ECONOMIC COSTS OF LAND DEGRADATION: ASSESSMENT, ANALYSIS AND POLICY IMPLICATIONS[1]

By

Thilak Mallawaarachchi & Mike Young

CSIRO Division of Wildlife & Ecology
P O Box 84, LYNEHAM, ACT 2602
AUSTRALIA
Ph 06-242 1783; Fax 06-241 3343

ABSTRACT

Growing emphasis on socially compatible land management entails reduction of costs of degradation associated with current land-use systems. In this paper areas of confusion over the assessment of land degradation costs and their use in policy are examined. A framework to incorporate net private and social costs of land degradation is presented. This framework incorporates the paddock level costs as NAIL (net agricultural income lost), extends to include the wider implications of land degradation (WILD) represented by the regional impact EVIL (external value of income lost) through effects on regional employment, and then off-site impacts on other resources.

It is argued that careful analysis of these costs not only provides criteria for evaluating current land-management systems, but also offers a platform for the development of policy options. The potential of this platform is demonstrated with an examination of soil conservation policy alternatives.

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1. Introduction

Governments across the globe are faced with a challenge to promote resource management policies that are economically efficient as well as environmentally benign and equitable. The case for intervention depends on the degree to which existing markets and institutional arrangements fail to achieve these policy goals. The rate of change in this policy area suggests that governments perceive a significant mismatch between social preferences for the use of natural resources and the uses being made of them. Conditions necessary for a match include perfect information, negligible transaction costs, fully mobile resources, fully specified and enforced property rights and limited interest in non-market considerations. For many environmental goods and natural resources, like land, these criteria are often not satisfied. Market choices do not coincide with social preferences.

Throughout Australia, the amelioration of agricultural land degradation ranks high as a policy goal. The approaches being taken to reduce land degradation are a mix of persuasive, regulatory and economic instruments. The persuasive approach is typified by the National Landcare Program, and the regulatory approach by the prohibition in NSW of clearing of slopes greater than 18%, and the requirement for Western Land Lessees to obtain a cropping licence. The economic approach is typified by state subsidies for the use of soil conservation equipment and the special treatment of soil conservation expenditures in the income taxation system. Whenever these policies are reviewed, the demand for physical and economic information is high.

While there has been some enthusiasm to respond to this demand, available information on economic assessments and valuations remains limited. There is also some notable confusion among economists and non-economists about the nature of economic costs, their assessment and as to how these estimates can be used in policy analysis and development. Several complementary approaches have been used to assess the economic costs of resource depletion. Often the objectives of these assessments and their significance for policy differ. In particular, the trade-offs between the goals of economic efficiency and environmental quality are addressed differently. For example, Sinden and Yapp (1993) used regression analysis to estimate opportunity costs of agricultural production from the relationship between spatial changes in the value of production and land degradation data. Dumsday and Oram (1990) used *SOILEC,* — a process-based computer model— for selection of efficient on-farm enterprises. Wilson (1992) extended this analysis by linking *SOILEC* to

SCASEE to incorporate off-farm impacts. Hall and Hyberg (1991) provide evidence of the effects of degradation on output using ABARE farm survey data.

There is some controversy over the most appropriate way to measure opportunity costs of degradation. Conventionally, opportunity cost is the value of the things foregone in the process of achieving an outcome. If the difference between the value of an outcome and the opportunity cost is negative then a loss is incurred. Typically, opportunity cost estimates include a computation of profit forgone as well as an assessment of changes in outlays. The issues include arguments about

- the conflict between profit maximisation and stewardship motives of land holders (Van Kooten *et al.* 1990);
- the philosophical basis that underlies the economic analysis of soil erosion (Van Kooten and Furtan, 1987);
- social and private optimal levels of soil erosion (McConnell, 1983);
- relative importance of *off-site* costs (Seitz *et al.*, 1979; Clark *et al.*, 1985)
- the distinction between cost of erosion control and the cost of erosion (Russell *et al.* 1990); and
- the use of non-market valuation techniques to estimate social preferences for these considerations (Hamilton 1993; Blamey and Common 1992).

Recognising all the above issues, the objective of this paper is to present an analytical framework that facilitates the assessment of the opportunity costs of current land-use practises across space and through time for large areas of Australia. The framework integrates physical and economic aspects of production at a level of disaggregation sufficient to capture the heterogeneity in natural, social and economic systems. Using SRIAS - a Statewide Resource Information and Accounting System - being developed by CSIRO (Walker and Young, 1993), economic implications of reducing the off-site impacts of sheet and rill erosion in the Lachlan catchment of NSW are explored. The Lachlan Valley region covers an area of approximately 10,000 square kilometres along the Lachlan river in NSW, Australia. The annual agricultural output from the region in 1989-90 was around $358 million.

2. ECONOMIC ASSESSMENT OF LAND DEGRADATION COSTS

Economic assessment of land degradation costs, for example those arising through soil erosion, is complicated. Some effects are local (on-farm or on-site) and only affect production potential where the erosion occurs. But erosion can also have off-site effects on neighbouring properties, water storage capacity and expenditure on recreation. Ecosystem function values and non-use values associated with existence and bequest values can also be important. Finally, the effect of erosion on national and regional income needs to be accounted for.

What is value?

Market values result from the collective impact of individual choices as people buy and sell goods and services. Using these values as a reference point, economic valuation attempts to describe or measure social preferences. As Pearce (1993) notes "measuring preferences is a clumsy phrase but at least it tells us what economic valuation is." Economic valuation uses monetary reference points to rank alternatives and identify the options most likely to be preferred by society. From a policy perspective it is useful to distinguish between 'use values', that relate closely to the notion of utility, and the non-use values or intrinsic values associated with many resources (Pearce and Turner, 1990).

For those goods and services available through the market, price offers a basis for valuation. Equity issues aside, when markets are efficient, prices tend to reflect the values that society places on resource use, including natural resource use. For a market to work efficiently, however, clearly defined rights of access, availability of perfect information — including a clear description of the various attributes of the resource, and clearly defined and enforceable property rights are essential. It is also important that resources are perfectly mobile, and that transaction costs are insignificant. In the case of soil erosion and most other forms of resource degradation, few of these conditions apply. Thus governments have an incentive to intervene in an attempt to make resource use consistent with their perception of social preferences for resource use. Taking a precautionary stance, there is also an important intergenerational equity argument that suggests that, irrespective of market circumstances, future generations would prefer present generations to maintain the productive potential of conditionally-renewable resources (Young 1993). This argument for "ecologically sustainable forms of development" provides an additional dimension for the concept of value.

Why value beyond the market?

One of the goals of economic valuation is to capture and reveal the nature of social opportunity costs. Then information is available to develop policies and instruments consistent with social preferences. Inadequate availability of information; differences in the time frame linked to the resource-use decisions between individuals and society; existence of transaction costs; the high costs of enforcing property rights; and a concern for future generations all lead to a divergence between market and social preferences for the use of natural resources and the maintenance of environmental quality. Economic valuation provides a mechanism to evaluate the extent of this divergence and "assess" the likely social benefits of policy alternatives in an objective manner. It seeks information about the magnitude of these divergences (and, also, information that is not intuitively obvious). *On-farm (site)*, the first challenge is to measure losses caused by lack of information about technological options and the substitutability for natural resource attributes. A second on-site issue is to measure the consequences of the lack of market incentives to adopt land use practices that preserve opportunities for future Australians. *Off-site*, the issue is one of the extent of the costs not met by the farmer. When farmers select a particular rotation, for example, some soil and associated nutrients may be lost to a neighbour's land and some may be delivered to the stream network. When soil erosion only decreases productivity elsewhere, farmers who owns the land where the soil came from has little economic incentive to adjust their practices. It should be noted that many farmers face strong social incentives to avoid practices that reduce the productivity of their neighbour's land. The Landcare movement capitalises upon this fact. Our framework ignores this last point.

How to value?

Economic valuation of resource degradation needs to establish spatial and temporal effects of degradation, and more importantly, the distribution of economic costs indicating the likely bearers of the costs and the extents of the costs.

In the absence of revealed measures of willingness to accept sacrifices (or willingness to pay for benefits), or market indicators of the value of degraded resources, assessment of environmental implications of land use, such as land degradation, must be based on value-imputation techniques.

Impacts of land use generally reflect on the environmental quality and the productivity of resources associated with land–use, they in turn affect the market measured variables such as product prices, availability of commodities and demand for technology. Value–imputation techniques use these indirect signals as the basis for assigning values to non-market measured changes in resource attributes.

Environmental cost assessments are not uncommon in Australia. Notwithstanding their limitations and weaknesses (Sinden, 1993), they have served the useful role of highlighting the issues and demonstrating the need for concern. They have also sparked widespread interest, healthy debate and notable reaction from different stakeholders.

Nevertheless, the benefits remain patchy and what seems to be required is a more coordinated effort with meaningful policy targets to be achieved within conceivable time frames. The framework of assessment presented below and the analysis and policy implications discussed in the two sections that follow aim to meet this objective.

3. A FRAMEWORK OF ASSESSMENT

This framework is developed with the following assumptions and understanding. Land degradation is a dynamic process linked to natural and human induced processes. Degradation affects land capability and restricts land management options and income generating opportunities. The processes of degradation are generally well understood at the paddock level. This enables the development of effective management options to mitigate the consequences.

The framework views land degradation as a whole farm management issue with temporal and spatial interactions. Time scale is incorporated by making annual estimates of degradation and associated economic costs which allow inter-year comparisons. Estimates are based on production data aggregated over statistical local areas (SLA), through to larger catchments and finally the state. This allows true representation of spatial variation. Care is taken to partition costs among private market-based assessments and the broader social implications of land use. This framework:

a) separates on-site effects associated with changes in production opportunities at the site (paddock) level where degradation occurs,

- from off-site effects associated with the transport of soil to other locations;

b) separate private assessments of cost,

- from social assessments of cost which tend to be characterised by lower discount rates, recognition of market distortions and the interests of future generations; and

c) identifies the flow-on or multiplier effects that degradation can have on future opportunities to add value to agricultural products at the regional and national level.

Care is also taken to avoid double counting.

Techniques of assessment

Various techniques have been developed for imputing monetary values on environmental impacts. Pearce and Warford (1993) considered three categories. The first category, surrogate–market techniques include approaches such as hedonic pricing and the travel–cost method; the second category includes survey–based methods to determine the willingness to pay for benefits, and the third involves estimating dose-response functions from experimental data and then valuing the impact using market prices corrected for distortions arising from market failure to reflect social preferences.

The approach used in this research falls under the third category and employs physical production and market information, organised over production units to estimate the opportunity costs of land degradation (Mallawaarachchi, 1993).

Estimating soil loss

Soil erosion estimates developed using annual weather data and, landscape and soil characteristics using the USLE (Wischmeier and Smith, 1965). USLE produces an estimate of the potential erosion hazard, rather than the expected that may result from the variations in causal factors, that an annual estimate should really reveal. We plan to revise these estimates using PERFECT (Littleboy et al, 1989) once we meet the data requirements.

The USLE relates soil loss to rainfall erosivity, *R*; the soil erodibility, *K*; the slope of the land, *LS*; a crop factor, *C*; and a conservation practice factor, *P*. The soil loss *D* is then calculated as

$$D = R \cdot K \cdot LS \cdot C \cdot P. \tag{1}$$

For the area covered in this study, the ranges of USLE parameters are given in Table 1. Value of 1 was used for parameter *P* in all areas.

Table 1: Ranges of USLE parameters for the study area.

Parameter	Range
R	850 - 1300
K	0.024 - 0.039
LS	0.13 - 4.8
C	0.16 - 0.23
P	1 (for all areas)

To estimate the effect of erosion on yield, an average yield penalty factor derived from Aveyard (1983) was used. The resulting value of yield reductions were based on the local value of agricultural outputs to obtain the Net Agricultural Income Lost (NAIL) for each SLA. Alternatives are to use the relationships developed by Sinden and Yapp (1993), which produces somewhat higher estimates, or to use PERFECT (Littleboy et al, 1989) to simulate erosion-productivity effects.

Net Agricultural Income Lost — NAIL

NAIL incorporates the direct potential market consequences or the opportunity cost to the landholder of land degradation — the market value of forgone net farm income due to reduced land productivity (Figure 1). It varies primarily with the rate of soil erosion and the rate of productivity decline.

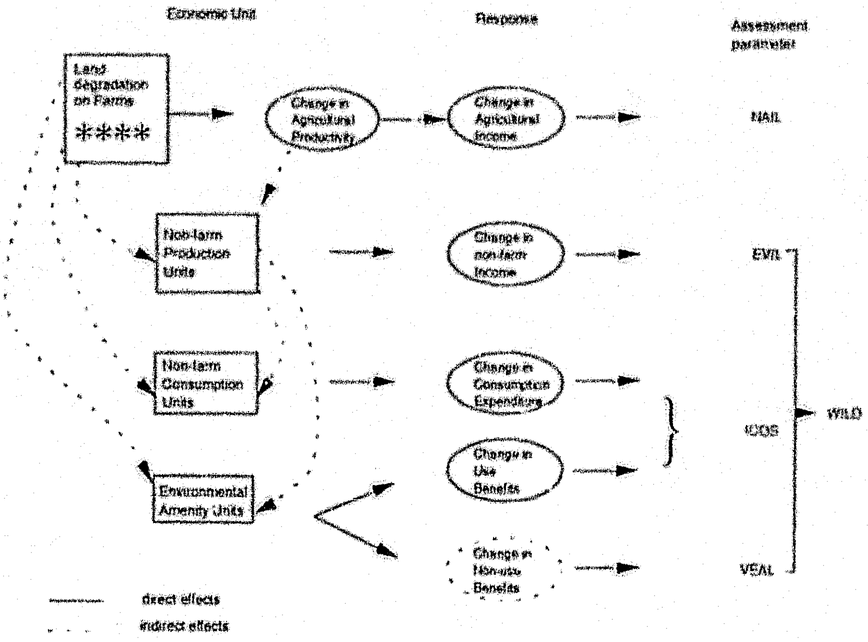

Figure 1: Potential economic effects of soil erosion

The formula used to compute *NAIL* over a mapping unit (pixel) a is as follows:

$$NAIL_a = \sum_i AIL_{ia} \cdot A_{ia} \cdot D_{ia}$$

where AIL_{ia} is net farm income loss for crop i over area a, A_{ia} is area of pixel, and D_{ia} is the potential level of erosion. *NAIL* estimates for Lachlan catchment are shown in Table 2.

Table 2: Net Agricultural Income Lost *(NAIL)* 1989/90 for Lachlan catchment.

Land use	*NAIL($m)*	*NAIL($/ha)*
Pasture	15.5	3.95
Cereals	2.7	2.77
Other annuals	2.23	48.37
Horticulture	0.68	135.01
All uses	21.09	4.27

If these estimates reasonably reflect the actual levels of erosion taking place in Lachlan Valley and the same level of production is possible without degradation, then, nearly 6 per cent of potential agricultural income is lost due to soil erosion. This is based on an estimated gross value of agricultural output of $358 million in 1989-90 for the Lachlan Valley. This reduction in potential income is rather small compared to a value of 38.8 per cent estimated for the wheat-sheep zone of NSW by Sinden and Yapp (1993), using econometric methods.

Wider Implications of Land Degradation — WILD

NAIL incorporates the first order impacts of degradation impart on the users of farm land. On the other hand, *WILD* represents the second order effects of degradation or the off-site impacts, including the value of negative externalities borne by other economic agents than the landuser who contributes to land degradation. These implications can vary widely and are rather difficult to capture. The analytical framework adopted in this study considers these implications under three categories — *EVIL*, *ICOS* and *VEAL* (Figure 1).

The first, *EVIL* measures the value of lost income opportunities to people who would normally add value to the agricultural products that as a result of degradation are no longer produced. Those jobs are external to the factors usually included in estimates of opportunity cost so we call these 'EVIL', the external value of income lost.

The second measure, *ICOS* — imposed costs on society —, incorporates the potential social ramifications associated with deterioration of environmental quality such as, increased water treatment costs, lost recreation income and reduced asset values. Other implications, for example, the changes in non-use values of environmental and ecological resources such as water bodies and fauna and flora habitats are grouped under *VEAL*, which is the value of environmental amenity loss. At this stage, however, our data only permits valuation of use benefits and no estimates for *VEAL* are produced.

In reality, land degradation on one farm generates costs on adjoining farms, for example from trampling of seedlings due to sediment deposition, and on distant farms due to impacts on salinity. Such impacts are not currently incorporated in the analytical framework as our current understanding and data availability do not allow us to isolate net effects.

External Value of Income Lost — EVIL

EVIL attempts to measure the net non-farm market value of potential income losses as a direct consequence of *NAIL*. This represents the value of income losses to the individuals beyond the farm gate where the erosion originates. It also varies depending on whether the effects are seen as a private individual or as a community but includes lost marketing, transport and processing opportunities.

A thorough estimation of *EVIL* requires access to detailed regional input–output coefficients for agricultural activities. Such data was not available for the current exercise. Therefore, the *EVIL* estimates reported in Table 3 are based on first approximations using the difference between gross and local value of agricultural products.

Table 3: External value of Income Lost *(EVIL)* 1989/90

Land use	*EVIL ($mpa)*	EVIL ($/ha)
Pasture	2.86	0.73
Cereals	0.98	1.00
Other annuals	0.29	58.37
Horticulture	0.22	43.74
All uses	4.36	0.88

Imposed costs on society — ICOS

Reduction in environmental quality imposes costs on individuals in terms of asset depreciation, increased defensive expenditure and reduced productivity of assets. However isolating and assembling these costs in a non-duplicatory manner needs careful analytical attention and requires an extensive range of data.

Australian estimates of the wider income losses associated with land degradation are non-existent but may be similar to those found in the USA. The best known of these studies is that by Clark *et al.* (1985) which found that the ratio of on-farm to off-farm costs (not including *EVIL*) ranged from 1:2 to 1:8.6 with a best estimate of 1:4. For the purpose of this paper, we assume conservatively that it is 1:2 because the recreational impact in Australia is likely to be much less than that found in the USA. On this assumption, the *ICOS* estimates would represent a doubling of *NAIL* estimates presented in Table 2. Other ratios are possible and await more empirical work of the type currently undertaken by Dumsday *et al.* (1992).

5. ANALYSIS OF LAND DEGRADATION COSTS

Economic analysis helps identify and assess the strength of linkages and relationships between economic activity and economic agents. It provides the basis for policy planning and program development. In general, policies are developed with broader objective focus at national or state levels. They include several programs designed to meet policy objectives, with possible variation at regional levels. Programs in turn are implemented as projects at a more local level—such as the farm or household level—, with narrow but compatible focus with broader program and policy objectives. Execution of these projects in turn takes place at field or paddock level. These four levels correspond to the four-fold hierarchy of sustainability defined by Lowrance *et al.* (1986): field, farm, region and nation. Objective setting, planning and implementation at each of these levels would benefit from information from economic analyses.

Analysis of degradation costs provides opportunities for determining whether a particular activity or land–use option should be facilitated or encouraged through public policy and/or community initiatives, such as the National Landcare Program, over other possible uses. It highlights areas for policy intervention, program targeting and selection of project attributes. In this section the economic cost measures developed for soil erosion in the Lachlan catchment are analysed to identify policy relevant information.

Cost characteristics

It is noteworthy that despite the low levels of estimated soil erosion hazard over horticultural land uses, for example the estimated economic impact of erosion upon them is substantially higher per unit area due to the high value of horticultural crops (Table 2). Also, there appears to be considerable variation in erosion levels both between regions and within regions among different land uses (Mallawaarachchi, 1993). Seasonal changes in weather patterns contribute to noticeable year-to-year variations. Moreover, problems are neither uniformly distributed across space nor through time.[2]

Management issues

Under Australian conditions, the rate of soil formation, even under most restricted land-use options, may not compensate for soil loss. Thus, some level of soil erosion is inevitable. On the other hand, there is a notable concentration of costs downstream, due to incremental contribution to costs from the paddock level.

In a policy context, it is important to try and minimise erosion at the farm level. Identification of factors contributing to erosion that is within the control of land-holders would provide a leverage for policy manipulation. Benefits could also be gained by restricting the avenues through which the eroded soil escapes the landscape into the watercourses thereby contributing to *ICOS*.

For instance, a close look at the USLE (Equation 1) which predicts potential sheet and rill erosion indicate that soil loss is affected by climatic, soil, topographical and crop management characteristics associated with the paddock. The parameter values in Table 1 also suggest that for a given paddock, the landholder has the greatest control over the ground cover factor C and the conservation practice factor P, as he can adjust his agronomic practices.

Another factor of interest to policy in Equation 1 is LS, which reflects the length of slope and the slope steepness. Although it would be difficult to change the topography of a farm, it would always be feasible to plan appropriate land–uses to suit topography to minimise erosion. There is, for example scope to prohibit clearing of slopes vulnerable to high erosion and to enforce the current prohibition for clearing slopes greater than 18%.

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[2] Although, this paper presents results for year 1989/90, the analysis will be extended to cover years 1988/89 through 1992/93, as currently planned.

Policy insights can also be gained by examining the assumptions behind the USLE. USLE ignores soil deposition. Not all the eroded soil escapes the paddock, and in some cases soil accretion can improve productivity (Tongway, 1994). Cost-effective means to trap deposits and minimising opportunities for soil escape to stream outlets would be effective in managing consequences. These are some examples of policy relevant information that comes out of the analysis. This information will be used in the following section to examine policy candidates for promoting soil conserving land-use practices.

6. POLICY IMPLICATIONS

Natural resource accounting approach to land degradation cost assessment and analysis employed in this research has several implications for resource management, including allocation of public and private resources on research, extension and policy development.

A primary criterion for public funding is to maximise net social pay-off. Hierarchical aggregation ability in the GIS offers an efficient mean to account for the resource costs of soil productivity depletion associated with agricultural production, at each level of aggregation: farm, region, state. It also provides the flexibility to match appropriate policy responses to multiple objectives of resource use at each of these operational stages.

In this context, development of policy options to promote soil conserving management options are investigated in the next section.

Policy analysis

It is widely commented that the answer to finding the balance between economic levels of farm production and socially acceptable level of conservation of rural resources lies in the integration of conservation principles into cropping and grazing systems. However, there seems to be poor coincidence in cropping systems performance in terms of profitability and soil erosion hazard (Stonehouse and Bohl, 1993). While it may be possible to eliminate such differences through knowledge-based system improvements in the long-run, policy measures to encourage economically-rational farmers to adopt soil conserving practices may be necessary in the interim.

Targeting policies to reduce erosion losses from the most vulnerable areas would be one such policy with potentially high community returns, as well as that minimise landholder reluctance, as those areas are more likely to be associated with the lowest farm returns.

Likely economic implications of introducing such a policy were studied through experimental simulations using the GIS.

In this experiment, the economic impacts of introducing a 100m buffer zone along the stream banks for soil deposition are investigated. This is on the assumption that soil eroded from the immediate vicinity of the water courses are most likely to be washed into the stream network causing pollution, and providing a vegetated buffer would encourage sediment deposition. Imposition of the buffer is associated with reduced income opportunities from the affected lands (the cost). The benefit of the policy is assumed to be the saving in associated land degradation costs (NAIL, EVIL, and ICOS –not fencing cost), on the basis of present land uses. Contribution to wildlife conservation, biodiversity maintenance and increased recreational and aesthetic values are not accounted for but in some cases may be substantial. The results of this experiment are presented in Figure 2 and Table 4.

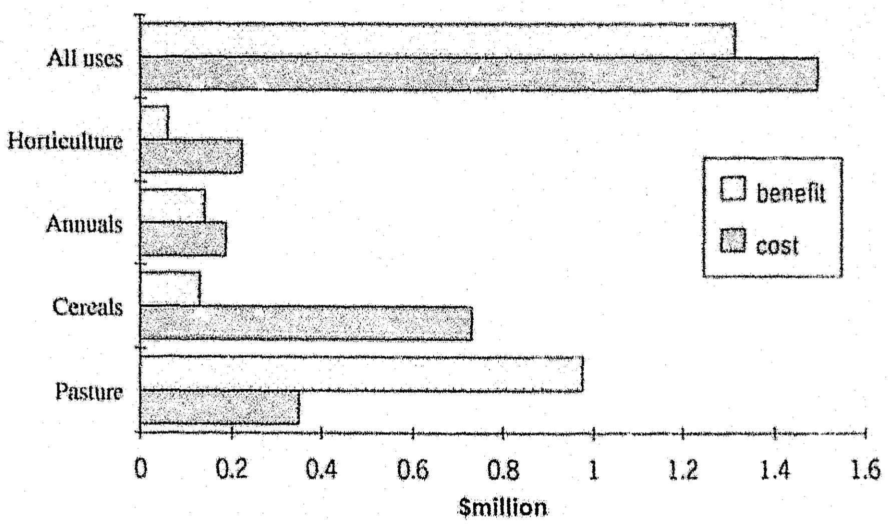

Figure 2: Likely economic impacts of imposing a 100 metre stream buffer in the Lachlan catchment

Information depicted in figure 2 indicates that a 100m buffer along the river corridors would only be economically efficient over areas under pasture. However, overall benefits of the policy over all land-uses would not be far from viable, particularly given the currently unaccounted environmental and social benefits from biodiversity maintenance and likely contribution to heritage improvements (see for example Dumsday *et al.* (1992)).

Table 4: Effect of current land-uses of a 100m stream buffer policy in the Lachlan catchment

Land-use	Composition of the affected area	Affected area as a % of total area of land use in the region
Undeveloped *	41.1	3.3
Pasture	44.4	4.9
Cereals	8.2	3.6
Annuals	0.5	5.0
Horticulture	0.1	6.3
Public land*	5.7	4.9

Information in Table 4 is also of interest. It reveals that close to 85 per cent of the land falling within the buffer are under low return land-uses, and also that the total area affected of those uses are not significant overall. On the other hand the likely impact on the high return land uses of annual crop industries and horticulture is somewhat significant as those uses are generally associated with more fertile soils along the river corridors.

This suggests that introduction of blanket policies over different crop industries would not be possible, and any policies need to consider the current land use options and relative economics associated with each use.

6. DISCUSSION

Economic valuation of land degradation is controversial as many of the implications being valued do not have tangible market impacts as measured in conventional GDP, rather the costs would be in terms of reductions in environmental quality, as attempted to capture under WILD in this analysis. Although these valuation exercises cannot comprehensively capture all likely impacts, the information generated indicates the direction of change in the environmental status.

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* No erosion estimates were produced for undeveloped and and public land.

The GIS-based modelling approach used in this work facilitates the evaluation of policy options at various operational levels for conformity with local conditions and for overall operational feasibility. In a regional development context, such hierarchical planning and evaluation processes would be of advantage in promoting collective responsibility among different stakeholders. It could, for example, demonstrate the mutual interdependencies of individuals in a catchment.

Flexibility required for such adjustments must come through a better understanding of the intricacies of social, biological and physical systems. Analytical approaches such as Hayden's (1982) Social Fabric Matrix would be advantageous in constructing likely policy agendas. Such information could improve policy development (Chapman *et al.* 1984, Weaver and Harper 1993), and minimise the likelihood of unwanted policy outcomes. GIS-based natural resource modelling allows some scope for investigating, monitoring and guiding progress in such developments.

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