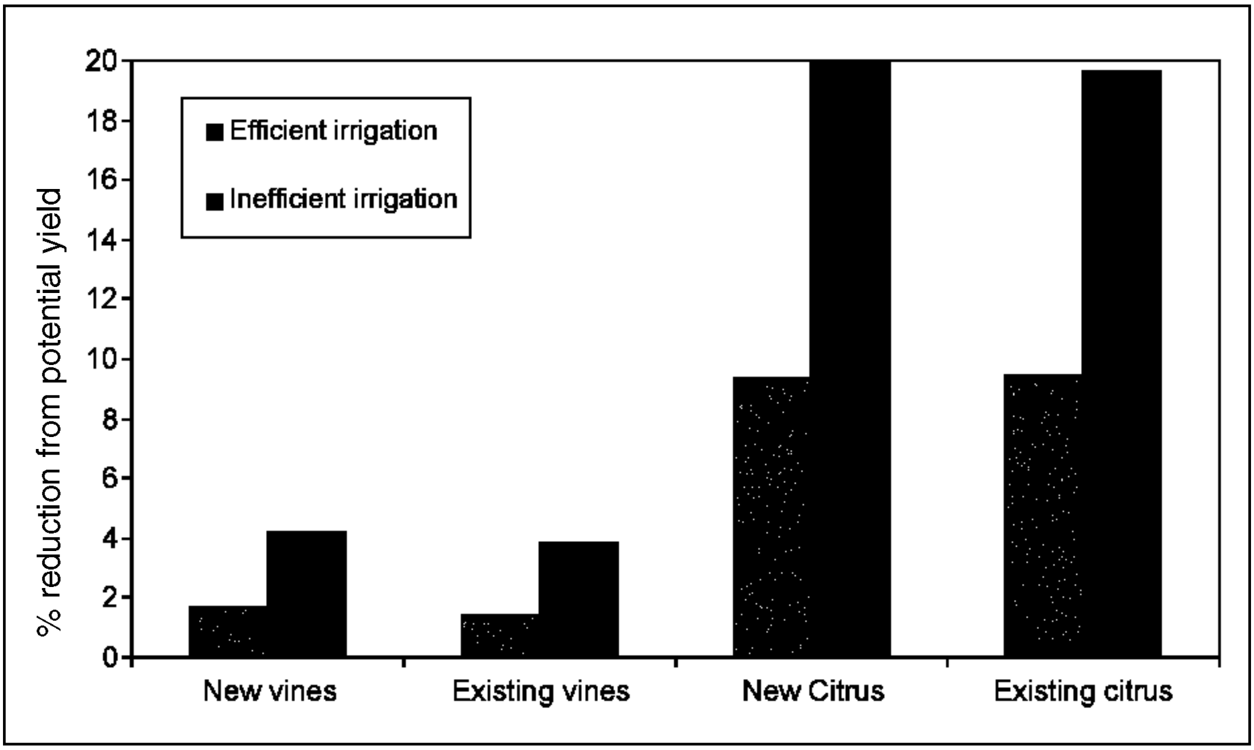

Figure 22.Effect of irrigation efficiency on crop yield

This shows that, with poor irrigation management, vine yields were reduced by about 2 to 3% compared to the average yield obtained with good irrigation management. The effect of poor irrigation management on citrus yield was more pronounced; about 10% less yield is obtained in new and existing citrus with poor irrigation management.

5. General Discussion

5.1 Impact of Using a Saline Disposal Basin on Farm Income

Subsurface drainage without the restriction of a saline disposal basin was most attractive in terms of net income; returns were about 60% higher for grapevines compared to no drainage. This indicates that losses due to waterlogging and salinity without drainage are much higher than the cost of installing a subsurface drainage system. The 40% income advantage of subsurface drainage using a basin (over having no drainage) indicates that a subsurface drainage system with a saline disposal basin is still financially attractive. This shows that saline disposal basins are financially viable, but there are problems in terms of extra costs.

The financial analyses of drip irrigation found that it was a financially attractive alternative to subsurface drainage with a disposal basin. This was especially so if it was assumed that drip did not require any drainage; however drip was still attractive if subsurface drainage and basin were included, assuming the basin area required to be about half of that required under furrow irrigation. A drawback of using drip and a drainage-disposal system is the much increased capital costs. It would appear that serious consideration should be given to the possibilities of avoiding the need for subsurface drainage by using improved irrigation techniques and good siting.

5.2 Physical and Economic Conditions for Successful Use of On-farm Saline Disposal Basins

Vineyards

Farm size has a considerable impact on the financial attractiveness of a drainage system for a new development. The analysis indicated that subsurface drainage attractiveness increased considerably with increasing farm size. Subsurface drainage systems with or without a basin become financially unattractive at a farm size below 20ha. At a farm size below 20ha, every unit decrease in farm size decreased the profitability of the system by about 4% for DNB and by about 8% for DWB. Whilst with increasing farm size the profitability of the drainage/disposal system increased.

Crop price has a considerable impact on the financial attractiveness of a subsurface drainage system. The profitability of drainage with no basin increased at a rate of 1.6% with per unit increase in price; this rate of change was about 1.4% for DWB. The DNB scenario become unattractive when about a 40% decline in crop price occurs, whereas the DNB scenario was marginal with only a 20% decrease in price.

The subsurface drainage systems were less sensitive to change in yield compared to change in prices; a unit change in yield has more impact on the profitability than price. The results indicated that DNB could sustain a yield loss of up to 40% and DWB only about 20%.

DNB scenario remained financially more attractive than DWB even when the land available to farmers for making saline disposal basin was cost free. Land value seemed to have an impact on the financial viability of subsurface drainage with a saline disposal basin, only with the inclusion of downstream cost and/or benefits in the analysis.

Efficient irrigation management is a key factor in deciding the financial attractiveness of a subsurface drainage/disposal system. The DWB showed that, with poor irrigation management, there was a decline in average yield of about 4%; in annual net cash flow of about 5%, the BC ratio declined by 2% and NPV by about 9%. Through better irrigation management a considerable saving due to a smaller basin area, effective watertable control and improved crop yield is possible.

Subsurface drainage/disposal is financially more attractive in existing vineyards, income for existing vineyards increased by more than 20% and the total cost was about 13% less than for a new vineyard.

Citrus orchards

The analysis for citrus (a more waterlogging sensitive crop than grapevines) indicated that drainage with a basin was financially attractive for new and existing planting. However, as citrus requires a larger basin of about 12% area, compared to 7.5% for grapevines, and the returns are lower, the use of a disposal basin has a far greater impact on the financial viability of citrus orchards. As citrus is so sensitive to waterlogging it cannot be readily grown without subsurface drainage. As such, any requirement to use a disposal basin may have a significant effect on investment in citrus orchards.

5.3 Optimum Basin Area

For the MIA, considerable improvement in grape yield was achieved with subsurface drainage using a basin. The reduction in waterlogging was not great for basins up to 5%. However, the improvement in yield and waterlogging was significant with a 7.5% basin area. The analysis indicated that a 5% basin area had the highest NPV and BCR, followed by a 7.5% basin area. This indicated that in new vineyards the optimal basin area would be between 5 and 7.5% of drained area.

The drainage system with 5 and 7.5% basin area had the highest annual Net Cash Flow. However, a 5% basin area had large variations (up to 50%) in NCF due to yield depression in wet years; these fluctuations were considerably reduced when the basin size was increased to 7.5%. A near steady annual NCF was only achieved with a 10% basin area; even this area had a dramatic reduction in annual NCF in one year.

Determining optimum output by marginal cost and returns (determining the conditions where MR= MC) showed that, in new vineyards in the MIA, optimum yield would be about 15 t per ha. This yield corresponded to the average yield obtained using a 7.5% basin area.

5.3.1 Scenario analysis for optimum basin area - existing plantings, citrus

Drainage with a disposal basin is more financially attractive for existing planting, due to higher crop yields and lower costs. The financial criteria indicated that profitability was approximately doubled in an existing vineyard compared to a new development. A 5% basin area was the most financially attractive in terms of highest BCR and NPV. However the average yield was significantly higher with a 7.5% basin area. The fluctuations in annual NCF reduced considerably for a 7.5% basin area, compared to a 5% basin area.

The marginal cost (MC) equated to the MR (output price) for a basin area more than 7.5% but less than 10%. The optimisation of output indicated that MR were higher than MC up to an average yield of about 18.1t/ha, which was derived from a basin area of about 8%.

A 5% basin area was not optimal because the profits were still increasing and peaked when the basin area was 7.5%. Therefore, for existing vineyards, an optimum basin area is about 7.5% in the MIA.

The financial analysis of subsurface drainage in citrus, a waterlogging sensitive crop, indicated that improvement in yield was significant when the basin size was increased from 5 to 7.5%. The profitability of drainage with disposal in citrus was highest with a 10% basin area in terms of NPV, BCR and Break Even Time. The annual NCF was highest with a 12.5% basin area in new citrus whereas in existing citrus it was 10%.

The optimisation of basin area showed that, in both new and existing citrus, the marginal cost equals the marginal return at a saline disposal basin area of about 12.5%. The corresponding output was about 35t/ha in new citrus and about 51t/ha in existing citrus plantations.

5.4 Overall Farm Economic Conditions for Long Term Financial Viability of a Sub surface Drainage-Disposal System

Farm size, crop yield, crop price and irrigation efficiency were the key factors affecting the financial viability of subsurface drainage with a saline disposal basin.

A minimum new vineyard size of about 20ha, and about 10ha for an existing vineyard or new citrus orchard, would be required for financial viability. In existing citrus orchards, the system was financially attractive for all farm sizes. Vines are more sensitive to change in farm size compared to citrus because of the higher crop price and smaller basin area required for vines compared to citrus.

Crop yield had greater impact on the financial viability of a drainage system in new plantings, compared to existing developments. Drainage/disposal for new citrus orchards becomes unattractive with only a small decline, about 10% in crop yield, whilst for existing orchards a 30% decline can be sustained. The financial attractiveness with optimum basin area increases with increasing yield of both crops. The increase being more prominent in existing vineyards due to higher yields and lower costs.

The effects of changing crop price on the financial attractiveness of drainage with disposal, using an optimum basin area, were similar to changes in crop yields. New vineyards can sustain a price decline of up to 30% whilst, for new citrus, only 10% decline in prices made it unattractive. For existing vineyards the drainage with disposal is attractive for up to 60% decline in prices and for existing citrus orchards up to 35% reduction.

The impact of poor irrigation management was not great in vines due to a lower sensitivity to waterlogging. However, irrigation management in citrus has an adverse impact on the subsurface drainage system viability. This analysis only considers waterlogging and not the longer-term salinity effects of poor drainage.

Comparing the yield under different irrigation management indicated that in grapevines about 2 to 3% less yield was obtained under poor irrigation management, compared to good irrigation management. The effect of poor irrigation management on citrus yield was more pronounced, about 10% less yield was obtained with poor irrigation management.

6. Conclusions

The following conclusions can be drawn from the previous analysis and discussion

1. Subsurface drainage with a saline disposal basin is an effective strategy in controlling waterlogging and therefore improving crop yields, especially in crops more sensitive to waterlogging.

2. Serious consideration should be given to the use of controlled irrigation systems such as drip if it will negate the need for a subsurface drainage system. The financial attractiveness of drip irrigation without subsurface drainage was far greater than any system of drainage-disposal.

3. The important factors affecting the financial viability of a subsurface drainage system with a saline disposal basin are farm size, crop price and yield, irrigation management, saline disposal basin size and sensitivity of crop to waterlogging conditions.

4. The subsurface drainage systems with a saline disposal basin are better suited to crops that have high yields and prices and crops that are more sensitive to waterlogging.

5. Subsurface drainage with a saline disposal basin is effective in new vines when downstream cost and/or benefits are considered and long term salinity effects on grapevine yield are included in the analysis.

6. Subsurface drainage with a saline disposal basin has greater economic viability for existing plantings than for new developments.

7. Irrigation management is a key factor in deciding the financial attractiveness of a drainage system. A considerable amount of saving is possible due to less water use and therefore drainage, resulting in a smaller basin area.

8. The financial performance of a subsurface drainage system is better with larger farms because of economies of scale associated with farm size. For the MIA, small farm sizes below 20ha in new vineyards and 10ha in existing vineyards and below 10ha in new and existing citrus should consider other options such as draining in to a larger community basin or draining to surface water drainage system.

9. For the MIA, a subsurface drainage system with a saline disposal basin area of about 7.5% is financially most attractive in new and existing vineyards. In citrus, however, a basin area of about 12.5% of farm area would be financially optimal due to its greater sensitivity to waterlogging than grapevines.

7. References

1. Doll, J. P. and Orazem, F. (1984). Production Economics: Theory with Applications. John Willey and sons, Inc. Brisbane. pp 61-84.
2. Farm Budget Handbook (1997). Farm budget handbook- NSW Citrus, NSW Agriculture, 1997.
3. Mass, E.V. and Hoffman, G.J. (1977). Crop salt tolerance- current assessment. Proceeding American Society of Civil Engineering: Journal of Irrigation and Drainage Division. 103(IR2), 115-134.
4. Minessy, F.A., Barakat, M.A. and EL-Azab, E.M. (1970). Effect of watertable on mineral content, root and shoot growth, yield and fruit quality in Washington Navel oranges and Baldy mandarin. Journal of American Society of Horticultural Science. 95(1): 81-85.
5. Moll, J. and Christen, E. (1996). Financial evaluation of options for managing tile drainage water to meet environmental constraints. CSIRO Division of Water Resources, Griffith (NSW). Technical Memorandum 96.20.
6. Singh, J. and Christen, E.W. (1999). Minimising the cost of saline disposal basins: siting, design and construction factors. CSIRO Land and Water, Griffith (NSW). Technical Report 12/99.
7. Stevens, R.M. and Prior, L.D. (1994). The effect of transient waterlogging on the growth, leaf gas exchange and mineral composition of potted sultana grapevines. American Journal of Enology and Viticulture. 45(3): 285-290.
8. West, D.W. and Taylor, J.A. (1984) Response of six grape cultivars to the combined effects of high salinity and rootzone waterlogging. J. Amer. Soc. Hort. Sci. 109(6):844-851
9. Wine Grapes Marketing Board (1997). Annual Report, Wine Grapes Marketing Board, Griffith (NSW).
10. Wu, Q., Christen, E.W. and Enever, D. (1999). BASINMAN- A water balance model for farms with subsurface pipe drainage and on-farm saline disposal basin. CSIRO Land and Water, Griffith (NSW). Technical Report 1/99.

8. Appendices

Appendix 1. Method for basin size optimisation

The optimum output can be determined by directly comparing total revenue (TR) and total cost (TC) at each output amount. Profit is the difference between the TR and TC and it occur when the TR is greater than TC.

The marginal conditions for the maximisation of profit as a function of output can be derived from the profit function. Here all the variables in the equation must be regarded as a function of output. The simple profit model can be expressed algebraically as;

$$\text{Profit} = TR - TC$$
$$= P_y.\ Y - P_x.\ X - TFC$$
$$= P_y.\ Y - P_x f\text{-}1\ (Y) - TFC$$

	Y	average yield (t)
Where,	X	basin area (ha)
	Py	the price of output ($/t)
	Px	the cost of input ($)
	TFC	the total fixed cost ($)

$P_x f$-1(Y) is the inverse production function expressing X as a function of Y

Taking the derivative of profit with respect to Y results in

$$\partial \text{Profit} / \partial Y = P_y - P_x\ \partial X / \partial Y = 0$$

Where $\partial dX / \partial dY'$ is the derivative of the inverse function with respect to Y.

But since $\partial X / \partial Y = 1 / \partial Y / \partial X = 1 / MPP$

the marginal condition can be rewritten as;

$$\partial Profit / \partial Y = P_y - P_x / MPP = 0$$

$$P_y - MC = 0$$

or

$$P_y = MC = P_x / MPP = P_x (\partial X / \partial Y)$$

or

$$P_y . \partial Y = P_x . \partial X$$

Therefore, P_y = MC at the optimum, and the yield level determined by this relation is the optimum yield.

More generally, differentiation of the profit equation with respect to Y would give

$$\partial Profit / \partial Y = \partial TR / \partial Y - \partial TC / \partial Y = 0$$

or

$$\partial TR / \partial Y = \partial TC / \partial Y$$

$$MR = MC$$

The farmer is expected to face a constant price represented by a straight line because the farmer sells in a purely competitive market and in pure competition, MR = P_y.

Using the marginal returns principle the optimum yield level was determined. This was then related to the average yield obtained for different basin sizes. The optimal basin area was taken as that giving the closest average yield levels to the optimum yield.

Appendix 2: Cash Flow Budget for New Vineyard

Vineyard - new development	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
INCOME																										
Annual area of vines planted (ha)		37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harvest area of 1st planting (ha)		0	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37
Harvest area of 2nd planting (ha)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Harvest area of 3rd planting (ha)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Harvest area of 4th planting (ha)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Yield 1st yr planting (kg/vine)		0	1	2	5	7	9	11	12	11	12	12	12	11	10	12	12	12	10	12	12	12	12	12	12	12
Yield 2nd yr planting		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yield 3rd yr planting		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yield 4th yr planting		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yield 1st yr planting (tonnes)	(based on	0	37	136	271	407	508	644	678	657	678	678	678	623	589	678	678	678	602	678	678	678	678	678	678	678
Yield 2nd yr planting	1587	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yield 3rd yr planting	vines /ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yield 4th yr planting		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grapes Total # tonnes	Shiraz	0	37	136	271	407	508	644	678	657	678	678	678	623	589	678	678	678	602	678	678	678	678	678	678	678
@ Grape price $/t	700	0	25905	94864	189728	284591	355739	450603	474319	459631	474319	474319	474319	435996	412436	474319	474319	474319	421686	474319	474319	474319	474319	474319	474319	474319
Total Annual Income	$	0	25905	94864	189728	284591	355739	450603	474319	459631	474319	474319	474319	435996	412436	474319	474319	474319	421686	474319	474319	474319	474319	474319	474319	474319
	4	0	23951	84334	162180	233913	281146	342421	346580	322931	320433	308109	296258	261848	238172	263373	253243	243503	208156	225132	216473	208147	200142	192444	185042	177925
Present Benefit @ Discount Rate (%)	8	0	22209	75306	139455	193688	224176	262923	256260	229930	219702	203427	188359	160315	140418	149525	138449	128194	105526	109905	101764	94226	87246	80784	74800	69259
	10	0	21409	71273	129587	176709	200806	231231	221273	194928	182871	166246	151133	126292	108607	113548	103226	93842	75844	77555	70505	64095	58268	52971	48156	43778

Appendix 2 cont...Cash Flow Budget for New Vineyard

Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
COSTS																										
Machinery/Equipment ($)																										
Tractor/spray/plough/rip/planter	100000	100000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sod sower/post driver/slasher/secateurs	9500	9500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Field bin/trimmer/pruner			22000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bins/hedger			0	14600	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Office	10000	10000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Office equip.	10000	10000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machinery shed	5000	5000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Repairs & Maintenance (5%)	7305	7305	7305	7305	7305	7305	7305	7305	7305	7305	7305	7305	7305	7305	7305	7305	7305	7305	7305	7305	7305	7305	7305	7305	7305	7305
Land Preparation ($/ha)																										
Survey/Clearing/Landforming	450	16650	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trellising ($/100m)																										
Posts	78	82535	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Post installation	28	29600	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wire (8 strands @6.5 c/m) & clips	59	62400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wire installation (labour @.02c/m)	16	16914	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Strainers/chocks ($/row)	66	14020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ends installation (labour) ($/row)	25	5311	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 2 cont...Cash Flow Budget for New Vineyard

	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Vine establishment costs ($/vine)																										
Vines/ha	1587																									
Vine cuttings	0.85	49921	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Planting vines (labour)	0.26	15270	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Training	0.45	26429	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pruning	0.15	8810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vine maintenance costs ($/ha)																										
Pruning/desucker/gen.maint/	330	0	12210	12210	12210	12210	12210	12210	12210	12210	12210	12210	12210	12210	12210	12210	12210	12210	12210	12210	12210	12210	12210	12210	12210	12210
mulch/tractor costs.																										
Irrigation System ($/ha)																										
Riverina Twin Furrow																										
Installation cost	2850	105455	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operating Cost $/ha/year	450	18001	18001	18001	18001	18001	18001	18001	18001	18001	18001	18001	18001	18001	18001	18001	18001	18001	18001	18001	18001	18001	18001	18001	18001	18001
watercost $/ML	30	1998	5884	4912	5941	5948	4970	7954	3991	4173	3941	4069	6902	0	1017	1957	2951	5913	1996	6912	5930	4986	8830	2021	5923	2970
Tile Drainage (optional) ($/ha)																										
Materials & installation	2848	105362	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pumping costs ($/Ml)	0.9	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43
R&M (5%) ($)	142	5268	5268	5268	5268	5268	5268	5268	5268	5268	5268	5268	5268	5268	5268	5268	5268	5268	5268	5268	5268	5268	5268	5268	5268	5268
Evaporation Basin Construction																										
Materials & Installation($/ha of basin)		49560	16107	16107	16107	16107	16107	16107	16107	16107	17211	16107	16107	16107	16107	16107	16107	16107	16107	16107	17211	16107	16107	16107	16107	16107
Variable Production Cost																										
Chemicals ($/ha)																										
Urea/super	130	4810	4810	4810	4810	4810	4810	4810	4810	4810	4810	4810	4810	4810	4810	4810	4810	4810	4810	4810	4810	4810	4810	4810	4810	4810
Fungicide	65	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Insecticide	14	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
Application of all sprays/fert etc	170	6290	6290	6290	6290	6290	6290	6290	6290	6290	6290	6290	6290	6290	6290	6290	6290	6290	6290	6290	6290	6290	6290	6290	6290	6290
Harvest ($/tonne)																										
Mech.Harvester (contract)	62	0	2294	8402	16804	25207	31508	39911	42011	40710	42011	42011	42011	38617	36530	42011	42011	42011	37349	42011	42011	42011	42011	42011	42011	42011
Contract carting	11	0	407	1491	2981	4472	5590	7081	7454	7223	7454	7454	7454	6851	6481	7454	7454	7454	6626	7454	7454	7454	7454	7454	7454	7454
Levies	4	0	148	542	1084	1626	2033	2575	2710	2626	2710	2710	2710	2491	2357	2710	2710	2710	2410	2710	2710	2710	2710	2710	2710	2710
Overhead Costs																										
Repairs to structures (3%)	5518.660635	5519	5519	5519	5519	5519	5519	5519	5519	5519	5519	5519	5519	5519	5519	5519	5519	5519	5519	5519	5519	5519	5519	5519	5519	5519
Rates	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Phone/Elec+Business expenses/charges	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Insurance of Machinery	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711
Insurance of Structures	2258.07	2258	2258	2258	2258	2258	2258	2258	2258	2258	2258	2258	2258	2258	2258	2258	2258	2258	2258	2258	2258	2258	2258	2258	2258	2258
Depreciation of Machinery (10%/yr)	17110	17110	17110	17110	17110	17110	17110	17110	17110	17110	17110	17110	17110	17110	17110	17110	17110	17110	17110	17110	17110	17110	17110	17110	17110	17110
Depreciation of Structures(3.3%/yr)	7526.9	7527	7527	7527	7527	7527	7527	7527	7527	7527	7527	7527	7527	7527	7527	7527	7527	7527	7527	7527	7527	7527	7527	7527	7527	7527
Interest on Cumulative Deficit	0.12	0	108998	29129	10170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Interest on Annual Deficit	0.12	97320	14329	5960	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Annual Costs	$	908319	268643	179617	151563	151835	158684	172102	170748	169314	171802	170826	173659	162541	160967	168714	169708	172669	162964	173669	173791	171743	175587	168778	172680	169727

Appendix 2 cont...Cash Flow Budget for New Vineyard

	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	4	873384	248375	159679	129557	124797	125410	130784	124764	118958	116063	110965	108467	97618	92954	93681	90608	88644	80443	82431	79316	75367	74090	68478	67366	63667
Present Costs @ Discount Rate (%)	8	841036	230318	142586	111403	103336	99998	100420	92250	84699	79577	73264	68962	59766	54803	53186	49536	46667	40782	40241	37287	34118	32298	28745	27231	24783
	10	825745	222019	134949	103519	94277	89573	88316	79655	71806	66237	59873	55333	47082	42388	40389	36933	34162	29310	28396	25833	23208	21570	18849	17531	15665
	4	-873384	-224425	-75345	32623	109116	155736	211638	221816	203973	204370	197143	187791	164230	145217	169691	162634	154859	127712	142701	137157	132781	126052	123966	117676	114258
Present Values @ Discount Rate (%)	8	-841036	-208109	-67280	28052	90352	124179	162502	164010	145231	140124	130163	119396	100549	85616	96339	88913	81527	64745	69664	64478	60108	54949	52038	47568	44476
	10	-825745	-200610	-63676	26067	82431	111233	142915	141618	123123	116634	106373	95800	79210	66220	73159	66292	59680	46533	49159	44672	40887	36698	34122	30624	28113
Net Cash Flow (total $) Vineyard #1	$	-908319	-242738	-84753	38165	132757	197056	278501	303571	290317	302517	303493	300660	273454	251469	305605	304611	301650	258722	300650	300528	302576	298732	305541	301639	304592
Cumulative Balance (total $) Vineyard #1	$	-908319	-1151057	-1235810	-1197646	-1064889	-867833	-589332	-285762	4555	307073	610566	911226	1184680	1436150	1741754	2046366	2348015	2606737	2907387	3207915	3510492	3809224	4114765	4416405	4720997
Net Cash Flow ($/ha) Vineyard #1	$/ha	-24549	-6560	-2291	1031	3588	5326	7527	8205	7846	8176	8203	8126	7391	6796	8260	8233	8153	6992	8126	8122	8178	8074	8258	8152	8232

Appendix 2b: Costs for Installing Tile Drains

Main and lateral drain variables.
(based on a 40 ha paddock)

Area m^2	400000
Total Metres of drain.	13333
No. laterals	17
Drain Spacing	30
length of laterals	800
Mains length	500
No.inspection sumps	68
No.main sumps	1

Trench Details

Lateral Depth	1.8
Main line depth	2.3

PIPE LAYING COSTS		Total ($)	$/ha
100mm Pipe $/m	5	69,166.67	1,729.17
SUMP COSTS			
Main sump:			
Materials $		520.00	13.00
Excavator Hire $		300.00	7.50
Diesel Pump:			
Pump cost $		7,370.00	184.25
Inspection sumps:			
Materials $/sump	330	22,440.00	561.00
Installation $/sump	120	8,160.00	204.00
Extra Costs			
Survey costs $/peg	5.1	3,527.50	88.19
T.D.C.Fee ($/20m)	3.5	2,420.83	60.52
Total Tile Drain Installation Cost		113,905.00	2,847.62/ha

Work Rate for trencher.

Speed (m/hr)	40
Laying time (hrs)	346
No. labourers	1

Surveying Details

Total Trench length	13833
No. Pegs (1 per 20m)	692

Appendix 2c: Parameters for Estimating Evaporation Basin Cost

A. Evaporation Basin Sizing			
Area proposed for vines		40	ha
Basin size		4.00	ha
Basin Area m^2	40000	4.00	ha
Evap. basin area ratio (%)		10	
Width (m)		200	
Length (m)		200	
Area of crop protected		36	ha
B. System Variables			
1. Earthworks			
Basin Area m^2		40000	
Basin Shape		Square	
No. of cells		2	
Size of cell (ha)		2	
Bank length (m)		1000	
Vol. soil per meter of bank (m^3)		5.9	
Vol. soil in banks of 4ha basin		5900	m^3
Vol. soil in floor of 4ha basin		6000	m^3
2. Perimeter Tile Drain/open drain			
Perimeter length		800	m
Vol. soil removed / m length for an open drain		9	m^3
Total vol. soil removed for open drain		7200	
3. Lateral leakage pumping			
Pump discharge rate (per m of perimeter length)		34560	litres per day
Pumping capacity of pump		112320	litres per day
Running time for pump		7.38	hours/day
Electric power of pump		0.5	kWh
Annual running time of the pump		1348	kWh

Appendix 2c: Estimated Costs of Evaporation Basin

2C. Estimated costs of evaporation basin																											
						Annual Costs $																					
Costs of earthworks					y1	y2	y3	y4	y5	y6	y7	y8	y9	y10	y11	y12	y13	y14	y15	y16	y17	y18	y19	y20	y21	y22	y23
Opportunity cost of land		$/ha		5000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
Geotechnical	low	$/ha		1059	4236	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
investigation	high	$/ha		1970	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Survey.																											
		$/ha		29.5	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Earth moving																											
Stripping vegetation		$/m^2		0.3	1800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
floor formation		$/m^3		0.7	4200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bank formation		$/m^3		0.7	4130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
floor compaction		$/m^3		2	12000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bank compaction		$/m^3		2	11800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Perimeter drains, pump& sump																											
Trencher hire + pipe		$/m		5	3680	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sump		$			600	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pump		$			800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Recurring expenses																											
Pumping costs		$/kWh		0.06	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81
Repair & mainentance		$			0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Spraying		$/ha		14	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56
insurance		$		481	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481
bank repair and maintenance		$		1593	0	0	0	0	0	0	0	0	0	1593	0	0	0	0	0	0	0	0	0	1593	0	0	0
Miscellaneous cost		$			634	634	634	634	634	634	634	634	634	634	634	634	634	634	634	634	634	634	634	634	634	634	634
Optional Costs																											
Plastic liner		$/m^2	0.8	32000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open drain		$/m^3	1	7200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Cost		$			64616	21292	21292	21292	21292	21292	21292	21292	21292	22885	21292	21292	21292	21292	21292	21292	21292	21292	21292	22885	21292	21292	21292