Linking Science and Economics for Policy Advice: Case-study of Trees for Salinity Control

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In the first part of this paper I wish to make some observations about the general subject of the workshop - the extent to which the sustainability debate has affected economic policy advice. This is based mainly on the experience with salinity control in Victoria.

The second part is a case-study in the integration of science and economics for policy purposes, outlining a tree-salinity computer model I have been developing.

1. Sustainability and economic advice

The sustainability debate has undoubtedly affected community demands and government policy; for example, expenditure on Victorian programs for land care and sustainable agriculture totalled $68m in 1990-91, of which $28m was on salinity programs (Victorian Government 1992). Economic advice played a limited part in the salinity plans. For example, it supported the groundwater pumping schemes for the Shepparton Irrigation Region with favourable benefit-cost ratios. On the other hand, for the Goulburn Dryland Salinity Plan, a package of mainly trees and perennial pasture was accepted even though the benefit-cost ratio was less than 0.5, because of the broader environmental and community benefits (SPPAC 1989). Expenditure on other activities such as control of erosion and pests is generally unsupported by explicit economic analysis.

On balance, scientific advice and community demands have been more influential than economic analysis in the programs that have been implemented. However, perhaps the lack of more general economic support explains why government action has been quite small relative to the perceived scale of national land degradation problems.

Sustainability issues have certainly become a significant part of the subject-matter of economic analysis[2]. However, it is more arguable as to whether all the fundamental concerns at the heart of the debate have been successfully woven into economists' practical analysis and advice.

At the theoretical level, economic thinking has ranged over externalities and common property, discounting and future generations, maintenance of natural capital stocks, and valuation of public goods such as wetlands and endangered species.

At the level of practical economics for direct policy advice, one of the main ways in which sustainability issues have been embraced is through inclusion of the more tangible costs of salinity in cost-benefit analysis. Thus externalities have been brought to account, although little attempt has been made to distinguish external from internal benefits in judging the need for government subsidies or incentives.

Some economic analysis has concentrated on reforming resource management through more market-oriented pricing and trading (eg. for water and timber) for efficiency of resource allocation. This often works fortuitously in favour of sustainability (eg. by reducing water usage and recharge), but other situations are possible where more commercial pricing would increase the rate of resource exploitation.

The cost-benefit analyses for salinity plans have been based on fairly conventional principles, including:

- time horizon limited to 30-50 years;

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[2] For example, see Chisholm and Dumsday (1987). At the 1992 Australian Agricultural Economics Society Conference, over 25 per cent of the papers touch on sustainability issues.

- discount rates of 4 per cent (real) for public projects and 8 per cent for private;
- implicit assumption of constant long-term prices for resources and agricultural products; and
- valuation only of marketable products such as agricultural produce and water.

The limited time horizon is not a problem when evaluating investments in assets whose life is just as short. However, it misses the point of the sustainability debate when evaluating, say, forest clearing or regeneration options where the effects may stretch over many centuries. The present value of effects beyond 50 years can be especially large if low discount rates are used.

The public discount rate of 4 per cent may be adequate as a long-term social discount rate, but if that is so, then the planning process for sustainable agriculture would be biased against private investments which have to compete at an 8 per cent rate (taken as the opportunity cost of capital).

Even the 4 per cent rate could be too high as a social discount rate if we accept the approach that the appropriate discount rate itself depends on expected future income growth. In the formula below, the discount rate is derived from components for pure time preference and utility of consumption (Pearce 1982):

$$SDR = RTP - c * m$$

where SDR = social discount rate; RTP = pure rate of time preference; c = growth rate of consumption per capita; and m = elasticity of marginal utility with respect to consumption per capita.

Assuming RTP = 2 (from Pearce's suggested range of 1 to 3) and m = -1.5 (range -1 to 2)

if c = 1.5, then SDR = 4.25
if c = 1, then SDR = 3.5
if c = 0, then SDR = 2.

With these assumptions, a discount rate of 4 per cent is approximately right if consumption growth continues at a rate of 1.5 per cent, as in past decades. However, if fears of declining income growth are realised and income growth drops to zero, a discount rate of 2 per cent (just the time preference component) would be appropriate.

Under the assumption of constant prices, the analyses cannot capture the fears underlying the debate - that through land degradation and other pressures, future generations could face great scarcity of both material goods and environmental quality, with resultant sharp rises in the prices of such goods. Any one landcare project may have little influence on primary product prices, but it would be necessary to allow for higher future values for primary products or resources if the consequences of general resource decline and scarcity are to be tested.

The past analyses perhaps implicitly assume that technological improvements and substitution will continue to offset any tendency to resource depletion or diminishing returns. However, there is no inherent economic reason why the favourable trends of the past will continue inexorably, particularly with increasing pressure on the environment's capacity to assimilate waste. There seems, however, to have been little attempt to reconcile the price assumptions in economic analysis with the fears of long-term scarcity.

Linking science and economics is crucial because much of the sustainability debate is based on physical/scientific estimates of change in soil characteristics, groundwater pressures, stream salinities, species numbers etc., often showing a deterioration in quality or quantity. Either economics needs to be extended to bring the scientific information to account, or vice versa. In some cases, however, it may never be practicable to apply economic valuation (eg. ecological diversity). A safer but limited approach is cost-effectiveness studies - estimating the cost of different methods of attaining a physical target, or optimising under restraints of maintaining certain reserves of environmental capital.

2. Tree-salinity-economics model

SALTREC is a computer model which provides an economic (cost-benefit) framework for integrating scientific data on the processes involved in tree growing and salinity[3]. It is designed to estimate the

[3] It is part of a project funded equally by the Rural Industries Research and Development Corporation and the Victorian State Salinity Program over 1990-91 and 1991-92.

economic value of the salinity and water yield consequences of tree growing, which are frequently external to the tree grower's property. It operates in conjunction with another model FARMTREE which evaluates the direct costs and certain other on-farm benefits (timber and shelter) from farm trees. Less tangible benefits such as aesthetic value, wildlife habitat and erosion control are not included. Special attention is given to salinity because a great deal of quantitative information is being produced from research work, but is otherwise used only in a fragmented way.

The main aims of the modelling include:
i) estimating the size of government grants for tree planting that might be justified; and
ii) estimating the private profitability of tree growing for salinity control in order to help advise farmers.

Key features of the model include:
- simulation of tree growth, water use, groundwater and salinity levels over time, with discounting of future years benefits;
- integration of runoff, groundwater and streamflow effects; and
- summation of economic effects on
  - agricultural productivity through land salinity
  - stream salinity
  - water yield.

The model incorporates a highly simplified view of hydrological processes, but is based on the need to include at least an approximation of the causal linkages between the economic inputs and outputs involved, i.e. between:
i) farm management options such as planting trees on a given area at a given density, and
ii) the consequent effects on the community's welfare through productivity and water quality and quantity.

Most of the program is concerned with hydrological data and relationships rather than economics. The intermediate effects on various hydrological variables have no inherent economic significance, but are necessary to make the link between management actions and welfare effects, and also to allow validation of individual components against field measurements.

A diagrammatic view of the catchment model is shown in Figure 1, and a flowchart of the relationships is shown in Figure 2. A more detailed progress report is available from the author.

The analysis has concentrated on tree planting in **recharge areas** removed from the associated discharge area. An analysis for discharge areas in **irrigation areas** has been reported elsewhere (Joint Agroforestry Management Committee 1991).

The SALTREC program is written in QuickBasic 4.5, and runs in DOS on IBM-compatible computers. The compiled version with associated files requires about 400 kB of disk space. A single run of the model relates to just one tree project in a single catchment, and takes less than 15 seconds. Any of the input data can then be changed to test the effect of different strategies or site conditions.

The program includes the following components:

Catchment Zones: The catchment is divided into specified initial proportions of cleared and native forest, and different zones according to recharge characteristics and initial depth to watertable.

The simulation is first run for a catchment in its initial state; and then run with a specified area planted to trees, and the consequent cost and savings calculated. The program has been extended to allow perennial pasture to be tested as another option.

Runoff and Streamflow: The initial components of streamflow from runoff and recharge are inferred from data on the average salinity levels of streamflow, runoff and groundwater.

Tree size: Tree height year by year is estimated from a logistic growth function, and crown width and root width are taken as simple proportions of height. Percentage crown cover is calculated from crown area and tree spacing.

Water use: Water use by plants (pasture, native forest and planted trees) is computed from a quarterly simulation of demand and supply for water.

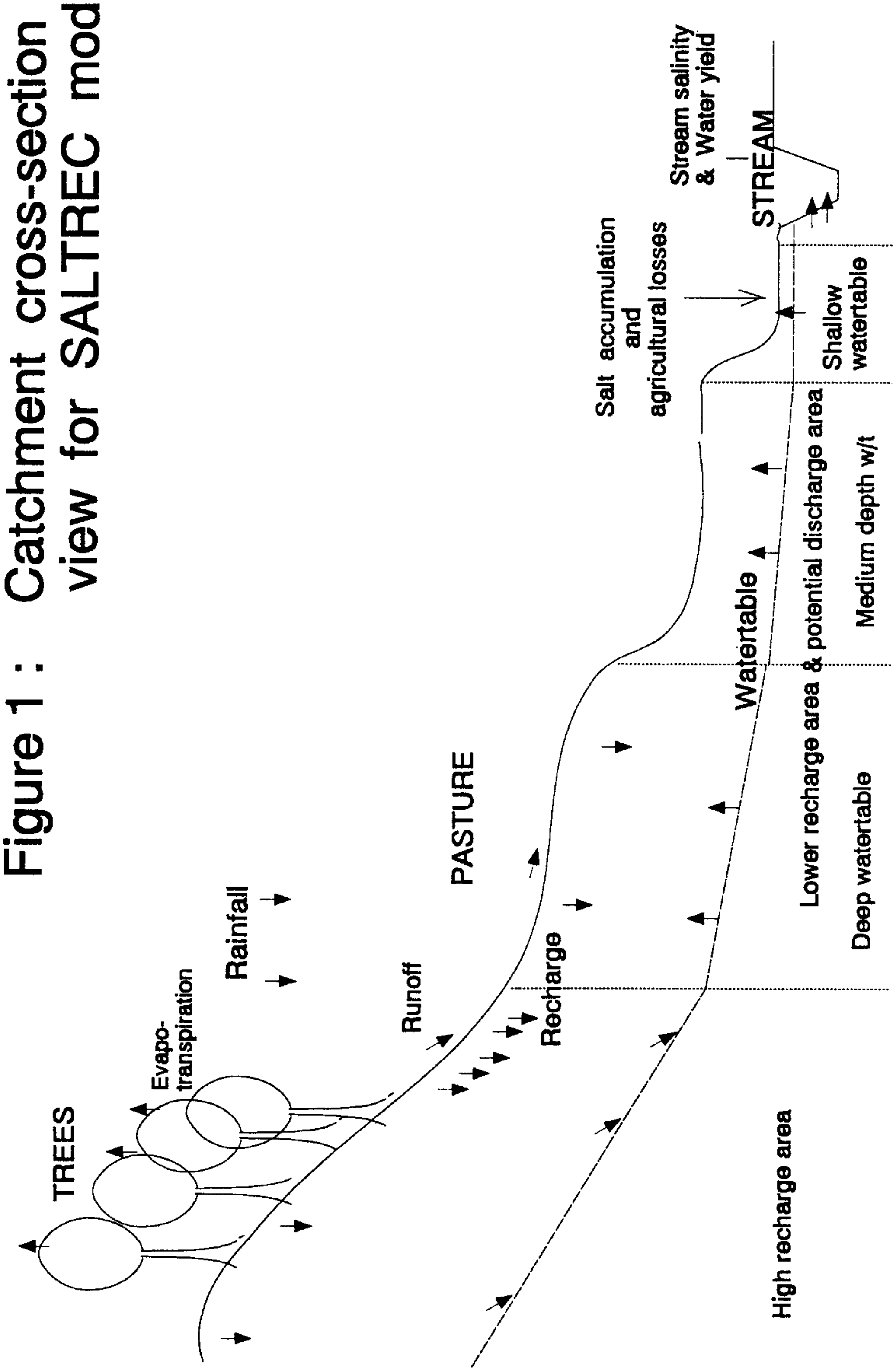

Figure 1 : Catchment cross-section view for SALTREC model

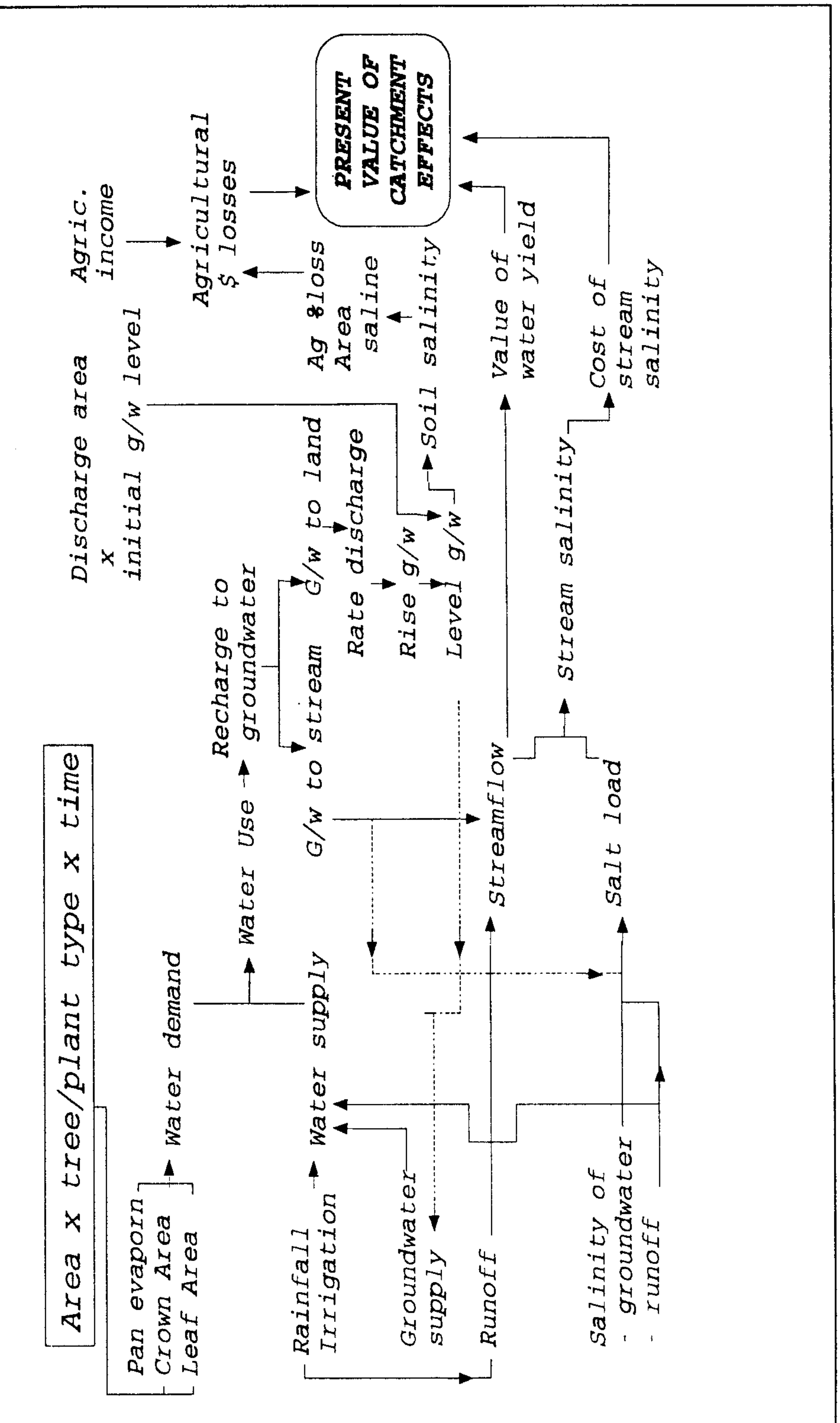

Figure 2 : Flowchart of relationships in tree-salinity -economic model

Water use is equated to the minimum of demand and supply.

Potential demand is equated to:

Pan evaporation x Crop factor (benchmark for unlimited supply) x Leaf area index x Crown coverage.

Supply of water is equated to:

Rainfall + Irrigation + Groundwater + Soilwater less (Runoff + Use by residual pasture).

Groundwater supply depends on the extent to which the watertable is within reach of the trees' root zone. Soilwater depends on whether the previous season's unused infiltration is within reach, which in turn depends on the rate of infiltration and root depth. A factor for reduction in runoff under trees is given as input.

The salinity benefits of trees and perennial pasture in the model derive from the higher evaporative crop factor and deeper roots, and hence increased water use and reduced recharge and discharge. Water use by trees increases to a maximum as their crown coverage and root depth expand, depending on spacing and growth rate.

Accessions to groundwater: Accessions = (Rainfall + Irrigation) less (Runoff + Water use).

Groundwater accessions are split between two destinations: land (affecting the watertable) and stream.

Streamflow and salinity: Volume streamflow = Runoff + Groundwater flow to stream.

Salt load in stream = Salinity concentration x Water volume.

The salt components from runoff and groundwater are computed separately, the latter having a higher salinity level.

Stream salinity = Salt load / Water volume.

Change in salinity concentration in the Murray River at Morgan (in SA) = Change in salt export from river catchment x Dilution factor based on estimates by Rural Water Commission.

Value of water yield (at the margin) is derived from budgets of irrigation enterprises.

Cost of salinity to water users is based on surveys of damage for households, industry and agricultural users, up-dated and used by the Murray-Darling Basin Commission. The greater part of the cost falls in South Australia, but may be transferred to Victoria through the requirements to earn salt disposal entitlements. The cost of salt interception downstream would then be more appropriate.

Discharge: The groundwater accessions not directed to streamflow are assumed to raise the groundwater level uniformly across the whole lowland area (ie, all parts of the catchment other than the high recharge area). This is perhaps the weakest link in the chain of assumptions in the model, but alternatively the discharge rate can be imported from a more detailed groundwater model.

Change in watertable level = Rate of discharge / Soil moisture storage coefficient.

New level of watertable (up to equilibrium level) = Initial depth of watertable + Change in last period.

Soil salinity is based on accumulated mass of salt in plant root zone, which is derived from rate of discharge and salinity of groundwater, less a leaching fraction.

Agricultural income: In areas where watertable has risen to within root zone, agricultural productivity is assumed to decline linearly as the soil salinity level increases[4].

Agricultural income loss = percentage loss in productivity x net income per hectare (presalinity) in discharge areas.

Constant long-term agricultural prices were assumed in the absence of firmer evidence of change within the 50 year life of trees used in most cases tested.

Net savings: Net catchment saving = Discounted

[4] Coefficients representing the threshold salinity level before damage, and the rate of decline for different plants were developed from work by Maas (1986) and Mehanni and Repsys (1986) (P. Shaw, pers. comm.)

sum of change in value of streamflow, stream salinity and agricultural production.

Other net benefits are calculated with the aid of the FARMTREE model which is particularly designed to evaluate the costs and returns from planting at different spacings.

Overall Net Present Value = Timber value - Cost of establishment - Agricultural opportunity cost + Catchment saving.

Preliminary Economic Results

The results are highly site-specific: the size of net catchment benefit varies widely with the set of parameters characterising the particular site. It was frequently in the order of $250 per hectare of trees (at 4 per cent discount rate) in the cases tested.

The net catchment benefit can be strongly positive (up to $1000/ha) in certain high recharge areas with highly saline groundwater, or where the tree roots can tap sub-surface flow or aquifers. On the other hand, it can be negative in higher rainfall catchments where the reduction in yield of fresh runoff water outweighs the reduction in salinity.

In most cases in low rainfall recharge areas, the positive value of catchment effects is outweighed by the net cost of tree establishment and agricultural opportunity cost. However, there are limited areas where strategically-sited and well-managed agroforestry appears to be profitable, or in some cases could be worthwhile if the off-farm benefits are included. Perennial pasture produces somewhat lower salinity benefits, broadly in proportion to its ability to reduce recharge, but can be profitably planted across a broader area of the landscape.

The net catchment benefit increased from $100 at an 8 per cent discount rate, to $420 when 2 per cent is used. With agroforestry regimes, net benefits may be maximised by harvesting the trees on a rotation period of 25 to 40 years, but stands that are self-regenerating may have indefinite lives and ongoing salinity benefits. At the 2 per cent discount rate, the benefit increased from $180 for a 30 year life to $1500 for a 200 year life. The corresponding increase in annual equivalent value was from $8 to $37. By contrast, the annuity value of normal investments which require re-investment every 20 to 30 years is not altered by extending the period of analysis. Introducing a long-term increase in primary product prices would further increase the annual benefit for long-lived tree investments.

3. Conclusion

Salinity and other sustainable development issues have become a major topic for economic analysis, but evaluation at the practical policy level has proceeded on fairly conventional lines of discounted cost-benefit analysis and free market encouragement. The concerns in some scientific quarters and the wider community about resource scarcity for future generations are addressed in some theoretical economic discussion, but have usually not been reflected in practical economic work. Time horizons are usually limited to 30-50 years, and the discount rates and prices used assume away the possibility of long-term scarcity. There is still a considerable gulf between the detailed scientific research on deterioration of particular aspects of the environment and its economic application.

The tree-salinity model outlined above involves the integration of scientific data about long-term processes into a cost-benefit analysis. It addresses the deficiencies above in only a limited way - it accounts for salinity and water yield but not other externalities, and has been used for sensitivity testing of lower discount rates and longer time horizons, but the assumption of constant prices has been retained to date. The model remains a compromise between the great detail found in site-specific hydrological research and the need to design broad policies applicable across the State.

The model's estimates of the magnitude of catchment externalities are most relevant to government policies to correct the market failure. The other private costs and benefits are relevant to landholders' profit-maximising decisions and to government extension efforts. The net returns are highly site-specific, and trees are likely to be economic only on a small percentage of existing farmland.

Questions remain as to how to apply the quantitative estimates from the model in government policy.

Subsidisation of tree growing and other means of salinity control is the predominant approach in Victoria. Taxing salt export may be more in line with the 'polluter pays' principle, but has generally been seen as impracticable.

If it is accepted that a divergence between private and social discount rates is causing sub-optimal allocation over time, then a partial response would be to provide a component in grants for tree-growing designed to compensate. This would inevitably be a second-best approach, and broader policies should be considered to address the divergence more directly. However, investments that protect important endangered environmental assets would warrant priority assistance.

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