Economic benefits and costs of tree planting for salinity control

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Abstract

This study reviewed case studies and research focussed on the issues of managing native vegetation, the problems of salinity and the relationship between the two. It then addressed the economic feasibility of six tree planting configurations to reduce the impacts of salinity. The method used a spreadsheet model showing the benefits and costs of various planting configurations over a 30-year time span. This model can be used to assess the monetary net benefits/costs of reducing recharge of a vegetation management proposal. Inputs can be varied to tailor the model to different catchments. Even when applied to local groundwater systems, the impact on salinity in terms of land salinised, salt loads and dollars was small. These factors can represent major impediments to the implementation of tree planting and vegetation regeneration.

keywords: vegetation, salinity, benefit cost.

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EXECUTIVE SUMMARY

This study addressed the economic feasibility of managing native vegetation to reduce the impacts of salinity. As well, it quantified the economic feasibility of six tree planting configurations. A spreadsheet model was developed to show the benefits and costs of various planting configurations and methods over a 30-year time span. This model assessed the monetary net benefits/costs of reducing recharge of a vegetation management proposal. Inputs can be varied to tailor the model to different catchments.

This study reviewed case studies and research focussed on the issues of managing native vegetation, the problems of salinity and the relationship between the two. Research in Western Australia (Read et al (2001) has indicated that where the groundwater system is local, planting trees can affect watertables within economically viable timeframes. However, where groundwater systems are not local and lag effects between planting and watertable levels are much longer, the economic benefits of native vegetation are only realised in the longer term while costs are incurred in the short term. As well, the benefits accrued are not always solely enjoyed by those incurring the costs of both salinity and vegetation management. These factors can represent major impediments to the implementation of tree planting and vegetation regeneration.

Biophysical modelling studies have indicated that very extensive areas of tree planting are necessary in a catchment to significantly affect the rate of spread of salinised land, reduce the loss of productivity and reduce salt loads in rivers (Heaney et al (2001), Herron et al (2001), Walpole and Lockwood (1999), Hill (1997)). Clearly these large areas of plantings are not feasible in the current rural economic climate unless the broader community shares the cost. Not all the benefits flow directly to the landholder. Significant benefits in terms of biodiversity are direct returns to society. This raises the issue of how to share the costs of protecting the environment.

The outcomes of the modelling undertaken confirmed that avoided recharge from tree planting is a small component of the total benefits of treeplanting. Landholder costs can be significant with fencing being a major component together with land preparation and establishment costs.

Benefits of planting native trees were quantified as stock and crop shelter, timber benefits and recharge benefits measured as avoided salt load entering waterways and salinised land. Some of these benefits were external to the landholder. Costs incurred were land preparation and planting costs, fencing and ongoing maintenance and foregone use of the land under trees. Sensitivity analysis included consideration of carbon sequestration benefits. The benefits and costs in this study represented the most readily identifiable and quantifiable variables.

Benefits and costs were discounted over 30 years at a discount rate of 7%. The net present value was negative for a number of planting configurations and sensitive to a number of variables.

The modelling indicated that the discounted benefit value over 30 years of a hectare of native trees planted in a block pattern was $3,621 per hectare. Of this, the present value of recharge benefits was only $25.50 per hectare, which was approximately 1% of total benefits quantified. The discounted value of the costs was $3,224 per hectare. The main benefit was from timber, while the main cost was fencing.

Table A: Net present values of benefits and costs over 30 years

planting pattern	present value benefits	present value costs (electric fencing)	net present value	benefit cost ratio
	$ per ha	$ per ha	$ per ha	
block	3,621	3,224	397	1.1
windbreak	3,921	7,414	-3,493	0.5
timberbelts	4,209	6,250	-2,041	0.7
scattered trees	831	4,155	-3,324	0.2
denser scattered trees	821	4,155	-3,334	0.2
alley	4,457	3,482	975	1.3

Under the assumptions of the modelling, both block and alley planting appeared to be economically feasible for the community. This was sensitive to the type of fencing applied. The results were annualised to indicate the benefits or costs on a per hectare basis in each year.

Table B: Annualised benefits and costs- electric fencing

planting pattern	annualised benefits	annualised costs [a]	difference
	$ per ha	$ per ha	$ per ha
block	292	260	**32**
windbreak	316	598	**-282**
timberbelts	339	504	**-165**
scattered trees	67	335	**-268**
denser scattered trees	66	335	**-269**
alley	359	281	**79**

[a] includes electric fencing

Sensitivity analysis indicated that the quantified annualised community benefits (ie. excluding all private benefits) of tree planting were $112 per hectare while costs exceeded benefits to the landholders in all but two cases by more than that amount. This analysis indicates that unquantified environmental benefits need to be valued up to $170 per hectare per year for benefits to equal costs, depending on the planting configuration. Where stockproof fencing is required this shortfall would be up to $790 per hectare per year. A significant part of this shortfall would need to be provided by the community.

Environmental benefits, other than carbon sequestration, were not quantified. All planting configurations would be expected to provide environmental benefits both to the landholder and the community. Therefore the study underestimates the benefits of planting and rehabilitating trees in the landscape.

The study found that specific native tree planting configurations of block and alley planting in the study area of the Murrumbidgee Region were economically feasible where electric fencing was used. Salinity benefits, measured as reduced land salinisation and reduced salt loads, were a small component of overall benefits. The modelling can be applied to other native vegetation management techniques and in a variety of geographical areas by changing the input data.

1 INTRODUCTION

This conference paper is based on the project, *The economic benefits and costs of native vegetation management techniques for salinity control,* which was proposed by the Department of Infrastructure, Planning and Natural Resources (DIPNR, formerly the Department of Land and Water Conservation) following the Dubbo Salinity Summit in 2000 as part of the NSW Salinity Strategy (Hill 2003).

This study reviewed case studies and research focussed on the issues of managing native vegetation, the problems of salinity and the relationship between the two. It then addressed the economic feasibility of six tree planting configurations to reduce the impacts of salinity. An economic spreadsheet model was developed to enable assessment of the readily quantifiable benefits and costs of a range of vegetation management actions. The nature of this study is broad, with the aim of providing readily accessible and understandable figures to indicate the economic viability of a range of potential vegetation management actions.

This study is underpinned by technical work from the Department of Land and Water Conservation (now DIPNR) studies by Kuginis and Daly (2001) and van der Lely (2001a, 2001b).

Kuginis and Daly (2001) undertook a comprehensive review of the technical impact of plant based options on dryland salinity, addressing the question as to whether trees and other types of perennial vegetation can save catchments from salinity. The following relevant constraints on the impact of vegetation management were listed:

- hydrological setting
- amount of catchment revegetated
- location within the landscape
- depth and salinity of the watertable
- planting density and age of vegetation
- soil type and
- climate.

Van der Lely (2001a, 2001b) modelled the groundwater response times for the Murrumbidgee region in relation to vegetation growth.

2 ECONOMIC ISSUES /VALUING FRAMEWORK

Economic benefits and costs are identified and quantified where possible. In this study, a number of assumptions are applied which can be altered to specific circumstances. There are several steps in quantifying economic benefits and costs. The first step is to identify the economic benefits and costs of native vegetation management in controlling salinity. The scope of these benefits and costs will be influenced by the scale of study, whether a farm, a catchment, or a region.

Benefits of maintaining native vegetation include:

- increased productivity of land otherwise affected by salinity
- increased productivity of crops and stock due to shelter provided by vegetation
- timber for firewood and fencing
- reduced salt loads in rivers
- reduced maintenance costs caused by dryland and urban salinity on infrastructure such as roads, bridges, houses, gardens,
- reduced erosion from runoff
- biodiversity
- aesthetic appeal
- carbon sequestration.

Benefits can be categorised as use or non-use benefits. Use benefits include increased productivity of land by avoided degradation and use through recreation. Non-use benefits include existence values, where the community or landholder derives a benefit from knowing that the good, or in this case, the native vegetation, exists (Hill (1994), Gillespie (2000)). Many benefits can be readily quantified where they are traded on the market. Other benefits are not traded but valued indirectly.

Costs of establishing, rehabilitating or protecting native vegetation are more often traded and therefore can be valued directly. They include:

- fencing, labour, maintenance, weeding,
- ripping, sowing, planting,
- foregone income from alternative landuse of the area under vegetation.

Not every site or circumstance will have the same benefits and costs, or the same timeframe of benefits and costs. An economic assessment identifies the magnitude of benefits and costs over a time period, often between 5 and 50 years. Economic studies addressing natural resource management tend to include time frames of at least 30 years because the environmental benefits are realised in the longer term. Given that benefits and costs are incurred at differing times, benefits and costs are discounted over the time period of the study so that they can be directly compared in present day dollars. Economic viability is indicated where the discounted value of benefits is greater than the discounted value of costs over the time period of study.

However, many benefits and costs are not readily quantified as they are not traded in the market place, for example the benefit of increased biodiversity from rehabilitating a native vegetation area. Often time and resource limitations in a project dictate the extent of quantification of benefits and costs. The purpose of undertaking economic evaluations is to assist the decision making process by indicating whether a project/course of action is likely to result in a net benefit or cost to society. This does not necessarily require quantification of every benefit and cost. Threshold analysis can be used to indicate the magnitude of unquantified environmental benefits and costs required for a project to at least break even.

3 LITERATURE REVIEW

This section outlines the major factors addressed in the literature which influence the economics of addressing salinity. They include:

- groundwater flow systems
- impediments to change
- uptake incentives
- planting native trees and shrubs on recharge and discharge areas
- planting configuration and
- a modelling review.

3.1 Groundwater flow systems

While there is a range of management techniques applied to native vegetation in addressing salinity, generally the aim is to lower watertables and thus lower the rate of spread and impact of salinity in dryland and urban areas as well as irrigation areas. The groundwater characteristics affect the economic as well as the technical viability of a course of action.

The successful application, timeframe and extent of externalities of native vegetation management are largely dependent on the underlying groundwater characteristics. Groundwater flow systems have been classified as local, intermediate or regional.

In brief, local groundwater flow systems have recharge and discharge areas within a few kilometres, occur within subcatchments in foothills to ranges and show dryland salinity within a decade or so of clearing. Intermediate groundwater flow systems tend to occur in valleys and over 10-50 kilometre areas. Saline discharge can occur from 50-100 years after clearing. Regional groundwater flow systems occur in areas of low relief with a delay time from clearing to discharge of over 100 years (Coram et al (2000)).

The groundwater flow systems indicate the potential effectiveness of vegetation management and the relative significance of externalities. The long time lags between planting or rehabilitating vegetation and impact on the groundwater system mean that often significant benefits are not realised in the lifetime of the initiators. Local groundwater flow systems are most prevalent in Western Australia, comprising 67% of total area assessed for the National Land and Water Resources Audit as high risk by 2050 in Western Australia and 37% nationally (Read et al 2001). In New South Wales, local groundwater flow systems occur in the east, with intermediate systems occurring from the east through to the central west areas and regional groundwater flow systems occur in the southwest, far west and north of the State. In NSW, 21% of the State is affected by local groundwater flow systems, 36% by intermediate and 43% by regional groundwater flow systems (Bureau of Rural Science (2000), DIPNR (2003)).

Where a high incidence of local groundwater flow systems exist, externalities can be less than expected. Local groundwater flow systems facilitate a shorter-term response to vegetation management and salinity.

Read (2001) undertook case studies of tree planting at four different sites (two in Western Australia, one in central Victoria and one in Southern NSW). He cited studies in Western Australia that indicated extensive tree planting would have little effect on watertables beyond 10-30 metres from the planted area. However the type of groundwater flow in each sub-catchment and the spatial relationship between groundwater discharge and recharge influenced the impact of remedial measures on and off site. Read concluded that for the four catchments studied, tree planting for large-scale recharge control would be a poorer investment than shifts to perennial pastures. The study recommended that revegetation with trees is most useful where:

- only a small proportion of the catchment needs revegetation or
- there would be substantial off site benefits.

The Read (2001) project highlighted that vegetation management techniques are not always sufficient to arrest the current and continuing costs of dryland salinity. Two of the case study catchments contained characteristics which encouraged landholder attempts to stabilise dryland salinity. In another catchment no viable technical options were considered available to arrest the impacts of salinity. The other catchment had a small impact from salinity and no action was considered economically feasible or warranted. These studies indicate that retaining native vegetation will not always result in a significant or positive impact on the dryland salinity problem.

3.2 Impediments to change

A common theme throughout the literature and policy implementation is the issue of acceptance of change in landuse.

Crosthwaite and Malcolm (2001) found that the complexity of the farm management and investment decisions were affected by:

- debt levels
- age of farming family
- off farm income
- current enterprises, farm characteristics
- community attitudes
- attitude to risk.

In addressing the issue of implementing change, this study claimed that the economic approaches of regulation, property rights and economic incentives are inadequate as they do not account for the issues contributing to whole farm management. Their conclusion that "… how farmers manage the area of public interest will be influenced by the expected profitability and financial feasibility of investment opportunities elsewhere on the farm" (Crosthwaite and Malcolm 2001) summarises the issue influencing uptake of change and the ability of landholders to implement actions aimed at addressing productivity threats such as salinity.

They suggest that there are four areas to be addressed for public policy to be successful in encouraging on-farm management or site-specific changes in management:

- create opportunities
- develop business skills
- increase capabilities and competencies
- provide support (Crosthwaite and Malcolm 2001).

Uptake of change is influenced by perceived risk. Crosthwaite and Malcolm (1999) identified five risk factors affecting farmer decisions:

- the potential loss of initial capital.
- the timelag before the benefits are realised and the break-even point is reached. The longer the delay the greater risk of changes in costs and prices.
- the scale of the change in stocking rate needed to break even. The greater the gap, the greater the chance of a sufficient increase not being achieved.
- the greater the potential productivity of the land the more likely that the investment will succeed.
- the anticipated gross margins for each farming activity.

Even though there is an awareness of the costs of salinity, adoption of change is often slow due to a host of reasons. Curtis et al (2000) surveyed the attitudes of 480 landholders in the Goulburn Broken Dryland. The Goulburn Broken Dryland Salinity Management Plan (GBDSMP) recommendations included tree planting in recharge areas and protecting and rehabilitating native vegetation in discharge areas.
Of immediate interest were the following observations:

- often dryland salinity originates in poor country with low returns from grazing.
- aging rural population and less expectation of inter generational transfer of properties.
- positive link between on-farm profitability and scale of adoption of best practices to mitigate salinity.
- most landholders did not have the financial capacity to change management practices.
- no strong link between expectation of passing property to other family members and adoption of best practices.
- take up of change is related to the extent of the gap between proposed practice to the current practices/activities.

Other impediments to change (Martin and Metcalfe (1998), Cacho et al (2001)) include:

- establishing trees is a long-term strategy with some time before benefits are realised.
- establishment requires capital.
- lag before water tables affected.
- high percentage areas of catchments need to be planted.
- problem of adoption where recharge area is separate from apparent salinity problems (discharge areas) ie benefits are external.
- need to integrate trees into farming system.
- need for infrastructure to support farm forestry.
- loss of productive land.

These perceived impediments often reflect a lack of understanding of the long-term effects in specific areas of no action to address salinity. They could also reflect the non-financial viability of tree planting in many cases.

The Land Management and Salinity Survey 2002 (Australian Bureau of Statistics (2002)) indicated that the major barriers to changing land management practices were lack of financial resources and time. Insufficient information, doubts about success and age/health were not seen by farmers as limiting factors. The same survey found that reasons for changing land management practices were increased productivity, farm sustainability and improved environment protection.

3.3 Uptake incentives

Lockwood and Walpole (1999a) assessed an incentive policy to protect remnant vegetation. They were against compensation for owners for the opportunity costs of preventing clearing, but did see a role for farmers in providing a public conservation service and receiving assistance for loss of productivity from reduced grazing and timber products from remnant areas. Reimbursement of costs of management such as fencing, weed control and feral animal management were recommended in the form of non-binding agreements, which were preferred by landholders to binding agreements.
From their study in Victoria and New South Wales concerning remnant native vegetation, Lockwood and Walpole proposed 5-year renewable agreements to include:

- remnant native vegetation management plans.
- direct grants for fencing and annual payments for management costs.
- rate rebates for the areas under agreement.

Financial incentives were considered important based on their studies indicating that direct remnant native vegetation management would incur costs to landholders. Alternative methods of payment were proposed as meeting the shortfall between costs incurred by the landholder in managing/retaining native vegetation and the willingness to pay for the benefits as perceived by the general public.

3.4 Planting native trees and shrubs on recharge and discharge areas

The placement of plantings in the landscape is a significant variable. Planting can be broad scale revegetation of a significant proportion of a recharge area or intensive plantings on high recharge areas. This study assumes that recharge and discharge sites can be identified. It is a targeted planting plan, based on planting species appropriate for the area and with sufficient salt tolerance for the site.

Increased recharge has been caused by increased clearing and the replacement of native deep-rooted perennial vegetation with annual shallow rooted crops. Studies (cited in Kuginis and Daly 2001) indicate recharge increases from 3-9% of average rainfall with changes in landuse from forests, pine and woodlands to cropping and pasture. The watertable response[1] to revegetation is variable and depends on the hydrogeology of the area, as well as the location, type and density of plantings. The impacts on the watertable are greater where the watertable is perched or local rather than intermediate or regional. Response rates of the watertable to plantings also vary with salinity, being greater the lesser the salinity. Impact on the watertable depends on the quality of groundwater as well as tree canopy area and the age of trees.

Therefore tree plantings need to be strategically located for maximum effect on watertables. Often the required information on the subsurface water availability is not available. Trees use more water when their roots can reach the watertable than if they can't, or are planted in discharge areas. Kuginis and Daly (2001) cite Western Australian studies indicating that watertable response is greater for upper slope and widespread plantings than midslope and then valley floor plantings. Plantings in discharge areas can be adversely affected by high salt content and poor drainage in soils.

Revegetation of discharge areas can reduce water levels over the short period but the accumulation of salt in the root zone can inhibit impact on waterlevels in the longer term. Generally, planting on discharge areas is considered not desirable or particularly successful.

A consistent theme through the literature is that significant areas, at least 20-50% need to be revegetated to achieve impacts on the watertable (Kuginis and Daly (2001), Herron et al, (2001)). Revegetation can reduce run off in the short term, which increases stream salinity, particularly in the case of catchments with high rainfall (over 900 mm pa).

3.5 Planting configuration

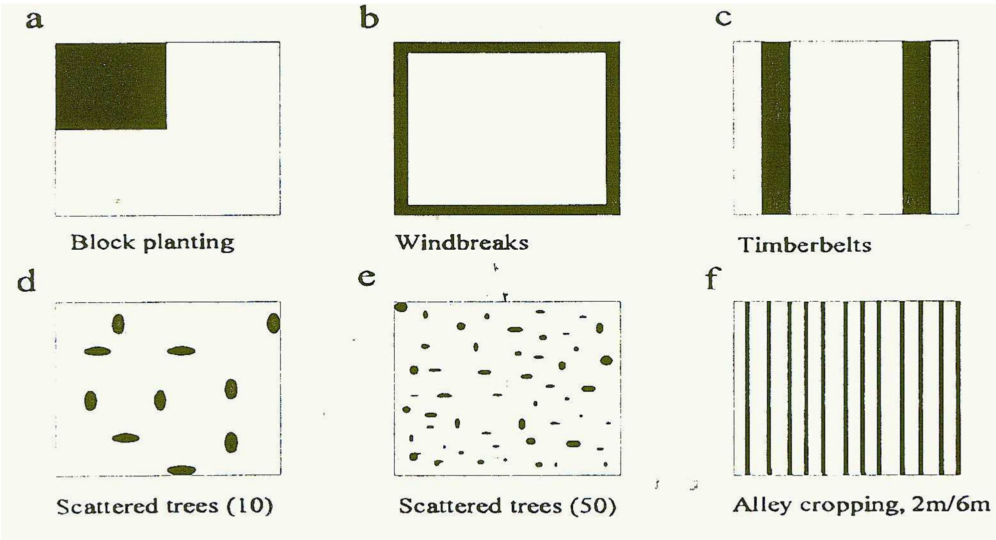
A wide range of planting configurations is possible. The most appropriate for different sites can depend not only on the geography of the site and historical layout, but also on the purpose of the planting apart from reducing salinity impacts. Strip and landscape planting refers to the strategic location of strips and isolated blocks of trees to intercept groundwater before it enters the discharge areas (Kuginis and Daly 2001). Variations in location of plantings can include:

- block
- windbreaks
- timberbelts
- scattered trees, light or dense
- alley cropping or farming, which is mixing tree belts with agriculture.

Diagrammatically the interface and planting patterns are below, as outlined in Stirzaker and Lefroy (1997).

[1] Watertable response is the extent to which the watertable level changes under a given activity, such as landuse change.

Diagram 1 Planting patterns for Trees covering 25% of one hectare



source: Stirzaker and Lefroy (1997)

Many benefits and costs are common amongst these different planting patterns but vary in magnitude (Stirzaker and Lefroy (1997), Hill (2003)).

Planting decisions are complex, with a number of variables to consider, and can be unique to each set of circumstances. Factors influencing decisions can be:

- purpose of planting trees
- value of trees compared with value of displaced crop and other landuse
- value of trees in context of whole farm enterprise
- planting the right proportion of trees in the landscape in optimal places
- current infrastructure, eg fences where landuse is grazing.

3.6 Modelling review

There are a number of ways of modelling the interaction between groundwater, plant use and impacts and potential impacts of salinity. Martin and Metcalfe (1998) outline an extensive list of models developed for assessing various aspects of salinity and landuse. In their review of modelling approaches, van Bueren and Pannell (1999) identify shortfalls in methodologies. Their recommendations for the profession include:

- less focus on cost estimation
- more focus on marginal impacts
- more focus on the potential for GIS application
- the importance of defining and developing the benchmark scenario.

Data constraints influence the methodology. Trends in salinity can be obtained by asking experts, local landholders, or by assessing experimental data. The method used depends largely on data availability, time and resource constraints. Salinity trends need to be linked to the economic modelling. Significant variables include the extent that:

- tree planting affects externalities
- the area of drawdown around tree planting areas. This can vary and depends on watertable (hydrological) characteristics.
- total area of trees to drawdown.

Heaney, Beare and Bell (2001) modelled simulated land use changes on downstream salinity by catchment. This modelling enables comparison of catchments for efficient resource allocations and is a broad scale assessment tool with long time frames of 50-100 years. The study concludes that while the modelling shows significant direct economic costs if increases in dryland and river salinity occur, they are not considered a serious threat to the viability of agriculture in the Murray Darling Basin. However, the results are based on end-of-valley targets, which do not necessarily indicate salinity impacts within regions.

Wandilla catchment (Western Australia) results, as cited in Pannell (2001b), indicate that with 100% tree coverage in the upper catchment and 50% tree coverage in the lower catchment, over 20 years the impact on reduced area lost to salt was 10%. Other modelling has indicated that vast areas of trees need to be planted to reduce salt loads in rivers. Herron et al (2001) used a simple empirical model to estimate the effects of tree planting scenarios on water flows and salt loads in the mid Macquarie catchment and at the end of valley gauging station. The four tree planting scenarios were:

1. business as usual
2. blanket tree planting over the whole mid- Macquarie area, with full forest cover being re-established in the first 15 years, which became effective in reducing runoff and recharge for the next 15 years.
3. blanket planting of the focus areas, (22% of the mid-Macquarie) which were based on land management units identified as being relatively high salt exporting areas.
4. the target scenario based on the best management practices that landholders would be likely to implement. The Herron et al (2001) study applied an increase of 12% in areas under trees in this scenario but these plantings are not based on specific planting, for example, of high recharge areas.

Table 1: Change from year 2000 water yield and the year 2000 salt load estimate for mid-Macquarie over 200 years from a base year of 2000.

	water yield				**salt load**			
year	business as usual	blanket	focus	target	business as usual	blanket	focus	target
2000	100				100			
2020	102	84	98	101	124	124	124	124
2050	109	50	95	107	194	188	189	193
2100	114	54	98	112	252	178	187	244
2200	114	41	98	112	253	92	187	245

source: from Herron et al (2001)

Table 2: % reduction in water yield and salt load from the business as usual scenario for 200 years from base year 2000.

	water yield			salt load		
year	blanket	focus	target	blanket	focus	target
	%	%	%	%	%	%
2020	18	4	1	0	0	0
2050	54	12	2	3	3	0
2100	52	14	2	30	26	3
2200	64	14	2	64	26	3

source: Herron et al (2001)

These tables indicate that under the assumptions of this modelling in this catchment, water yield increases level out in about 100 years and are only marginally affected in that time period by target planting (2% reduction) and slightly more by focus planting (14% reduction). The blanket-planting scenario has the most significant impact on water yields and salt loads. In the business as usual scenario salt load increases also level out in 100 years. Salt loads are affected similarly by blanket and focus plantings in 100 years, but further impacts are achieved on salt loads only by blanket plantings in 200 years.

The results identified the problems in data availability and uncertainty of the most effective areas for tree planting, but did indicate:

- large areas of tree planting are required to reduce downstream salt loads
- modelling was too broad to determine the impact of tree planting on local land salinisation and salt export
- uncertainty in determining timeframes of impacts on flows and loads
- large-scale tree planting will reduce salt loads in the long term but with streamflow losses in the short term.

Cacho et al (2001) approached the question of how much area to plant to trees by applying an optimal control model to determine the impact of tree planting on groundwater levels over a period of 40 years for a series of variables such as yields, land quality, discount rates. This modelling included the costs of foregone productivity of changes in landuse, which incorporated lucerne and eucalypt woodlots as alternatives to wheat. The modelling addresses the profitability of landuse change. This resultant land use mix would appear to be dependent on the initial groundwater level of the base case. The study concludes that the main economic value in woodlots is in reducing recharge for adjoining cropping land.

4 MODELLING

The model developed in this case study is designed to determine the benefits and costs over time of various native vegetation management techniques. The model can assist decision making by indicating preferred planting patterns through analysis of their cost structures. The model has two components. One is the underlying assumption about groundwater response to various landuses. The default position is groundwater response rates based on those for the Murrumbidgee region (van der Lely 2001). The second component is the valuation of benefits and costs associated with each planting configuration and management activity. The model is a spreadsheet model and inputs can be readily tailored to specific areas or conditions.

The modelling estimated the economic benefits and costs of six separate planting patterns of native trees over 30 years as shown in diagram 1. The underlying data was sourced from Kuginis and Daly (2002), van der Lely (2001) and DIPNR CNR Wagga Wagga native forestry plantings (Vic Shoemark DIPNR personal communication). Where data was not available, data from previous studies undertaken by the Department of Land and Water Conservation in the Murrumbidgee and Central West regions (Hill, (1997, 1999,) Jerrems and Hill (1999)) were applied.

The following tree planting configurations, as shown in Diagram 1, were quantified:
- block,
- windbreaks
- timberbelts
- scattered trees
- denser scattered trees
- alley

Diagram 1 (from Stirzaker and Lefroy 1997) shows the above six tree planting patterns for covering 25% of one hectare of land with trees. In this modelling exercise the patterns were applied to covering one hectare of land with trees and all calculations were based on dollars per hectare.

Quantifying the benefits and costs raised the issues of comparison and absolute figures. In some cases it appears that there is little difference in the characteristics of each configuration. However each configuration has its own benefits and costs. Also, how do the estimated benefits compare to another configuration? Even if they appear similar, there are a number of other attributes not quantified that would be significant.

The following quantified benefits of planting native trees were included in the current modelling. For details of underlying assumptions see Hill (2003).
- increased gross margins (income less variable costs) from wind shelter
- gross margins of grazing 3 years after planting
- benefits from timber (sales, on farm use)

- benefits of reduced recharge calculated as avoided areas of land salinised and reduced river salt loads.

Benefits that were not quantified included environmental benefits of aquatic habitats, biodiversity, aesthetic values, etc.

Costs were estimated as:
- costs of planting trees, including tree guards, ripping, and ongoing weeding costs
- costs of erecting and maintaining fencing, both electric fencing and stockproof fencing
- gross margins foregone from the area planted to trees.

4.1. Recharge benefits modelling

Recharge benefits consisted of two components. One was the avoided salt load[2] entering the rivers from a particular change in land use. The other component was the avoided lost productivity of agricultural land that was not salinised[3] due to the change in landuse. The former component is an externality to the landholder. The latter is also an externality to each landholder where the benefits are not received on their holding. Among other variables, this is affected by the groundwater flow system. Where the agricultural benefits of reduced recharge are achieved by a landholder on their own land this benefit is internalised.

Calculations of recharge benefits were based on van der Lely (2001a, 2001b). This modelling incorporated variables and assumptions relating to impacts of tree planting on recharge rates, salt loads and productivity impacts. Recharge savings were based on:
- the volume of recharge reduction due to the change in landuse
- the salinity of the discharging groundwater to a saline area or stream
- value of the salt load reduction
- proportion of saline land which benefits from recharge reduction
- a response time between a reduction in recharge and the full equivalent reduction in discharge.

The value of the reduction in salt load was based on the daily salt load (in this case from Wagga Wagga) and the value of an EC at Morgan being $130,000 per year (van der Lely 2001a). The benefits of avoided land salinisation were based on an average value of production loss per hectare in the Murrumbidgee Region. The modelling provides a dollar value per megalitre of recharge saved.

The response time in achieving salinity benefits from a recharge reduction was based on data in van der Lely (2001b).

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[2] Reduced river salt loads were derived by decreasing recharge, leading to decreased groundwater pressure levels, leading to decreased piezometric head and thus decreased saline discharge

[3] Prevented land salinisation was derived by assessing decrease in recharge, leading to lower watertables, less capillary movement and thus lower rates of salinisation.

Table 3: Input data underlying recharge modelling

variable	input data
value per tonne of salt at Wagga Wagga	$17.63
salinity of groundwater discharge	2000 EC
recharge saved	15 mm per year
period until option is 100 % effective	10 years
area of catchment currently salinised	1 %
multiplier of area salinised	3
value of recharge based on land benefits	$18.60 per ML

source: van der Lely (2001a), van der Lely (2001b)

Based on the assumption of native forestry achieving a recharge saving of 15 mm per hectare after 10 years and avoided losses of salinised land, the total recharge benefits were small at a total dollar benefit of $45 per hectare over 30 years and a discounted benefit of $25.50 per hectare. This consisted of a present value over 30 years of $11.93 per hectare for the avoided land salinisation and $13.57 per hectare for the reduced salt load. Under current calculations the model assumed all planting patterns achieved a similar recharge benefit result. The modelling can accommodate comparing planting patterns and their effectiveness on recharge. The siting of the trees, such as on a discharge area, could reduce their long-term effectiveness and consequently reduce recharge benefits. However, the benefits are relatively so low compared to the other benefits quantified that the impact would be negligible over 30 years. The total present values of the above-quantified benefits of shelter, grazing, timber returns and recharge are shown in the following table. Timber returns are the major benefit (except for the scattered trees).

Table 4: Summary of present value of benefits per hectare over 30 years

	Present Value				
planting pattern	shelter	grazing	timber returns	recharge	**total**
	$/ha	$/ha	$/ha	$/ha	**$/ha**
block	121	403	3,072	25.5	**3,621**
windbreak	270	554	3,072	25.5	**3,921**
timberbelts	508	604	3,072	25.5	**4,209**
scattered trees	201	604	-	25.5	**831**
denser scattered trees	201	554	-	25.5	**821**
alley	604	755	3,072	25.5	**4,457**

Clearly recharge savings formed a small component of overall benefits of planting native trees. Table 5 shows the breakdown of benefits as a percentage of total benefits. While the timber returns are significant, the recharge benefits were less than 1% of total benefits in four planting patterns. The fact that recharge benefits are relatively greater for the scattered tree patterns is due to the assumption that there are no commercial timber returns for those plantings.

Table 5: Benefits as percentage of total benefits over 30 years

planting pattern	shelter	grazing	timber returns	recharge	total
	%	%	%	%	%
block	3	11	85	0.7	100
windbreak	7	14	78	0.7	100
timberbelts	12	14	73	0.6	100
scattered trees	24	73	0	3.1	100
denser scattered trees	29	67	0	3.1	100
alley	14	17	69	0.6	100

4.2 Costs

The major costs incurred in planting trees were compared over the six planting configurations. Costs consisted of preparation costs, fencing costs and gross margins foregone.

A summary of the present value of costs over 30 years is shown in the following table.

Table 6: Present value of costs per hectare over 30 years

	Present value					
planting pattern	preparation and planting [a]	stockproof fencing [a]	electric fencing [a]	foregone gross margin	total present value of costs[b] stockproof fencing	total present value of costs[b] electric fencing
	$ per ha	$ per ha	$ per ha	$ per ha	$ per ha	$ per ha
block	1,114	2,328	931	1,179	4,621	3,224
windbreak	1,114	12,805	5,122	1,179	15,097	7,414
timberbelts	1,114	9,895	3,958	1,179	12,187	6,250
scattered trees	1,114	4,656	1,863	1,179	6,949	4,155
denser scattered trees	1,114	4,656	1,863	1,179	6,949	4,155
alley	1,114	4,656	1,189	1,179	6,949	3,482

[a] including ongoing maintenance costs
[b] errors due to rounding

5 RESULTS AND SENSITIVITY ANALYSIS

5.1 Results

The economic viability of planting trees in these patterns is outlined in this section.

Clearly in this analysis the recharge benefits were a small component of overall benefits. Benefits not quantified were biodiversity and aesthetic benefits. Also not quantified were avoided damage to major infrastructure such as buildings, roads, railways lines etc. resulting from reduced salinity or lowered water tables. Such benefits are site-specific and could be expected to result in positive net present values, especially if the asset is valuable.

Foregone gross margins from alternative activities were significant, as were the preparation costs of establishing tree plantings. The results indicate that economic viability of the various planting patterns is highly sensitive to the assumptions about fencing costs and lengths. Table 7 indicates that if stockproof fencing is assumed, none of the planting patterns show a benefit cost ratio of greater than one. However, the shortfall was only $1,000 per hectare over 30 years for the block-planting pattern.

Table 7: Net present values with stockproof fencing over 30 years

planting pattern	present value benefits	present value costs	net present value	benefit cost ratio
	$ per ha	$ per ha	$ per ha	$ per ha
block	3,621	4,621	(1,000)	0.8
windbreak	3,921	15,097	(11,176)	0.3
timberbelts	4,209	12,187	(7,978)	0.3
scattered trees	831	6,949	(6,118)	0.1
denser scattered trees	821	6,949	(6,128)	0.1
alley	4,457	6,949	(2,492)	0.6

To further understand the magnitude of present values of benefits and costs, the present values were annualised into yearly amounts over the 30 years of the study as shown in Table 8. This indicates that the annual discounted shortfall in block planting would be $81 per hectare.

Table 8: Annualised present values of benefits and costs

planting pattern	annualised benefits	annualised costs [a]	difference
	$ per ha	$ per ha	$ per ha
block	292	372	**-81**
windbreak	316	1217	**-901**
timberbelts	339	982	**-643**
scattered trees	67	560	**-493**
denser scattered trees	66	560	**-494**
alley	359	560	**-201**

[a] includes stockproof fencing

Table 9 indicates that the benefit cost ratios are improved if electric fencing is assumed rather than stockproof fencing.

Table 9: Net present values with electric fencing over 30 years

planting pattern	present value benefits $ per ha	present value costs $ per ha	net present value $ per ha	benefit cost ratio
block	3,621	3,224	397	1.1
windbreak	3,921	7,414	-3,493	0.5
timberbelts	4,209	6,250	-2,041	0.7
scattered trees	831	4,155	-3,324	0.2
denser scattered trees	821	4,155	-3,334	0.2
alley	4,457	3,482	975	1.3

Table 10 shows the annualised benefits and much smaller annualised costs if electric fencing is used. The results indicate that under the assumption of electric fencing, block and alley planting are economically viable from the community's perspective, in that the quantified benefits exceed the quantified costs.

Table 10: Annualised benefits and costs- electric fencing

planting pattern	annualised benefits	annualised costs [a]	difference
	$ per ha	$ per ha	$ per ha
block	292	260	**32**
windbreak	316	598	**-282**
timberbelts	339	504	**-165**
scattered trees	67	335	**-268**
denser scattered trees	66	335	**-269**
alley	359	281	**79**

[a] includes electric fencing

As noted, the benefit cost ratio improves with a change to lower cost fencing. This could occur by using electric fencing or because all or some of the fencing already exists. Table 11 shows that lower fencing costs can result in benefit cost ratios of over one for all patterns except for the scattered trees.

Table 11 Benefit costs ratios with stockproof fencing, electric fencing and no fencing over 30 years.

Planting pattern	BCR stockproof fencing	BCR electric fencing	BCR no fencing
block	0.8	1.1	1.6
windbreak	0.3	0.5	1.7
timberbelts	0.3	0.7	1.8
scattered trees	0.1	0.2	0.4
denser scattered trees	0.1	0.2	0.4
alley	0.6	1.3	1.9

5.2 Sensitivity Analysis

In this study there was uncertainty regarding the actual value and impact of each input variable. Sensitivity analysis enables assessment of a project's feasibility by varying the values of input variables and reviewing the consequent impact on results. The above table indicates that by changing the type of fencing costed the economic viability of a planting pattern can change. For example, if the stockproof fencing cost was reduced from $5,000 per kilometre to $2,850 per kilometre, the quantified benefits of the block planting would break even with the costs. Variables assessed in this section include the downstream costs of salinity; recharge; discount rate; vegetation rehabilitation; and carbon sequestration.

5.2.1 Value of EC at Morgan

Downstream costs of salinity were valued as an EC at Morgan. This is calculated from cost functions of saline river water in irrigated agricultural land and urban areas as well as rising groundwater. For this study the cost of a one unit increase in river salinity at Morgan was estimated at $130,000 per year (van der Lely 2001a). An increase in this figure had little effect on the final results. For example, with an increase of EC value from $130,000 to $300,000, the net present value for block planting was improved by only $18 from minus $1000 to minus $982 over 30 years.

Table 12: Effect of change in value of an EC at Morgan over 30 years

	Estimated value of 1 EC at Morgan	
	$130,000	$300,000
	benefit $ per hectare	benefit $ per hectare
land salinisation	11.93	11.93
salt load	13.57	31.32
total value per hectare over 30 years	**25.50**	**43.25**

5.2.2 Recharge

The modelling was based on recharge savings of 15 mm per hectare per year, which were fully achieved in 10 years with a groundwater salinity of 2000 EC. These assumptions were changed by doubling recharge to 30 mm recharge achieved in half the time (5 years) with groundwater salinity doubled at 4000 EC. Changing these assumptions tripled the benefit from recharge saving but did not result in a significant benefit as shown in the following tables.

Table 13: Impact of changed recharge assumptions discounted over 30 years

	15 mm, 10 years 2000 EC	30 mm, 5 years, 4000 EC
	present value $ per hectare	present value $ per hectare
land salinisation	11.93	25.92
salt load	13.57	58.97
present value of recharge benefit per hectare over 30 years	**25.50**	**84.89**

The impacts of a change in recharge benefits are shown in the table below. Even with a doubling of recharge avoided, with half the time lag for impact, the recharge benefits range from 1.9 percent to 9.6 percent of total benefits over 30 years, as shown in the table below.

5.2.3 Discount rate

The discount rate applied to the stream of benefits and costs over 30 years was 7%. As in many environmental benefits studies, the costs were incurred initially while the benefits continue over time. The discount rate was changed to 4% and 10%, as per NSW Treasury guidelines, to assess the impact of this variable on the total benefits and costs.

The changing the discount rate to 4% and 10% significantly changes the economic viability of the planting pattern options except for the scattered trees planting patterns where the impact of a change in discount rate was negligible in those two configurations.

If electric fencing is assumed, the benefit cost ratio is greater than one for block, timberbelt and alley planting under a 4% discount rate. Under a 10% discount rate all of the planting patterns had a benefit cost ratio less than one.

With the higher cost stock fencing option and the three different discount rates, only the block planting and alley planting appear economically viable with a 4% discount rate. Applying the discount rate of 7% and 10% resulted in none of the planting patterns being viable with stockproof fencing.

With no fencing costs, all the planting patterns except the scattered trees, were economically viable under all three discount rates. Applying the 4% discount rate resulted in benefit cost ratios greater than two while the 7% discount rate resulted in benefit cost ratios close to two and the higher discount rate of 10% resulted in benefit cost ratios of just greater than one.

5.2.4 Carbon sequestration

The value of carbon sequestration was estimated and added to the native vegetation benefits. In some cases of native forestry contracts with NSW State Forests, the value of carbon credits is included in the timber price. In other cases, such as private native forestry, carbon sequestration would be an additional benefit to the landholder. Benefits also accrue to society.

Based on data applied by Walpole and Lockwood (1999) and NSW State Forests (2001), an average annual carbon sequestration rate of 11 tonnes of carbon dioxide equivalent per hectare per year over a 30-year rotation cycle was applied. Using values of $2 and $60 per tonne of carbon dioxide equivalent at a discount rate of 7% per annum over the 30 years, the present values ranged from $273 to $8,190.

Note that payments for carbon sequestration are once off-payments: that is, the cleared and replanted native revegetation must remain in perpetuity. If timber harvesting is involved, the land must be immediately replanted to forestry otherwise carbon sequestration debits will be incurred and credits would have to be bought back.

Carbon sequestration could form a significant dollar benefit when quantified and included in the vegetation management benefits. The following table indicates the estimated present value from carbon sequestration from native vegetation over 30 years.

Table 14: Present value of carbon sequestration benefits

	$2 per tonne of CO_2 equivalent	$10 per tonne of CO_2 equivalent	$60 per tonne of CO_2 equivalent
benefit per hectare of native vegetation[a]	$273	$1,365	$8,190

[a] assumes all six planting configurations were equal.

Certainly including carbon sequestration in the benefits of native vegetation improves the economic viability of planting trees. With an increase in value to the forecast upper limit of $60 per tonne, all but the windbreak planting configuration appeared economically viable under stock proof fencing..

The combination of carbon sequestration benefits and electric fencing resulted in improved benefit cost ratios with alley planting also economically viable at carbon sequestration benefits of $2 and $10 per tonne. All planting configurations were economically viable with a return of $60 per tonne for carbon sequestration.

Table 15 Comparison of net present values and benefit cost ratios at carbon sequestration benefits of $2/tonne, $10 tonne and $60 tonne - electric fencing

planting pattern	$2/tonne		$10/tonne		$60/tonne	
	NPV	BCR	NPV	BCR	NPV	BCR
	$ hectare		$ hectare		$ hectare	
block	670	1.2	1,762	1.5	8,587	3.7
windbreak	(3,220)	0.6	(2,128)	0.7	4,696	1.6
timberbelts	(1,768)	0.7	(676)	0.9	6,149	2.0
scattered trees	(3,051)	0.3	(1,959)	0.5	4,866	2.2
denser scattered trees	(3,061)	0.3	(1,969)	0.5	4,856	2.2
alley	1,248	1.4	2,340	1.7	9,165	3.6

5.3 Distribution of benefits and costs

The benefits and costs in this study were apportioned between landholders and community to indicate the dollar scale of payment to the landholder for costs incurred in providing a community benefit for planting trees.

Landholders' benefits were:
- increased gross margins (income less variable costs) from wind shelter
- gross margins of grazing 3 years after planting
- benefits from timber (sales, on farm use)
- only half the recharge benefits of reduced land salinised. The balance of avoided land salinisation and the benefits of reduced river salt loads were attributed to the community.

The costs incurred by landholders were:
- costs of planting trees, including tree guards, ripping, and ongoing weeding costs
- costs of erecting and maintaining fencing, both electric fencing and stockproof fencing
- gross margins foregone from the area planted to trees.

The community enjoyed the benefits of:
- half the benefits from avoided land salinisation and all the reduced recharge benefits from reduced river salt loads

- sequestration benefits – in this case valued at $10 tonne. This assumed that the landholder did not receive payment for carbon sequestration and the benefits of tree planting were enjoyed by the community.

The shortfalls incurred by the landholders range from an annual per hectare shortfall of $902 for windbreak plantings surrounded by stockproof fencing to $82 per hectare for block plantings with similar fencing (Table 16). Applying electric fencing resulted in shortfalls ranging from $283 for windbreak plantings to $166 for timberbelts. Note that in two cases, those of block planting and alley planting, the use of electric fencing resulted in positive annual benefits to the landholder. This means that no public contribution should be necessary to prompt tree planting in these two cases. Applying only part of the recharge benefits to landholders makes a negligible difference to per hectare benefits.

Table 16: Landholder annualised benefits and costs

planting pattern	annualised benefits	range of annualised costs		range of annualised e differences	
		stockproof fencing	electric fencing	stockproof fencing	electric fencing
	$ per ha	$ per ha		$ per ha	
block	290	372	260	**-82**	**30**
windbreak	314	1,217	598	**-902**	**-283**
timberbelts	338	982	504	**-645**	**-166**
scattered trees	65	560	335	**-495**	**-269**
denser scattered trees	65	560	335	**-495**	**-270**
alley	358	560	281	**-202**	**77**

The community benefits were based on recharge benefits of avoided land salinisation and reduced salt loads, as well as carbon sequestration. These benefits were assumed to be the same for all planting configurations, and with no costs incurred by the community, the annual benefits of tree planting accruing to the community were $112 per hectare (Table 17).

Table 17: Community annualised benefits and costs

	annualised benefits	annualised costs	annualised difference
	$ per ha	$ per ha	$ per ha
all planting patterns	112	0	**112**

If landholders were reimbursed at the maximum rate of $112 per hectare per year, unquantified environmental benefits would need to range up to $790 per hectare per annum in the case of windbreak plantings with stockproof fencing for benefits to equal costs.

This study indicates that native tree planting will not always be commercially viable for the landholder and therefore cannot be expected to be undertaken without some public contribution based on external benefits. On the other hand, the instigation of tree planting by a landholder could be just reducing an existing negative externality. The study also indicates that it is difficult to generalise about whether the economic benefits exceed costs from the community's perspective. The complexity is in quantifying external environmental benefits such as biodiversity as a basis for public contributions.

6 DISCUSSION AND CONCLUSION

This study developed a straightforward methodology for evaluating proposed native vegetation planting projects through specifically evaluating tree planting options. It enabled the inclusion of variables significant to the landholders' costings as well as provision for the community perspective. Specifically, major economic benefits and costs of six planting patterns for native trees were quantified. Benefits consisted of shelter, timber and avoided recharge costs. Costs consisted of establishment, foregone earnings, fencing and maintenance costs. Benefits and costs were calculated over a 30-year period, discounted to present day values for comparison using a discount rate of 7%.

The quantification of economic benefits and costs of tree planting in the specific configurations indicates that there are benefits indirectly relating to salinity control. Under the assumptions applied in this modelling, which were based on data available in the Murrumbidgee region, the impact of native tree planting in reducing land salinisation and salt load was small compared to the benefits associated with shelter and potential timber returns.

The costs incurred in land preparation and tree planting were significant, with fencing being the dominant cost. Without fencing costs, tree planting appeared to be financially viable for landholders, based on the quantified benefits and costs. From the community's perspective, even where the benefit cost ratios were below one, it is likely that other non-quantified environmental benefits, such as enhanced biodiversity, riparian and aquatic habitats, would improve the benefit cost ratio. Planting trees for salinity control, even where there is a local groundwater system, required the expectation and recognition of other economic benefits before appearing economically viable.

Evaluating the six planting patterns raised some important issues:

- Difficulties in obtaining site-specific data: in the absence of site specific data, best guesstimate information can be used to assess viability of proposed native vegetation management for the landholder and for the community.
- Difficulties in comparing different planting patterns: is the data sufficiently sensitive to clearly indicate preferred planting options and sites? Based on the assumptions here, fencing requirements would be a key input into decisionmaking regarding the location of tree plantings. However, the landholder would realistically consider other

issues, for example, the prime reason for tree planting may not be salinity abatement but may be windbreaks, waterlogging, or timber returns.
- Time and cost involved in undertaking a comprehensive analysis: this study developed a straightforward assessment process to indicate economic viability. It can be used as an initial assessment to indicate the usefulness/need of further, more detailed and costly assessments.
- Often the salinity impact requirements of planting in recharge areas are in conflict with the location of optimal soils for farm forestry.
- Allowing grazing can adversely affect tree growth rates with flow-on effects on commercial returns for timber.
- Harvesting trees can cause erosion and remove nutrients, as well as adversely affect habitats.
- Square shaped plantations reduce windbreak effects, but large block plantings and uniform timber requirements reduce habitat diversity.
- Trees grown in saline areas often have poor wood quality, slow growth and short lifespan.

The study found that specific native tree planting configurations of block and alley planting in the study area of the Murrumbidgee Region were economically feasible for both landholders and the community where electric fencing was used. Therefore no financial payments would be needed for block and alley plantings. The results indicate that financial inducements would be required by the landholders to encourage the establishment of less financially viable planting configurations in the Murrumbidgee Region. Such inducements should be subject to the unpriced environmental benefits being sufficient to make total community benefits greater than total community costs.

The study found that salinity benefits, measured as reduced land salinisation and reduced salt loads, were a small component of overall benefits. While six planting patterns were evaluated, the methodology is suitable for establishing the economic viability of native grass management techniques in a variety of geographical areas by changing the input data. This model provides a tool to readily assess the economic indicators of proposed projects.

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