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ESTIMATION OF THE BENEFITS AND COSTS OF SOIL CONSERVATION ON A LOCAL BASIS

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Information about the net benefits of land degradation treatment is required at a relevant management level to assist decision-makers in the allocation of funds to soil conservation. In this paper, estimates of opportunity costs, and costs of treatment are used to derive benefit-cost ratios to assess the profitability of gully erosion treatment and management for Local Government Areas in the wheat-sheep zone of New South Wales. These results are used to develop models which predict benefit-cost ratios of treatment from land attributes including gully length, slope, soil type and land use. These predictive models form the basis of a rapid appraisal method to aid soil conservation decisions.

1 INTRODUCTION

Economic analyses of the treatment of land degradation must include the costs of conservation practices, as well as the benefits. Information about net benefits of treating particular forms of land degradation is needed in a readily accessible form at a relevant management level. Information at the Local Government Area (LGA) level can provide useful broad-scale estimates, but even more useful will be information for particular categories of land (as defined by slope, soil type, land use etc.). Once this information has been established, it can be presented in a form which will enable a rapid appraisal of areas where conservation may be required, giving an indication of the economic merits of particular projects.

This study was undertaken for LGAs in the wheat-sheep zone of New South Wales. The profitability of treating gully erosion was determined through a benefit-cost analysis for

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individual LGAs in the zone. Data on gully erosion were taken from the Land Degradation Survey of NSW 1987-88 (Graham 1989, 1992; Soil Conservation Service 1989). The gully erosion variable was chosen because it is the most precise degradation variable recorded in the survey. Also, regressions relating gully erosion to agricultural production gave the most conservative measure of increased revenue for the wheat-sheep zone (Sinden and Yapp 1993).

Benefit-cost analyses related to land degradation and conservation are generally undertaken for individual projects, and often incorporate some measure of off-site costs. It should be noted that this study does not include any evaluation of off-site costs due to degradation, or the likely reduction in these costs due to conservation. Bojö (1992) reviewed and compared 20 benefit-cost analysis studies applied to soil and water conservation projects around the world. He concluded that, if properly done, this technique is a useful tool in the appraisal and evaluation of soil and water conservation projects. A brief review of applications of benefit-cost analyses to Australian soil conservation projects follows.

A benefit-cost analysis was undertaken for the Eppalock Catchment Soil Conservation Project in central Victoria (Department of Environment, Housing and Community Development 1978; Abelson 1979). The evaluation assessed the costs and benefits of all activities associated with the project. The costs were comprised of public investment and landholder investment, and the benefits were determined as the effects following particular investments. The evaluation was made over a thirty year period, using a discount rate of eight percent, and indicated a net present value of $2.91m, and a benefit-cost ratio of 2.0.

An economic evaluation of waterponding, a technique for reclaiming areas with severe scalding, was undertaken by Chewings (1990) in western New South Wales. The costs included the establishment and maintenance of ponds, with three scenarios for financing the treatment being considered. The benefits were assessed in terms of maintaining stock numbers, improved capital value of the land, and taxation benefits. Over an evaluation period of 15 years, using a variety of real discount rates and wool prices, all three scenarios had benefit-cost ratios above 1.0, with feasibility of the project depending upon the source of finance available, the real discount rate and the expected wool price.

Yapp and Sinden (1992) summarised the evaluation of seven conservation projects targeting sheet and gully erosion and associated sedimentation in the wheat-sheep zone of NSW. Three projects had ratios above 1.0, three had ratios between 0.9 and 1.0 and one had a ratio of 0.6. For each of these projects, a number of unpriced benefits were identified, with these benefits representing the shortfall between the costs and measurable benefits.

A benefit-cost analysis of the Forest Creek Conservation project was undertaken by Penman (1988). The benefits identified included reduced road maintenance, improved property value and reduction in soil losses. The costs consisted mainly of structural earthworks. The net present value was calculated to be $319 924, with a benefit-cost ratio of 1.6. With the introduction of conservative land management practices to complement the structural earthworks, the benefit-cost ratio increased to 3.5.

It appears that few, if any, benefit-cost analyses of conservation projects have attempted to directly relate benefits and costs to particular categories of land. In this paper, the approach is taken that benefit-cost analyses need to be dissected into more detailed breakdowns of costs and benefits in relation to land use and land type, rather than the broad approach which is prevalent in the literature.

In this context, the paper aims to

(a) produce information about the net benefits of treatment of gully erosion for particular land management situations for LGAs in the wheat-sheep zone of New South Wales,

(b) model this net benefit information against particular land category attributes to determine any significant relationships, and

(c) determine net benefits for the treatment of gully erosion for given levels of defined land attributes.

2 METHOD

An analysis of the treatment of degradation must be based on well-defined land-management situations. These are illustrated in Figure 1. The net income $OS represents an income from undegraded land, or land where all degradation has been treated. The net income $OE represents income at present, from degraded land. Thus, the opportunity cost of degradation is represented by the decrease in net income $ES. Beyond the present time, the opportunity cost will become larger as the difference in net income increases. For example, at time T the opportunity cost of degradation would be the net income $FS.

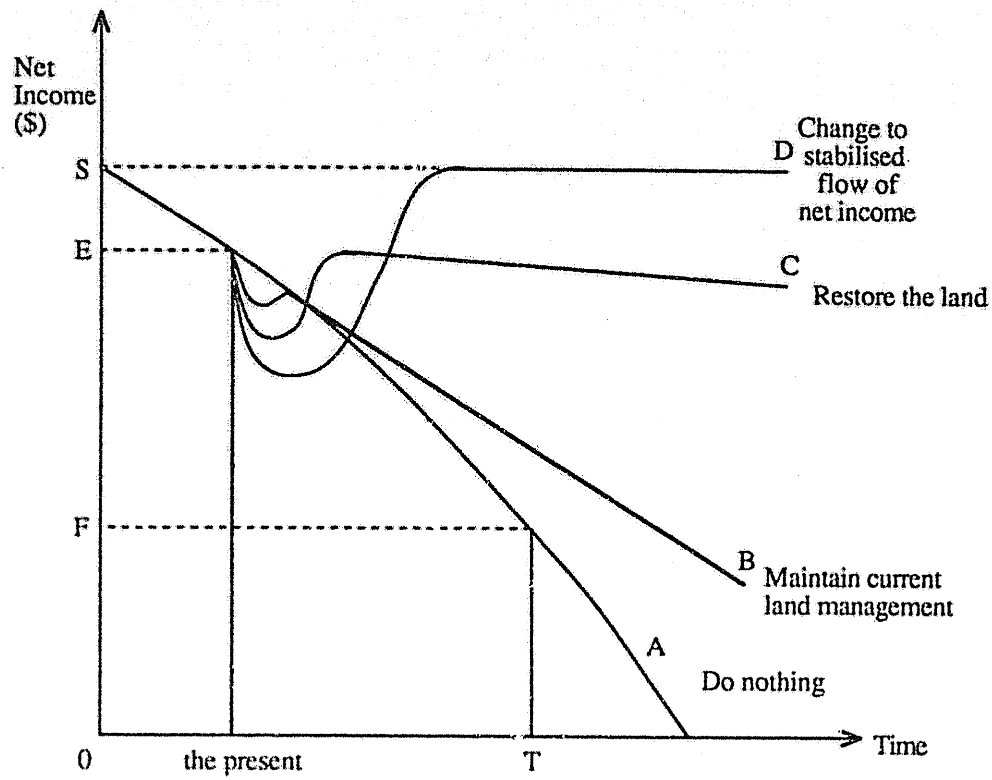

Figure 1

Flows of net income over time under alternative land management scenarios (Following Barlowe 1986, p. 205)

Four possible land-management scenarios (A to D) are now described.

(a) In the do-nothing situation of scenario A, no maintenance of the land is undertaken, so there is an accelerating rate of decline in net income, as shown by curve A.

(b) In scenario B, some level of conservation is undertaken at the present time to maintain the present rate of decline in net income. The net income curve moves from A to B.

(c) Conservation measures could be undertaken to restore the land to increase net income above that in scenario B, and in fact to maintain net income at the present level for a period of time. But in this scenario C, the net income will eventually decline as in curve C, because the system is not completely stabilised.

(d) To reach the stable level of net income $OS for scenario D, all degradation is treated and management changes are undertaken to ensure a stabilised net income flow. The curve of net income now moves from A to D. The stable level assumes that prices, yields and costs are constant, and that a change to pasture land use will provide a stable flow of net income (D. Schroder 1992, pers. comm.).

The net cost of reaching scenario C is derived by adding the cost of reaching B and the extra cost of moving from B to C. Similarly, the cost of reaching scenario D is derived by adding the cost of reaching B, and the extra costs of moving from B to C, and C to D.

An assessment of the importance of losses in on-site production and the costs of conservation treatment can be made with a benefit-cost analysis, where:

$$\text{Net benefit} = \text{Returns} - \text{Costs} \tag{1}$$

or, as a ratio:

$$\text{Benefit-cost ratio} = \text{Returns} \div \text{Costs} \tag{2}$$

A ratio exceeding 1.0 indicates an economic project, and a ratio of less than 1.0 indicates an uneconomic one. These equations can be expanded to consider the economic feasibility of conservation:

$$\text{Net benefit of conservation} = \begin{matrix}\text{Increased value of}\\ \text{agricultural production}\end{matrix} - \begin{matrix}\text{Costs of}\\ \text{conservation}\end{matrix} \tag{3}$$

In this study a benefit-cost analysis is undertaken, enabling LGAs to be identified within the wheat-sheep zone where it is profitable to undertake land management programs for the control and repair of gully erosion. The analysis is a comparison of the benefits and costs of shifting from scenario A to scenario D in Figure 1.

3 DATA

3.1 Benefits

The agricultural benefits are the increases in production that follow treatment of land degradation. Assuming that the impact of degradation on production is reversible, the potential benefits of treatment can be approximated by the estimated losses attributed to degradation which has already occurred. Estimates of this nature were derived in Sinden and Yapp (1993) for gully erosion for each LGA in the wheat-sheep zone.

3.2 *Costs*

The next requirement is cost data for each LGA for the necessary conservation measures. Costs incurred with treatment may include those due to installation of works, operation and maintenance, change in management practices, and technical assistance to the landholder. As well as recording levels of degradation, the Land Degradation Survey also reconled broad land use, soil type and slope class at each survey point, representing a particular 'land category'. Ideally, the cost estimates should relate to land which matches these land, soil and slope categories, and a possible set of such land categories is outlined in Table 1.

Table 1

A possible set of land categories for cost estimates

LAND ATTRIBUTE/MANAGEMENT	ALTERNATIVES
Degradation type	Sheet and rill erosion Gully erosion Dryland salinity Scalding Acidity
Soil type	Red brown earths Black earths
Slope (%)	<2 2 - <5 5 - <10 10 - <20 > 20
Current land use	Continuous grazing Pasture/crop rotation Lay/fallow/weed crop phase Continuous cropping
Potential management alte· .atives[a]	Do nothing Maintain current land management Restore the land Change to stabilised flow of net income

[a] The four alternatives are scenarios A to D respectively.

While 800 costs appear to be required (5 degradation types x 2 soil types x 5 slope classes x 4 land uses x 4 management alternatives) to cover all the land categories, far fewer are needed in practice because far fewer combinations exist in practice. For example, not all degradation types, and not all the kinds of land use, may occur in a particular LGA.

The required cost data include the change in income following a change in land use to a more stabilised level of net income, which would generally be pastures and grazing. For example, net income may decrease for a period of years as cropping is changed to grazing. The cost data may also include the direct costs of earthworks maintenance and new earthworks, gully fill and gully restoration, tree planting, and fencing.

4 ANALYSIS

4.1 Estimation of benefits of treatment

There are several kinds of degradation in the wheat-sheep zone in addition to gully erosion, but Equation (4) (taken from Sinden and Yapp (1993), Equation 10), relating gully degradation to agricultural production gives the most conservative estimate of increased revenue from treatment:

$$\begin{aligned} LGVAP = 1.584 &+ \underset{(2.2)^{**}}{0.223\ LAREA} + \underset{(3.8)^{***}}{0.511\ LLAB} \\ &+ \underset{(2.5)^{**}}{0.308\ LFERTA} - \underset{(3.0)^{***}}{0.000339 GULLY} \end{aligned} \qquad (4)$$

$R^2 = 0.792$ $\bar{R}^2 = 0.771$ $n = 45$

The levels of significance on the t statistics in parentheses are: * = 10 per cent or better, ** = 5 per cent or better, and *** = 1 per cent or better. The variables are defined below.

LGVAP	=	the total gross value of all agricultural production, in $000 dollars, as a three year average 1987/88 to 1989/90, in logarithms.
LAREA	=	the total area in agricultural production, in hectares, as a three year average 1987/88 to 1989/90, in logarithms.
LFERTA	=	the total area of any agricultural land spread with any kind of artificial fertiliser, in hectares, as a three-year average 1987/88 to 1989/90, in logarithms.
GULLY	=	gully erosion, as the total length of gullies (m) per 100 hectares.

Using Equation (4), estimates of the increases in agricultural production, if all gully degradation is reduced to negligible levels, were derived for each LGA. In this equation, LGVAP is the dependent variable, GULLY the relevant independent variable, and the coefficient on GULLY is -3.391 E-04.

The benefit per hectare, for a given LGA (LGA_i), can be derived from this equation as outlined:

(a) The value of GULLY for the LGA is identified. This is the mean value over all LGAs (404.67 metres per 100 hectares).

(b) It is assumed that a 'negligible' level of gully degradation is one metre per 100 hectares.

(c) If gully erosion is reduced to this negligible level, the reduction in GULLY is 403.67 (404.67 - 1).

(d) If the levels of all other inputs in Equation (4) are held constant, the change in LGVAP is given by the change in GULLY. The value of the change is determined from the reduction in gully length (403.67) and the coefficient on GULLY in the equation (-3.391 E-04). Numerically:

$$\begin{aligned} \text{Change in LGVAP} &= (-3.391\text{ E-04}) \times 403.67 \\ &= 0.0003391 \times 403.67 \\ &= 0.1369 \end{aligned}$$

(e) The mean value for LGVAP was 11.0220, indicating gross value of agricultural production (GVAP) itself of 61,206.

(f) The new value of LGVAP is 11.1589 (11.0220 + 0.1369), indicating a new value for GVAP itself of 70,186.

(g) The increase in GVAP is 8,980 (70,186 - 61,206). This variable is coded in \$000, so the change in output for the average LGA is \$8,980,000 or approximately \$9m.

(h) The per hectare value of the increase in output ($BENPH_i$) is obtained by dividing the increase by the area of the LGA.

(i) The present value of a sustained flow of benefits per hectare in perpetuity for LGA_i is now called PVB_i. It was calculated in the usual manner by discounting

$$PVB_i = BENPH_i/0.05$$

These benefits are used to calculate the benefit-cost ratio in Section 4.2.

4.2 *Estimation of costs of treatment*

The costs of treatment were estimated in the following series of steps.

(a) Collect the basic cost data

Cost data for LGAs in the northern, central and southern parts of the wheat-sheep zone were obtained from Des Schroder, Richard Chewings, and Glen Christiansen respectively, of the NSW Department of Conservation and Land Management. The costs were provided for different soil, slope, and land use categories, corresponding with the categories in the Land Degradation Survey, and in Table 1. They were provided for scenarios B, C and D (maintaining current land management, restoring the land, and changing land use to achieve a stable level of net income), and expressed as dollars per hectare.

The benefits were calculated on the basis of reducing all degradation to negligible levels, and then achieving a stable level of net income as in scenario D. Thus the costs must be calculated for the same situation, and so must include the costs of maintenance, restoration, and changes in land use. These calculations are now explained in steps (b), (c) and (d) respectively.

(b) Estimate costs to maintain current position

These are the costs ($MAINT) to maintain the current management position in scenario B, even though this position involves continuing degradation. They consist of the costs of establishing and maintaining contour banks and other earthworks, and they vary with soil type, land use and slope. However, they remain constant with varying degrees of gullying, because they are not a specific form of gully repair, but rather an overall form of treatment. Table 2 illustrates how different land categories affect the cost of

Table 2

Comparison of maintenance costs ($MAINT) for different land attributes for pasture or continuous cropping land use systems in the northern part of the wheat-sheep zone: $ per hectare per year

LAND USE	SLOPE	RED SOIL	BLACK SOIL
Pasture	0-<2%	4.24	12.70
	2-<5%	5.20	15.60
Continuous cropping	0-<2%	10.60	25.40
	2-<5%	13.00	31.20

maintenance for a pasture land use system in the northern part of the wheat-sheep zone. Some forms of earthworks may already exist, but it was not possible to determine this, hence the value of \$MAINT may be overestimated. The present discounted value (PVCMAINT) was determined for a perpetual flow of these maintenance costs.

Consider for an example, a particular point in an LGA with a land category defined as follows: a black earth soil type, a slope of five degrees, with a gully of severity class five (1000 - 2500 metres of gullying per 100ha), and under continuous cropping. Given these attributes, contour banks will require maintenance every five years, at a cost (\$MAINT) which is equivalent to \$31.20/ha/year. PVCMAINT is then calculated by discounting:

$$\begin{aligned} \text{PVCMAINT} &= \$\text{MAINT}/0.05 \\ &= 31.20/0.05 \\ &= 624.00 \end{aligned}$$

(c) Estimate costs to restore the land

Restoration involves filling and stabilising the gullies, and requires a one-off cost for the necessary earthworks (\$REST). These costs, expended in addition to those for maintenance for scenario B, will restore net income from the land to the existing level \$OE for a period of time. Then, following curve C in Figure 1, net incomes will eventually decline again. The cost varies with soil type, slope and severity of gully erosion, but is constant over all land use types. The present value of the restoration costs (PVCREST) was derived by discounting, as in the following example.

Consider the same specific point of land as in step (b), for which \$REST is \$99.00/ha to repair the gully erosion. If the costs are incurred at the end of year one, PVCREST is calculated in the following way.

$$\begin{aligned} \text{PVCREST} &= \$\text{REST}/1.05 \\ &= 99.00/1.05 \\ &= 94.29 \end{aligned}$$

(d) Estimate costs to achieve a stable flow of net income

These costs (\$CHANGE) are incurred to move to a system with a stable flow of net income, and they include any loss in gross margin returns due to changing from cropping to either a rotational or pasture land use. They may also include additional capital costs (\$CAPITAL). It is assumed that prices, yields and costs will remain constant. Once these land uses are established, and once all maintenance, restoration and capital costs have been invested, it is assumed that net income will settle to a stable level as if all existing degradation were restored.

The loss in gross margin would be greatest in the first three years due to the cost of management changes, that is pasture establishment, the reduction in cropping income, and the expenditure to increase stock numbers. However, enterprise budgets determined by Turvey (1988) indicate that the gross margin may not necessarily be lower after cropping is changed to grazing. An additional one-off capital cost would also be incurred in the flatter cropping and rotational areas due to fencing and watering requirements. These additional capital costs must be discounted to a present value. The present value of all the costs of moving from current to sustainable practice (PVCCHANGE) were determined by discounting.

Using the same specific point as in steps (b) and (c), changing from continuous cropping to a more stable system, $CHANGE has costs of $70.00/ha/year, and $CAPITAL has costs of $100.00/ha. They are discounted as follows. The discounted value of all these costs (PVCCHANGE) is now calculated from its two parts, namely the present value of the three-year change costs and the present value of capital costs.

PVCC = present value of $CHANGE
= ($CHANGE x 2.7232)

where 2.7232 is the present value of an annuity of unit value per year for a term of three years at a compound rate of interest of five per cent.

PVCCAP = present value of $CAPITAL
= ($CAPITAL/1.05)

The present value of all the costs (PVCCHANGE) is then calculated:

PVCCHANGE = PVCC + PVCCAP
= (70.00 x 2.7232) + (100.00/1.05)
= 285.86

(e) <u>Calculate the total costs for a given land category</u>

The landholder in the example has a number of management options, each with different costs. The present level of degradation may be maintained (PVCMAINT), resulting in a gradual loss of net income over time as depicted in scenario B. Alternatively, gully restoration may also be undertaken (PVCREST), incurring an initial one-off cost, but bringing more land into production, and reducing levels of degradation. The net income flow of scenario C is now obtained. In the case of rotation and cropping land use, further costs may be incurred to move to a system which achieves stable flows of net income. These costs are PVCCHANGE and scenario D is achieved. These land management changes may cause an immediate reduction in income, which recovers once a stable system has been established. It is assumed that for pasture land use, PVCCHANGE will be zero, indicating that if maintenance and restoration have been undertaken, no further change to the system is required to achieve stability.

The total treatment costs (PVC) for a land category, to move from a do-nothing scenario A to the stable scenario D, are calculated:

$$PVC = (PVCMAINT + PVCREST + PVCCHANGE)$$

Or for the example of this section,

$$\begin{aligned} PVC &= 624.00 + 94.29 + 285.86 \\ &= 1004.15 \end{aligned}$$

Alternatively, PVC values can be calculated to only include PVCMAINT, or only PVCMAINT + PVCREST. In doing this, it is recognised that the idea of a stable flow of net income (PVCCHANGE), would not be achieved in all cases.

(f) Estimate the present value of costs for a whole LGA

Consider now a whole LGA with its many survey points and many different categories of land use. The PVC value calculated in (e) represents a single hectare at a single survey point, and so represents just one land category within an LGA. It is therefore necessary to calculate the mean value per hectare (PVC_i) for the categories of land at all survey points in LGA_i. In LGA_i let there be:

n_a points within the particular land category a,
n_c different kinds of land category, and
n_i points in all within the LGA.

Thus,

$$PVC_i = [\sum_{a=1}^{n_c} (PVC_a \times n_a)] / n_i$$

where PVC_a is the present value of costs for land category a, from step (e). This calculation is illustrated in Table 3, and discussed in more detail in Section 4.3.

(g) Calculate the Benefit-cost Ratio

The benefit-cost ratio (BCR) for LGA_i is calculated as follows:

$$BCR_i = PVB_i/PVC_i$$

where PVB_i is calculated as in section 4.1, and PVC_i is calculated as in step (f) above. The values of BCR_i, PVB_i, and PVC_i, and PVCMAINT, PVCREST and PVCCHANGE for each LGA, are all recorded in Tables 4, 5 and 6.

4.3 An example for one Local Government Area

An illustration of these cost calculations is now provided for Quirindi LGA (Table 3). Quirindi displays a variety of slope, gully and land use types, in both of the two broad soil groups. The land category of black soil, <2% slope, gully class one, and continuous cropping land use had the highest frequency (n_a) of eleven survey points, with most other land categories recording just one point.

High maintenance costs for Quirindi are reflected in the PVCMAINT values. The presence of cropping on steeper slopes also contributes to the higher costs. Quirindi has a high number of survey points with severe gully class recordings, resulting in some high PVCREST values. The distribution of land use types is divided almost evenly between continuous cropping and pasture, so PVCCHANGE values reflect the need for changes in land use practices for about half the shire. Following the procedure in (f) from Section 4.2, PVC_i was calculated to be \$647.47.

The calculation of PVB_i follows the method described in Section 4.1, and was estimated to be \$882.40 for the LGA. The BCR_i is 1.36 and indicates that investments in treatment and changes in land use would be a profitable proposition for Quirindi. The BCR is calculated on the assumption that there is no change in prices, yields or costs. The result also suggests that the changes would be profitable on average, and indeed, landholders will only implement changes which are economically worthwhile and ignore those that lower the average BCR.

5 RESULTS

The values of present value of benefits per hectare (PVB_i), present value of costs per hectare (PVC_i), and benefit-cost ratios (BCR_i) for each LGA in the wheat-sheep zone are now discussed. These are shown in Tables 4, 5 and 6 for the northern, central and southern parts of the wheat-sheep zone respectively.

Table 3

Calculation of present value of costs (PVC) for Quirindi LGA

SOIL[a]	SLOPE[b]	GULLY[c]	LU[d]	n_a	$MAINT	PVC MAINT	$REST	PVC REST	$CHANGE	PVCC	$CAPITAL	PVC CAP	PVC CHANGE	PVC_a	$PVC_a \times n_a$
Black	<2	1	1	1	12.70	254.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	254.00	254.00
		1	3	11	25.40	508.00	0.00	0.00	70.00	190.62	100.00	95.24	285.86	793.86	8732.48
		3	1	1	12.70	254.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	254.00	254.00
		3	3	3	25.40	508.00	0.00	0.00	70.00	190.62	100.00	95.24	285.86	793.86	2381.59
		4	3	1	25.40	508.00	0.00	0.00	70.00	190.62	100.00	95.24	285.86	793.86	793.86
		5	3	2	25.40	508.00	0.00	0.00	70.00	190.62	100.00	95.24	285.86	793.86	1587.72
	<5	1	3	2	31.20	624.00	0.00	0.00	70.00	190.62	100.00	95.24	285.86	909.86	1819.72
		3	1	1	15.60	312.00	10.00	9.52	0.00	0.00	0.00	0.00	0.00	321.52	321.52
		3	3	1	31.20	624.00	10.00	9.52	70.00	190.62	100.00	95.24	285.86	919.39	919.39
		5	1	1	15.60	312.00	99.00	94.29	0.00	0.00	0.00	0.00	0.00	406.29	406.29
		5	3	1	31.20	624.00	99.00	94.29	70.00	190.62	100.00	95.24	285.86	1004.15	1004.15
		6	1	1	15.60	312.00	990.00	942.86	0.00	0.00	0.00	0.00	0.00	1254.86	1254.86
	<10	4	1	1	23.80	476.00	65.00	61.90	0.00	0.00	0.00	0.00	0.00	537.90	537.90
		5	1	1	23.80	476.00	150.00	142.86	0.00	0.00	0.00	0.00	0.00	618.86	618.86
	<20	1	1	1	32.50	650.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	650.00	650.00
		4	1	3	32.50	650.00	135.00	128.57	0.00	0.00	0.00	0.00	0.00	778.57	2335.71
		5	1	1	32.50	650.00	300.00	285.71	0.00	0.00	0.00	0.00	0.00	935.71	935.71
Red	<2	1	3	1	10.60	212.00	0.00	0.00	60.00	163.39	0.00	0.00	0.00	375.39	375.39
	<5	1	1	1	5.20	104.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	104.00	104.00
		3	1	1	5.20	104.00	10.00	9.52	0.00	0.00	0.00	0.00	0.00	113.52	113.52
	<10	3	1	1	7.92	158.40	15.00	14.29	0.00	0.00	0.00	0.00	0.00	172.69	172.69
		3	2	1	13.20	264.00	15.00	14.29	15.00	40.85	0.00	0.00	0.00	319.13	319.13
		4	1	1	7.92	158.00	65.00	61.90	0.00	0.00	0.00	0.00	0.00	220.30	220.30
	<20	1	1	2	10.84	216.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	216.80	433.60

[a]Black = heavy textured grey and brown soils, black earths, coastal peats

[a]Red = light textured brown soils, skeletal soils, red brown earths

[b]<2 = 0-<2% slope, <5=2-<5% slope, <10=5-<10% slope, <20=10-<20% slope

[c]Class 1 = no appreciable (<10m gullying/100ha), Class 7 = extreme (>5000m/100ha)

[d]LU - Land Use 1 = pasture, 2 = rotation, 3 = continuous cropping

$n_i = 41$

$PVC_i = [\Sigma (PVC_a \times n_a)] / n_i$

$PVC_{Quirindi} = 647.47$

5.1 Northern part

The results for the northern part are shown in Table 4. The variability in ratios across the LGAs highlights the importance of being able to make comparisons between the potential benefits and costs of soil conservation at this level, as well as the importance of the physical land attributes that influence the benefits and costs of treatment.

Table 4

Comparison of costs and benefits for treating gully erosion for Local Government Areas in the northern part of the wheat-sheep zone

Local Government Area	Mean gully length per 100ha	PVCMAINT (\$/ha)	PVCREST (\$/ha)	PVC CHANGE (\$/ha)	PVC (\$/ha)	PVB (\$/ha)	BCR
1 Barraba	1770.20	179.90	695.26	20.42	895.58	1853.20	2.07
2 Bingara	1190.44	193.99	301.37	39.89	535.25	910.00	1.70
3 Coonabarabran	605.16	263.56	54.30	72.46	390.32	453.40	1.16
4 Gunnedah	412.04	386.79	34.02	187.01	607.82	517.20	0.85
5 Inverell	1170.62	271.49	143.96	73.13	488.58	1065.80	2.18
6 Manilla	645.71	196.22	58.77	59.30	314.29	474.00	1.51
7 Moree Plains	98.58	322.19	2.31	102.23	426.73	155.40	0.36
8 Narrabri	332.38	298.07	21.57	109.76	429.40	575.00	1.34
9 Nundle	412.22	249.60	24.54	50.27	324.41	584.40	1.80
10 Parry	489.91	278.57	57.24	102.81	438.62	794.00	1.81
11 Quirindi	474.20	444.20	51.87	151.40	647.47	882.40	1.36
12 Yallaroi	1394.02	352.62	160.26	133.37	646.25	2064.80	3.20
AVERAGE	749.62	286.43	133.79	91.84	512.06	860.80	1.61

The variability in annual maintenance costs (\$MAINT) was demonstrated in Table 2. It is important to keep this variability due to land categories in mind when examining Table 4. Each LGA has a particular combination of soil, slope and gully types depending on its location, as well as a particular set of land use types. These attributes will affect the quality of the land and the ability of the landholder to undertake conservation measures.

The range of PVCMAINT values (\$179.90 to \$444.20 per hectare) reflects the fact that the cost of maintenance is constant over different levels of gully severity, and changes only with soil type, slope and land use. The PVCREST values display a higher level of variability, with costs ranging from \$2.3 per hectare for Moree Plains to \$695.3 per hectare for Barraba. The LGAs with gullies, mostly at minimum levels of severity and at low gradients, had low PVCREST values as in Moree Plains. In contrast, LGAs like Barraba with high frequencies of severe gullying on steep gradients incurred the highest restoration costs. The variability in values for PVCCHANGE reflects existing land use and the need to change. LGAs having cropping as the predominant land use had the highest costs in changing to a sustainable land use system.

The benefit-cost ratios indicate that treatment of gully erosion may not be profitable in all cases, with Gunnedah and Moree Plains having ratios less than one, and Coonabarabran just over one.

5.2 *Central part*

The results for LGAs in the central part of the wheat-sheep zone are summarised in Table 5.

Table 5

Comparison of costs and benefits for treating gully erosion for Local Government Areas in the central part of the wheat-sheep zone

Local Government Area	Mean gully length per 100ha	PVCMAINT ($/ha)	PVCREST ($/ha)	PVC CHANGE ($/ha)	PVC ($/ha)	PVB ($/ha)	BCR
1 Bland	209.74	70.82	5.31	121.77	197.90	215.80	1.09
2 Boorowa	935.42	91.34	41.88	0.00	133.22	1785.60	13.40
3 Cabbone	358.95	248.29	27.22	106.33	381.84	734.60	1.92
4 Coolah	571.71	200.82	23.08	129.62	353.52	592.20	1.68
5 Cootamundra	405.00	151.88	65.79	40.07	257.74	839.00	3.26
6 Cowra	210.64	90.12	5.03	115.42	210.57	476.60	2.26
7 Dubbo	349.02	190.12	22.8	134.32	347.24	418.00	1.20
8 Forbes	104.20	124.62	4.62	172.67	301.91	150.20	0.50
9 Gilgandra	166.46	223.99	6.26	323.37	553.62	153.80	0.28
10 Harden	594.00	215.93	23.94	12.53	252.40	1528.80	6.06
11 Narromine	107.22	118.17	6.40	168.05	292.62	179.20	0.61
12 Parkes	136.19	149.32	8.31	172.79	330.42	171.00	0.52
13 Temora	383.08	93.67	37.66	74.47	205.80	644.20	3.13
14 Weddin	673.73	87.02	23.28	82.78	193.08	1360.80	7.05
15 Wellington	170.28	180.21	12.15	72.98	265.34	250.20	0.94
16 Yass	889.60	85.76	51.03	0.00	136.79	1541.40	11.27
17 Young	270.38	63.09	7.49	51.58	122.16	572.80	4.69
AVERAGE	384.45	140.30	21.90	104.63	266.83	683.19	3.52

As with the northern part, the LGAs cover a large geographic area, and so encompass a wide variety of land categories, a variety which is reflected in the range of PVC and PVB values. The PVCMAINT values range from $63.09 to $248.29 per hectare, while the average PVCREST is $21.90, reflecting a much lower average gully length (384.45m/100ha) than the northern area (749.62m/100ha). Despite recording the two highest mean gully length figures for the central area, Boorowa and Yass have no costs for PVCCHANGE, because the majority of land is pasture.

The BCR values have a much larger range than the northern part, with Forbes, Gilgandra, Narromine, Parkes and Wellington having BCRs below 1.0, while Boorowa and Yass have BCRs of 13.40 and 11.27, respectively. These values reflect generally lower PVC values and a large amount of variability in PVB values.

5.3 Southern part

The results for the southern part of the wheat-sheep zone are summarised in Table 6.

Table 6

Comparison of costs and benefits for treating gully erosion for Local Government Areas in the southern part of the wheat-sheep zone

Local Government Area	Mean gully length per 100ha	PVCMAINT ($/ha)	PVCREST ($/ha)	PVC CHANGE ($/ha)	PVC ($/ha)	PVB ($/ha)	BCR
1 Berrigan	7.30	15.81	0.28	81.51	97.60	14.80	0.15
2 Conargo	1.00	35.65	0.00	15.49	51.14	0.00	0.00
3 Coolamon	335.66	110.97	56.12	230.95	398.04	544.80	1.37
4 Corowa	102.44	0.00	4.83	133.44	201.11	249.00	1.24
5 Culcairn	417.10	52.06	31.41	76.38	198.36	809.60	4.08
6 Griffith	1.00	44.23	0.00	119.82	164.05	0.00	0.00
7 Hume	405.68	49.82	36.31	44.78	154.83	768.20	4.96
8 Jerilderie	16.79	39.15	0.46	31.81	71.42	22.00	0.31
9 Junee	396.83	78.08	56.05	203.13	337.26	854.60	2.53
10 Leeton	19.05	42.90	2.36	38.12	83.38	65.80	0.79
11 Lockhart	491.66	51.77	159.66	114.37	325.80	792.80	2.43
12 Murray	2.08	48.27	0.19	77.02	125.48	1.20	0.01
13 Murrumbidgee	1.00	36.53	0.00	4.49	41.02	0.00	0.00
14 Narrandera	79.76	44.22	10.24	119.55	174.01	92.40	0.53
15 Urana	162.12	33.81	15.77	67.24	116.82	127.20	1.09
16 Wagga	239.26	70.66	21.63	116.37	208.66	355.00	1.70
AVERAGE	167.42	54.95	24.71	105.32	171.81	293.59	1.32

The most important observation for this area is that five of the 16 LGAs recorded average gully lengths at negligible levels (<10m gullying/100m). Three of these (Conargo, Griffith and Murrumbidgee) have mean gully lengths of 1.00m/100ha, and therefore recorded PVB values of zero. The low levels of gullying are a result of their location in an area that is extremely flat (all survey points were recorded on slopes less than five per cent), combined with soil types that are not as vulnerable to this type of degradation.

The general pattern of all LGAs in the southern part was for generally lower PVCMAINT values than the northern and central areas, with similar PVCREST and PVCCHANGE values to the central area. Half of the 16 LGAs in the southern area have BCRs less than 1.0, with the majority of LGAs with BCRs above 1.0 being in the eastern part of the area.

6 A RAPID APPRAISAL SYSTEM

So far, this study has highlighted the importance of land categories, made up of various combinations of soil type, slope, degradation severity, and land use, and their usefulness in determining the levels of cost at a particular point within an LGA. The availability of data for particular categories of land from the Land Degradation Survey, coupled with the benefit-cost ratios calculated in the previous section, provide relevant information to determine which factors within land categories are the most influential in changing the levels of the ratios.

The following model may help to determine the relationship between individual land category factors and BCRs.

$$BCR = f(SOILG, SOILE, SLOPE, GULLY, CROP, NTH, STH) \qquad (5)$$

where,

BCR	=	Benefit-cost ratio.
SOILG	=	Mean soil group class (3 classes, where Class 1=sand dunes (coastal and inland), Class 2=light textured brown soils, skeletal soils, red brown earths, and Class 3=heavy textured grey and brown soils, black earths, coastal peats).
SOILE	=	Mean soil erodibility value, K (very stable soil = 0.02, highly erodible soil = 0.04).
SLOPE	=	Mean slope gradient (%).
GULLY	=	Mean gully length (m/100ha).
CROP	=	Proportion of cropping land use.

NTH	=	Dummy variable (north area), where 1=north, 0=south.
STH	=	Dummy variable (south area), where 1=south, 0=north.

The observations are from the 45 LGAs in the wheat-sheep zone, with the models providing the most useful relationships being summarised in Table 7. The most useful models were developed when a logarithmic transformation of BCR was used as the dependent variable, and four outlying LGAs with high mean gully lengths and BCRs were excluded. The dummy variables were included to determine whether there was any significant difference in the data provided from the northern, central and southern part of the zone.

Equation (6) indicates significant relationships between the level of benefit-cost ratios and length of gullying, the proportion of cropping and soil type. Equation (7) indicates significant relationships between the level of benefit-cost ratios and length of gullying, the proportion of cropping, and slope. Thus for Equation (7), increases in benefit cost ratios to repair gullying appear to be associated with increases in the amount of gullying, the amount of cropping and the degree of slope.

Having determined these equations, it was then possible to derive benefit-cost ratios, given certain levels of the regressor variables. Thus for Equation (7), SLOPE, NTH and STH were set at their mean values, and benefit-cost ratios were generated given particular values of GULLY and CROP. The generated BCRs are shown in Table 8. Similarly, with CROP, NTH and STH set at their mean values, benefit cost ratios were generated given particular values of GULLY and SLOPE. These are shown in Table 9.

These values give rise to a rapid appraisal method, where at a particular point, and given certain combinations of the defined land attributes, it is possible to predict the ratio to determine whether a proposal to repair gully erosion is likely to be profitable. For example, from Table 8 gully repair becomes profitable when levels of gullying are at 500m/100ha, and there is 20 per cent cropping (BCR = 1.01). From Table 9, gully repair becomes profitable when levels of gullying are at 400m/100ha and slope is one per cent (BCR = 1.06).

This rapid appraisal method gives an important on-the-ground indication of the likely profitability of conservation projects likely to be undertaken. The benefit-cost ratios do not reflect potential off-site benefits due to conservation works, so from a public perspective, the ratios can be taken as more conservative estimates of profitability.

Table 7

Preferred models for the relationship between individual land category factors and benefit cost ratios for LGAs in the wheat-sheep zone[a]

Regressor variables	Equation 6	Equation 7
GULLYL	0.004 (4.3)***	0.005 (4.8)***
CROP	1.907 (2.7)***	2.521 (3.1)***
SOILG	-2.403 (3.4)***	
SLOPE		0.093 (1.4)*
NTH	0.079 (0.2)	-0.482 (1.0)
STH	-0.704 (1.8)**	-0.142 (0.3)
n	41	41
Constant	3.508	-3.044
R^2	0.744	0.677
$\bar{R}^2$	0.707	0.630

a The levels of significance on the t statistics in parentheses are indicated as follows: * = 10 per cent or better, ** = 5 per cent or better, and *** = 1 per cent or better.

Table 8

Benefit-cost ratios given particular gully lengths and proportion of cropping land use

Proportion of cropping (%)	Gully length (m/100ha)									
	50	100	150	200	250	300	350	400	450	500
10.0	0.10	0.12	0.16	0.20	0.25	0.31	0.39	0.50	0.62	0.79
20.0	0.13	0.16	0.20	0.25	0.32	0.40	0.51	0.64	0.80	1.01
30.0	0.16	0.20	0.26	0.33	0.41	0.52	0.65	0.82	1.03	1.30
40.0	0.21	0.26	0.33	0.42	0.53	0.66	0.84	1.05	1.33	1.67
50.0	0.27	0.34	0.43	0.54	0.68	0.85	1.08	1.36	1.71	2.15
60.0	0.35	0.44	0.55	0.69	0.87	1.10	1.39	1.75	2.20	2.77
70.0	0.45	0.56	0.71	0.89	1.12	1.42	1.78	2.25	2.83	3.57
80.0	0.57	0.72	0.91	1.15	1.45	1.82	2.29	2.89	2.64	4.59
90.0	0.74	0.93	1.17	1.48	1.86	2.34	2.95	3.72	4.69	5.91
100.0	0.95	1.20	1.51	1.90	2.39	3.01	3.80	4.79	6.03	7.60

Table 9

Benefit-cost ratios given particular gully lengths and slope categories

Slope (%)	Gully length (m/100ha)									
	50	100	150	200	250	300	350	400	450	500
1.00	0.21	0.26	0.33	0.42	0.53	0.67	0.84	1.06	1.33	1.68
3.00	0.25	0.32	0.40	0.51	0.64	0.80	1.01	1.27	1.61	2.02
5.00	0.30	0.38	0.48	0.61	0.77	0.97	1.22	1.54	1.93	2.44
7.00	0.37	0.46	0.58	0.73	0.92	1.16	1.47	1.85	2.33	2.93
9.00	0.44	0.56	0.70	0.88	1.11	1.40	1.77	2.23	2.80	3.53
11.00	0.53	0.67	0.84	1.06	1.34	1.69	2.13	2.68	3.38	4.25
13.00	0.64	0.81	1.02	1.28	1.61	2.03	2.56	3.23	4.07	5.12
15.00	0.77	0.97	1.22	1.54	1.94	2.45	3.08	3.89	4.90	6.17
17.00	0.93	1.17	1.47	1.86	2.34	2.95	3.71	4.68	5.89	7.43
19.00	1.12	1.41	1.77	2.23	2.82	3.55	4.47	5.63	7.10	8.94

7 CONCLUSIONS

7.1 Summary

The profitability of treatment of land degradation was assessed in Sinden and Yapp (1993) for broad zones within the state. In this paper, the same method has been applied to individual LGAs within the wheat-sheep zone to assess the benefit-cost ratios for treatment of gully erosion. Several general points can be summarised.

(a) The profitability of treatment of gully erosion varies widely across the LGAs of the wheat-sheep zone.

(b) In some LGAs treatment is profitable (on average) whereas in others it is not.

(c) In some LGAs, treatment is highly profitable as indicated by Yallaroi, Inverell and Barraba in the northern part; and Boorowa, Yass and Gilgandra in the central part.

(d) Overall, there seem many localities for profitable treatment of gully erosion to achieve a stable level of net income.

(e) The results provide a 'filter' which can be applied to guide gully restoration and land use changes to those areas where such efforts are more likely to be profitable and avoid those areas where it is less likely to be so.

(f) If other, non-agricultural, impacts of gully erosion were involved these should be taken into account.

(g) Significant relationships were found to occur between benefit-cost ratios and the length of gullying, the proportion of cropping, slope and soil group.

(h) Using the rapid appraisal method, benefit-cost ratios for conservation can be predicted given particular values of individual land category factors.

7.2 *Discussion*

Information about the net benefits for the treatment of land degradation is required at the relevant management level to assist decision-makers in the allocation of funds to soil conservation. The sort of information, from the method outlined and applied in this paper, aids in the identification of LGAs where it is profitable to undertake land management programs for a particular degradation type, to achieve stable levels of net income. The method and this information is of course subject to limitations, and these are now discussed.

An important limitation to this method is the desirability for the degradation variable to be measured on an arithmetic scale. In this analysis gully erosion is measured on such a scale (metres per 100 hectares). Limitations will however apply to degradation types which are not as easy to measure as gully erosion.

The calculations have assumed that it is possible to move from the present, or 'do nothing', management system to a system that achieves stable levels of net income, and have implied there are no fixities and no irreversibilities in land use changes. Therefore, if there are fixities or irreversibilities, the level of benefit has been overestimated. For example, there may be some cases where the land has been degraded up to a point where it will not be possible to achieve an economically stable productive system. Some soils may be so degraded in structure from cropping that they will not be productive in a pasture system. Also, there may be no economic management options or only cost minimising options on areas with slopes greater than 20 degrees due to the prohibitive costs involved.

The data reflect the level of degradation occurring at a particular point in time, and so another potential problem is the lack of information on the rate of change of degradation. This would be a problem in an LGA in which low levels of degradation were recorded at the time of the survey, but the levels are rapidly increasing in severity, because the costs of treatment are rising at a corresponding rate.

The calculations have assumed that the prices and costs prevailing in the base period, 1987/88 to 1989/90, will continue. This convenience allowed the research to concentrate on developing the method and developing the models. This limitation could be addressed by calculating benefit values with changing prices over time.

The benefit calculations use a restoration of income of $SE in Figure 1 each year. The true increase in income is the difference between scenario D, for a stable situation, and scenario A for the do-nothing situation. The true increase is therefore $SE at the present time, but rises to $SF at time T and so on. For this reason, the benefit calculation underestimates true benefit. The benefit from the stable flow, from balanced management (scenario D), is calculated from existing data for existing management practices. Several local experts consistently advised that a stable flow requires changes to pasture from continuous cropping. The effect of any associated changes in existing land use, and in net income is accommodated in the values used for $CHANGE. These values were incorporated as step (d) in the estimation of costs.

The overall effect of these limitations on the benefit-cost ratios generated in this paper is hard to judge. But if prices of agricultural output had maintained their base-period levels, the benefit-cost ratios may have been under-estimated.

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