8. Paddock results

8.1 Introduction

The results from the previous chapter indicate that the provision of economic and bio-physical information within the farm-management unit may be useful for the control of land degradation. This is determined by the complexity of the bio-physical landscape of a particular farm unit. Management and production decisions are made at and below the farm unit, with individual paddocks requiring specific attention.

In the past paddocks have been subdivided within the farm boundary according to requirements such as ease of cultivation, or to meet minimum area requirements for stock-management purposes. However, with the development of whole-farm planning techniques, farmers are beginning to recognise the advantages of re-designing paddock boundaries or managing existing paddocks according to bio-physical attributes such as soil type and slope.

The increasing availability of large-scale GIS data means that many landholders now have access to detailed bio-physical information specific to their own farm. Site-specific economic information relating to the profitability of land management projects is not generally available and lacks a direct link to bio-physical information. One of the objectives of this research is, of course, to develop methods to provide these links and display such information.

In this context, the objectives of this chapter are to:

(1) apply the general approach developed in Chapter 4 to analyse the effects of land degradation on a paddock-level basis,

(2) derive paddock-level information about the BCRs for treatment of sheet and rill erosion for particular land-management situations,

(3) determine bio-physical and management factors that most influence these BCRs and,

(4) using predictive modelling in a GIS, disaggregate paddock-level BCRs according to bio-physical and land-management factors to give a higher resolution of information.

The impact of land degradation on agricultural production, and the profitability of land-management programs have been estimated at the regional and farm level in the previous two chapters. It is also possible to apply the general method of analysis at the paddock scale. The main goal of this chapter is to determine whether information generated at this scale provides any significant improvement on the results generated using regional or farm information. Application of the general method to the paddock scale was originally explored by Walpole (1995).

The area chosen to examine these paddock-level issues falls within the Gunnedah area studied in the previous chapter. Paddock information was collected from two landholders who participated in the farm surveys. They were able to provide input and output information not only at the farm level but for each individual paddock on their farms. This detailed economic information, coupled with the bio-physical data from the GIS, allows for site-specific examination of factors influencing the benefits and costs associated with land degradation.

8.2 Estimation of models

Estimated Cobb-Douglas models based on Equation 4.8 of the paddock-level relationship between degradation and output are now presented. Values of pasture output per paddock proved difficult for the landholders to estimate; however, they were able to provide information on livestock production. Not all of the paddocks had an output recorded for the 1992-93 period, thus the type of regression used for the model estimation must be reconsidered. As well as the usual OLS regression, Tobit regression[6], can be undertaken in order to model output in a 2-stage way, due to the presence of limited dependent variables (that is, zero and non-zero output values). Another way to deal with the zero output values is to re-estimate the output data as annualised values. The output value of livestock is the sale price of the animal. This represents a value that has accumulated over the life of the animal, which is generally more than one year, and from more than one paddock during the year. Therefore, the calculated annualised value represents an annual livestock output figure. Once calculated, these annualised output values can be redistributed across all paddocks listed as having pasture land use. Therefore, the models are estimated with both original and annualised data, using OLS and Tobit regressions, allowing a comparison of the results to be made before choosing a preferred model for further analysis. The model variables reported in this section are defined in Section 5.4.

8.2.1 Ordinary least squares estimations

The preferred Cobb-Douglas models estimated at the paddock level, together with the relevant test statistics, are presented in Table 8.1 (Equations 8.1, 8.2 and 8.3). Sheet and rill erosion (SUMTONHA) were found to have a significant negative effect on the gross value of agricultural output for the normal and both forms of annualised data.

All the estimated coefficients in Equations 8.1, 8.2 and 8.3 are significant at the ten percent level, apart from CONS in Equation 8.3. The diagnostic tests for Equations 8.1, 8.2 and 8.3 suggest that the estimated models are statistically sound. The DW statistic for Equation 8.2 is inconclusive in that H_0 is neither accepted nor rejected, according to the Durbin-Watson test (Griffiths *et al.* 1993). However, the estimated value is closer to 2 than 0, indicating that autocorrelation is negligible.

8.2.2 Tobit estimations

The estimated Tobit models, together with the relevant test statistics, are presented in Table 8.2 (Equations 8.4 and 8.5). Sheet and rill erosion (SUMTONHA) was found to have a significant negative effect on the gross value of agricultural output for the normal and annualised data. The fertiliser variable LTFERTHA was not significant in Equation 8.5.

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[6] I wish to thank David Godden for suggesting this.

Table 8.1

Estimated OLS models for the relationship between agricultural inputs and gross value of agricultural production using original and annualised pasture output values^a

	Original output	Annualised pasture output^b	Annualised pasture output^c
Regressor variable	Equation 8.1	Equation 8.2	Equation 8.3
LLABHA	1.522 (6.6)***	1.252 (4.6)***	0.247 (1.3)*
LTFERTHA	0.334 (1.9)**	0.276 (1.3)*	0.556 (3.9)***
LCHEMHA	0.392 (1.9)**	0.411 (1.7)*	0.558 (3.3)***
SUMTONHA	-0.222 (3.5)***	-0.252 (3.4)***	-0.119 (2.4)**
CONS	2.157 (3.2)***	1.922 (2.4)**	0.221 (0.4)
n	29	29	29
Constant	3.678	3.536	5.957
R^2	0.782	0.673	0.536
Adj R^2	0.734	0.602	0.436
DW Statistic	1.836	1.848	2.326
BPG Statistic	1.599	3.297	17.235

[a] The levels of significance on the t-statistics in parentheses are as follows:
* = 10 percent or better, **= 5 percent or better, *** = 1 percent or better.

[b] Original output values for paddocks with cropping land use recorded; annualised output values for paddocks with a pasture output recorded.

[c] Original output values for paddocks with cropping land use recorded; annualised output value for all pasture paddocks.

The likelihood ratios show that the set of coefficients as a whole is significantly different from zero at the five percent level or better in each model. The null hypothesis, that there is no relationship between the dependent variable and its set of explanatory variables, is rejected in each case.

8.2.3 Preferred model

The models estimated using OLS and Tobit regressions show a consistent pattern where sheet and rill erosion (SUMTONHA) have a significant negative influence on agricultural output. However, for the purposes of further analysis, Equation 8.4 appears to be the preferred model, reflecting the suitability of using a Tobit regression to explain the level of non-zero output, as well as being statistically sound.

8.3 Benefit-cost ratios

The benefits and costs for each paddock are calculated according to the procedures outlined in Chapter 4. A five percent discount rate is used to convert these to present values. BCRs are then calculated for each paddock.

The results of these calculations are summarised for each paddock in Table 8.3. Eight paddocks were excluded because they had no output recorded, thus PVBs could not be estimated for them. Paddock 14 has soil-loss levels that were already lower than the 'negligible' rate, therefore a PVB and hence a BCR cannot be calculated.

The areas of the remaining 20 paddocks ranged from 6.4 to 120.6 ha, with an average of 45.9 ha. The annual soil loss from sheet and rill erosion per paddock ranges from 15.18 to 567.66 t/year, with an average of 186.39 tonnes per paddock, or 4.02 t/ha/year. The values of PVB, PVCMAINT, PVCCHANGE, PVC and BCR for each paddock in the study area are recorded in Table 8.3.

The BCRs across the 20 paddocks range between 0.08 and 7.03, with an average of 1.71. These results are consistent with the farm-level results, where the average BCR was 1.86 (Table 7.3).

Table 8.2

Estimated Tobit model for the relationship between agricultural inputs and gross value of agricultural production using original and annualised pasture output values[a]

	Original output	Annualised output[b]
Regressor variable	Equation 8 4	Equation 8.5
LLABHA	1.281 (4.8)***	0.946 (4.1)***
LTFERTHA	0.253 (1.7)*	0.194 (1.3)
LCHEMHA	0.363 (2.0)**	0.336 (1.9)**
SUMTONHA	-0.254 (2.8)***	-0.276 (2.9)***
CONS	1.876 (3.0)***	1.520 (2.5)**
n (limit observations)	8	8
n (non-limit observations)	21	21
Constant	2.508	2.419
Likelihood ratio	-42.969	-46.648
Level of significance	0.05	0.05

[a] The levels of significance on the t-statistics in parentheses are as follows: * = 10 percent or better, **= 5 percent or better, *** = 1 percent or better.

[b] Original output values for paddocks with cropping land use recorded; annualised output values for paddocks with a pasture output recorded.

Table 8.3

Comparison of benefits and costs for treating sheet and rill erosion

Pdk. No.	Area (ha)	Soil loss (t/year)	PVB ($/ha)	PVC MAINT($/ha)	PVC CHGE($/ha)	PVC ($/ha)	BCR
1	15.7	59.58	133.44	263.69	0.00	263.69	0.51
2	9.9	37.38	876.40	322.13	0.00	322.13	2.72
3	7.6	39.06	1645.62	265.62	0.00	265.62	6.20
4	21.4	139.80	1547.61	220.10	0.00	220.10	7.03
6	35.2	157.6	108.72	125.89	0.00	125.89	0.86
7	101.0	567.66	111.39	252.10	163.39	415.50	0.27
8	65.5	71.2	11.47	139.93	0.00	139.93	0.08
9	133.6	431.10	70.34	263.84	163.39	427.23	0.16
11	38.1	109.36	234.54	173.89	163.39	337.28	0.70
12	96.3	380.00	294.46	232.05	163.39	395.44	0.74
14	120.6	47.27	-4.91	9.19	0.00	9.19	-
15	34.9	236.22	771.49	232.53	163.39	395.93	1.95
18	66.2	325.00	590.76	304.53	163.39	467.92	1.26
20	43.8	137.04	1122.46	258.58	163.39	421.97	2.66
21	6.4	17.88	449.94	227.19	163.39	390.58	1.15
22	17.8	40.2	369.52	167.70	163.39	331.09	1.12
23	59.9	312.68	616.66	296.06	0.00	296.06	2.08
26	45.8	237.30	661.63	267.52	0.00	267.52	2.47
27	47.5	268.90	566.18	267.87	163.39	431.27	1.31
28	55.5	144.12	295.67	252.04	163.39	415.44	0.71
29	15.4	15.18	41.92	137.45	163.39	300.84	0.14
Ave	45.9	186.39	526.01	233.54	98.03	331.57	1.71

8.4 Site-specific benefit-cost ratios

The estimated BCRs can now be regressed against land use and bio-physical factors, as illustrated in Equation 4.15, in order to determine which of these factors is most influential in changing the BCR levels as a possible basis for predictive modelling in a GIS. This increases the resolution of the BCRs, by allowing the BCR results at the paddock level to be disaggregated below the paddock level. The estimated model is shown in Table 8.4. The model variables reported in this section are defined in Section 5.4. Predictive modelling is used rather than discriminant analysis, as this was the only modelling module available with E-RMS.

Paddock 14 had sheet and rill erosion lower than the 'negligible' rate, therefore a positive PVB and hence a BCR cannot be estimated. Eight paddocks were excluded because they had no output recorded, thus PVBs could not be estimated for these paddocks. This left 20 farms in the estimation. The results from Table 8.4 indicate that land use, levels of erosion and proportion of the area of trees are the important bio-physical and land-management predictors for BCRs. Each of these indicators were obtained from the GIS data, thus allowing further analysis of these results in the GIS, as described Chapter 4.

The estimated BCR values (Table 8.3) are incorporated into the GIS database as a new layer. Once this information is in the database, maps of BCRs can be produced (Figure 8.1). These results give an indication of the profitability of land-management programs at the paddock level. Ground-surveyed BCR data do not have complete geographical coverage of the map sheet, as the two surveyed farms make up only a small area of the entire map sheet. Decision tree models can be derived to extend or interpolate these data across unsurveyed areas and other map sheets based on correlations between these data and remotely mapped predictor variables with complete geographical coverage of the map sheet. In this case, the induction process relates the ground-surveyed BCR data to the predictor variables of land use, erosion and area of trees (identified from Equation 8.6).

Once the decision tree has been built in the GIS, the predictive modelling module is instructed to run, and thus applies the model to every 20m x 20m grid cell in the database corresponding to the 1:25 000 map sheet. The mapped predictions are stored in a special grid cell variable, known as a modelled variable. The modelled BCR variable is shown in Figure 8.2. This provides the information at a higher level of resolution than at the farm level (Figure 8.1), thus allowing landholders to make decisions at a more relevant

Table 8.4

Preferred model for the relationship between BCRs and land-use and bio-physical factors[a]

Regressor variable	Equation 8.6
LAND USE	0.677 (2.2)**
SUMTONHA	0.378 (2.9)***
PROP TREES	1.524 (1.7)*
n	20
Constant	-1.910
R^2	0.570
Adj R^2	0.490

[a] The levels of significance on the t-statistics in parentheses are as follows: * = 10 percent or better, **= 5 percent or better, *** = 1 percent or better.

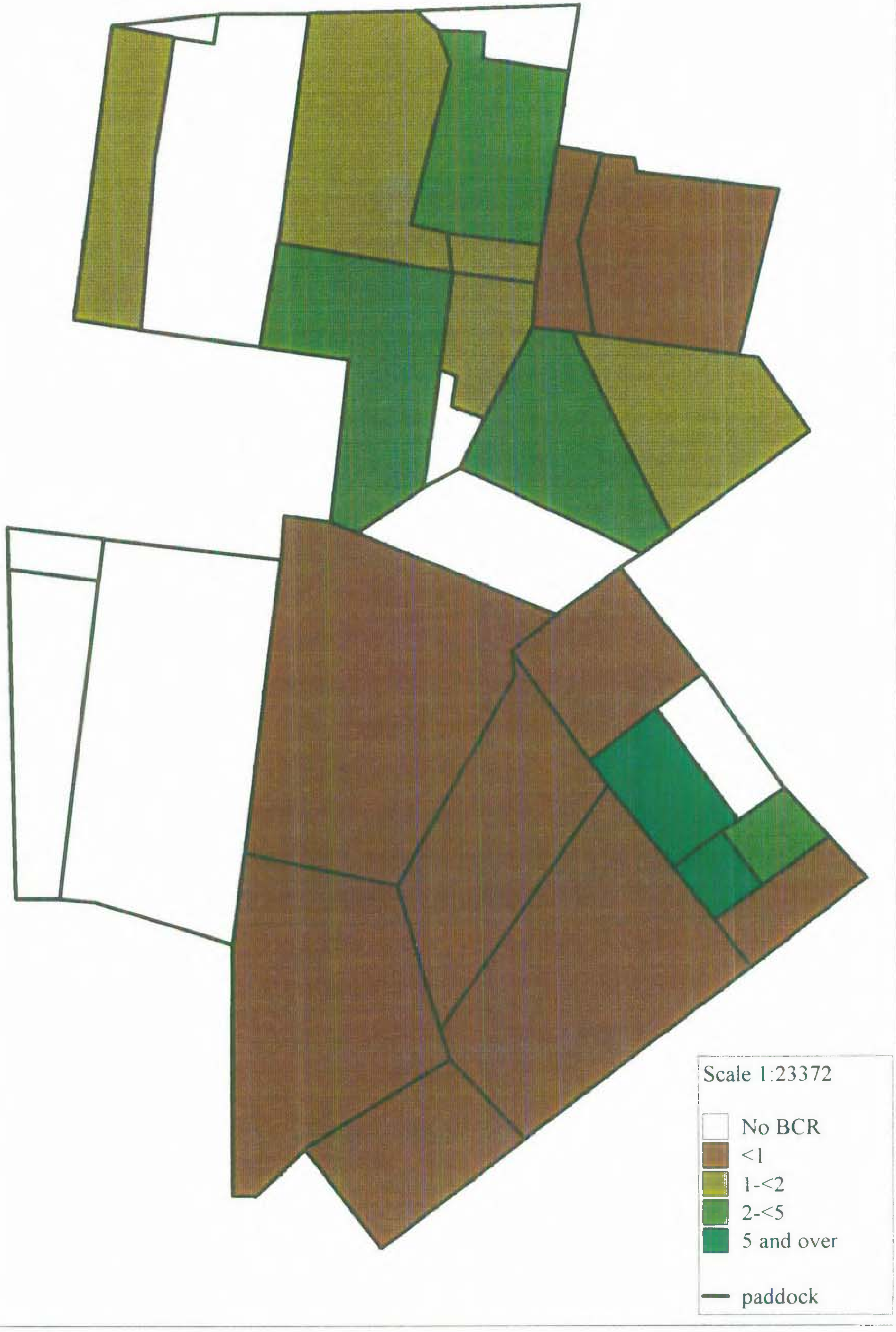

Figure 8.1

Estimated benefit-cost ratios of restoring sheet and rill erosion to negligible levels for management level. The 'No BCR' category indicates areas where the GIS did not have enough supporting information to predict BCRs

8.5 Discussion

The main goal of this chapter was to determine whether information generated at the paddock scale is an improvement on results generated at the farm or regional scale. The paddock is the basic unit of management for farmers; therefore, it seems logical that an attempt be made to apply the general method of analysis at this scale.

It is apparent that paddock-level information has the potential to enhance and reinforce the farm-level results, with the estimated BCRs being of the same order of magnitude at both scales. The bio-physical factors of erosion and area of trees appear to influence BCR values at both the farm and paddock level.

The main impediment to applying the method of analysis at this scale is the lack of agricultural-production information at the paddock level. It appears that even the most technologically advanced and well-informed landholders in the study area do not keep detailed records of production inputs and outputs at the paddock level, and they had some difficulty providing the information required. Therefore, although it was possible to successfully estimate a production function at this scale, the same reliability of interpretation of the results cannot be guaranteed.

Until more dependable paddock-level-production information can be obtained, and from a larger sample size than two farms, the farm-level analysis appears to provide the most useful results. The GIS predictive modelling provides a means of disaggregating farm-level results to a scale that resembles the paddock-management unit.

8.6 Summary

In this chapter, Cobb-Douglas production functions have been successfully applied at the paddock level. The estimated models show a consistent pattern where various land degradation types have a negative, significant influence on agricultural output. The preferred model is a Tobit estimation, which is used to explain the level of non-zero output from some paddocks. Benefit-cost ratios were calculated for each paddock, with

Figure 8.2

Predicted benefit-cost ratios of restoring sheet and rill erosion to negligible levels for the paddock survey area the BCR estimates ranging from 0.08 to 7.03, indicating that some areas may have the opportunity to undertake soil conservation works profitably, while it may not be economically worthwhile in other areas. The predictive modelling results show that variations in management practices and bio-physical characteristics of land may both determine the profitability of a particular project.

A general procedure to assess management programs for land degradation has been developed and applied to three scales of management. Final discussion of the results and conclusions from the study follow in Chapter 9.

9. Discussion and Conclusions

9.1 Introduction

This chapter will summarise the major findings of the study and present the conclusions reached. The findings are discussed in the light of the objectives defined in Chapter 1. Some broad policy implications of the study will be discussed, as well as showing how the findings relate to specific policy issues at each scale of management. Finally, the strong and weak points of the study will be assessed. Scope for further research is suggested and some concluding remarks are made.

9.2 Overview of results and conclusions

The title of this study is 'An Economic Assessment of Management Programs for Land Degradation on a Regional, Farm and Paddock Basis'. As the title suggests, this research has sought to develop a means of appraising the impacts of land degradation on agricultural productivity and determining whether subsequent conservation programs will be profitable. More specifically, the objectives of the thesis were:

(a) to develop a general procedure for estimating cost and benefit data to treat land degradation at the regional, farm and paddock level;

(b) to estimate net returns of treatment of a specific degradation problem at these different levels;

(c) to develop a general procedure to extrapolate and depict economic information beyond 'normal' socio-economic boundaries on the basis of bio-physical and management attributes; and

(d) to assess economic priorities for management programs and policies at these different levels.

What is unique about the approach taken in this study is that bio-physical and management factors have been linked directly to the net benefits associated with a particular management strategy for controlling land degradation. Benefit-cost ratio information can also now be presented in a fashion that is easily understood by both landholders and policy makers.

The results are now brought together with respect to the first three research objectives, and are discussed under corresponding headings. These concern (a) a general approach for estimation of cost and return data, (b) net returns of land degradation treatment, and (c) extrapolation of economic information. The final objective will be discussed in terms of policy implications in Section 9.3.

9.2.1 A general approach for estimation of cost and return data

A general approach was developed that consisted of specifying a production function to relate changes in land quality to changes in output, estimating the empirical models, and then calculating the costs of degradation and benefits of conservation.

The specification of production functions was examined, with the Cobb-Douglas model being the functional form chosen for estimation. The inclusion of a separate degradation variable in the model also had implications for the shift of the production function, with a linear variable that reflected constant returns to conservation works being preferred. Models were estimated at the regional, farm and paddock scale, with the preferred models having degradation represented as a linear variable.

The benefit of land degradation treatment at each scale was calculated as the increase in the value of agricultural output if degradation was reduced to negligible levels. Each degradation type was found to have a significant influence in the estimated models.

(a) Regional results

Ordinary least squares models were estimated for seven regions in NSW. In each of the models the inputs of area, labour, fertiliser, chemicals and degradation separately influenced the value of output. Gully erosion, sheet and rill erosion, induced soil acidity and woody shrub infestation were all found to have a significant, negative influence. The results are presented as the present value of benefits in Table 6.6.

(b) Farm results

Ordinary least squares models were estimated for the 31 farms surveyed in the Gunnedah region. In the first model the inputs of area, area of lucerne, fertiliser, chemicals, slope and sheet and rill erosion separately influenced the value of output. In the second model the inputs of area, fertiliser, chemicals, soil type and sheet and rill erosion separately influenced the value of output. The results are presented as the present value of benefits in Table 7.3.

(c) Paddock results

The nature of the paddock-level output data required a slightly different approach to the analysis. Values of pasture output per paddock proved difficult for the landholders to estimate; however, landholders were able to provide detailed information on livestock production. Annualised output values were then redistributed across all paddocks listed as having pasture land use. In each of the OLS models the inputs of labour, fertiliser, chemicals, the presence or absence of soil conservation, and sheet and rill erosion separately influenced the value of output. In both the Tobit models the inputs of labour, fertiliser, chemicals, the presence or absence of soil conservation, and sheet and rill erosion separately influenced the value of output. The present value of benefits per hectare were calculated for each paddock with a recorded output and are presented in Table 8.3.

9.2.2 Net returns of land-degradation treatment

Having determined the potential benefits associated with reducing land degradation to negligible levels at the regional, farm and paddock scale, the costs associated with the conservation works to achieve these reductions were calculated and compared with the benefits using a benefit-cost analysis framework. In calculating the costs, various land-management scenarios were considered and estimates were related directly to land use, slope and soil type. The estimates were then converted to present values, thus allowing the calculation of a BCR.

Region-wide BCRs were calculated for treating acidity, gully erosion, sheet and rill erosion and woody shrub infestation. The BCRs were 0.9 for acidity, 0.6 to 0.9 for gully erosion. 0.6 for sheet and rill erosion, and 1.1 for woody shrub infestation (Table 6.7). In order to disaggregate of information below the regional level, BCRs for treating gully erosion were also calculated for 12 LGAs in the northern part of the wheat-sheep zones, with the values ranging from 0.36 to 2.63. At the farm level, BCRs were calculated for treating sheet and rill erosion for 29 farms (Table 7.3). The BCRs ranged in value from 0.01 to 6.22, reflecting a high level of profit variability between farms. A sensitivity analysis was also undertaken in order to reflect the achievement of varying levels of soil conservation (Table 7.3). Benefit-cost ratios calculated for 20 paddocks ranged in value from 0.08 to 7.03 (Table 8.3), reflecting a consistency with the results achieved at the farm level.

9.2.3 Extrapolation of economic information

At each scale of management, economic priorities must be set according to the perceived needs of various stakeholders associated with land-degradation management. This study initially highlighted the limited amount of research that links economic information directly to bio-physical and management factors. Information about the profitability of land-management programs in the form of BCRs is generally restricted to management units that do not necessarily reflect or correspond to the bio-physical characteristics of the land.

To increase the resolution of the estimated BCRs below the scale of the management unit originally defined (region, farm and paddock), the bio-physical and management factors that were most influential in changing BCR levels were determined using regression analysis. The profitability of site-specific land-management proposals can then be predicted.

The availability of GIS data for map sheets at the 1:25 000 scale (see Chapter 5) enabled predictive modelling of the BCRs to be undertaken in a GIS at the farm and paddock scale. In order for predictive modelling to be undertaken in the GIS, the estimated BCR values for each farm were entered into the database as a new overlay. The GIS enables decision-tree models to be built, stored and used in a database. Estimated BCRs do not have complete geographical coverage of the study area. Decision-tree models can be derived to extend or interpolate these data across unsurveyed areas and other map sheets based on correlations between these data and remotely mapped predictor variables with complete geographical coverage of the map sheet. The decision-tree models are derived automatically using a technique called machine learning or induction.

(a) Regional results

Two equations were estimated for the Wheat-sheep zone (Zone 5). In the first model the inputs of gully erosion, area of cropping and soil type separately influenced BCR values. In the second model the inputs of gully erosion, area of cropping and slope separately influenced BCR values. Having determined these equations, it was then possible to predict BCRs for different values of the regressor variables. Significant relationships between BCRs and gully erosion, area of cropping and slope indicate that these variables are likely to provide useful predictors of BCRs. The predicted BCRs are shown in tables 6.9 and 6.10. Using this method it is possible to predict a BCR at a specific site, with its given combinations of land attributes, that indicates whether a proposal to repair gully erosion will be profitable.

(b) Farm results

One equation was estimated at the farm level, with the inputs of sheet and rill erosion, slope, soil type and area of trees separately influencing BCR values. At this scale it was possible to undertake decision-tree modelling of BCRs using GIS to predict BCRs according to management and bio-physical attributes. The predicted BCRs are presented in Figure 7.2. The original estimated BCRs were restricted in their spatial distribution within property boundaries, and had no variation across the entire property. The predicted BCRs cross conventional boundaries of management, and can be seen to vary according to the bio-physical attributes that exist in the landscape. By providing the results in a mapped output, it is also possible for individual landholders to identify specific areas of their property requiring particular attention. The results may also have benefits for Landcare groups allocating funding within their catchment or sub catchment. Further refinement of the predictive models may also allow their extrapolation to other map sheets in the area possessing similar land use and bio-physical characteristics.

(c) Paddock results

One equation was estimated at the paddock level, with the inputs of land use, sheet and rill erosion and proportion of trees separately influencing BCR values. At this level it was also possible to undertake predictive modelling of BCRs using GIS. The predicted BCRs are presented in Figure 8.2. Due the limitations in the data used to derive the original BCRs, some care must be taken in the interpretation of the predicted BCRs. However, by crossing conventional boundaries of management and varying BCRs according to the bio-physical attributes that exist in the landscape, the predicted BCRs are an improvement on the estimated BCRs as occurred with the farm-level results.

9.3 Policy implications

9.3.1 Policies for land degradation prevention and management

Policy instruments used to combat land degradation in Australia, and an indication of their varying levels of success, were outlined in Chapter 2. It could be argued that many of these policy instruments have had limited success due to a lack of reliable economic information associated with their implementation and the potential financial risks of investing in management practices. The current approach to funding allocation for land-management programs appears to be *ad hoc*. In the case of Landcare funding the emphasis has been on planning rather than specific on-the-ground activities (Paterson 1994). Edwards *et al.* (1996a) note there is no evidence that the benefits of projects funded by the National Landcare Program exceed the costs. Farley (1994) argues that in order to achieve more tangible results better financial incentives must be provided for landholders to undertake land-restoration activities. Therefore, a comprehensive and consistent framework for determining the basis for funding allocation needs to be developed.

Information that can only be supplied on the basis of socio-economic management units fails to recognise the important link developed by this research between economic, bio-physical and management information. The development of agro-ecological regions (ESD Working Group 1991) and the more recent biogeographic regions (Thackway and Cresswell 1995) provide the basis of alternative management units for analysis. As long as land management continues to be a state responsibility, the lack of uniformity of land-degradation assessment will continue to cause problems. This lack of uniformity also makes the task of determining accurate estimates of rates of change of particular degradation types more difficult. Therefore, there needs to be continued development of approaches to land-degradation assessment that link bio-physical and economic information on the basis of alternative management units.

9.3.2 Improvement of expenditure decisions

The general approach developed in Chapter 4, and applied in chapters 6, 7 and 8, offers a systematic way to analyse the effects of changes in land quality on output. This application provides some insight into the magnitude of the impacts of degradation on output. The empirical results from the approach provide some broad indicators which can be used, together with information about other considerations such as the value of offsite costs, to improve decisions on conservation expenditure at each scale of management and recommend policies to enhance land-degradation prevention and management.

(a) Regional

The regional results will help to guide policy related to funding allocation for land-degradation prevention and control by the State government and its relevant management authorities. The results highlight the continuing impact of land degradation 'sleepers' such as sheet and rill erosion and acidity. As these degradation types are often difficult to detect and cause larger losses in agricultural output than are generally perceived by the landholder, they may not receive the level of management or funding warranted. If funding were to be allocated specifically to areas and degradation types having a significant economic impact on agricultural output, then gully erosion and sheet and rill erosion should be given funding priority in Zone 1, according to the opportunity cost estimates at the regional level (Table 6.11). Acidity is causing considerable losses in agricultural output in both the northern and southern tablelands (zones 2 and 3), while the western part of the state is suffering from significant losses due to woody weed invasion. It appears that specific funding is needed therefore, to address the degradation problems that exist in these areas.

The estimated BCRs are also a useful guide to allocating funds, in relation to returns to investment. On the basis of these BCR estimates alone, only the treatment of woody shrub infestation will produce a positive return. However, more detailed examination at the LGA level indicates a greater variability in the BCR values. An important factor to consider is that these BCRs were only calculated for the onsite effects of land degradation. The presence of externalities arising from land degradation were discussed in Chapter 3, highlighting the fact that the wider community generally suffers losses as well as the individual landholder. Therefore, it is likely that the combined onsite and offsite benefits associated with land-degradation prevention and control would increase the BCR values reported in Table 6.6. A more detailed examination of BCRs for the treatment of gully erosion in the northern part of Zone 5 (Table 6.7) reveals the degree of variation in the profitability of management works.

As well as providing a guide for future funding allocation, the results can also highlight the inconsistencies in past expenditure on land degradation. The general approach, and the sort of result it provides at the regional scale, can help to identify and analyse whether excessive attention is being directed toward particular forms of degradation in areas where there may be little economic justification.

For instance, Table 9.1 gives examples of private and Landcare expenditure on the control and prevention of land degradation for three of the zones defined for this study. Private expenditure to combat water erosion is greatest in Zone 1 and least in Zone 2. Landcare grants for the same purpose follow a quite different pattern, being greatest in Zone 2 and least in Zone 3. Water erosion encompasses gully and sheet and rill erosion, and the opportunity costs of these erosion types were only found to be significant in Zone 1 (Table 6.11). Why, then, have grants been allocated to a zone that has been identified by private expenditure as being less affected by water erosion? The provision of improved information to individual landholders and funding bodies regarding the costs of water erosion and potential benefits of treatment could help to improve this disparity.

Table 9.1

Expenditure in 1991-92 on land-degradation control and prevention for selected zones of NSW

	Private expenditure[a] (%)		Landcare grants[b] (%)	
Zone	Water erosion	Salinity/ waterlogging	Water erosion	Salinity/ waterlogging
1	49.3	51.2	30.7	40.6
2	18.6	17.4	55.1	24.6
3	32.1	31.4	14.2	34.8
Total expenditure	\$5.46m	\$8.07m	\$0.02m	\$0.09m

[a] Nelson and Mues (1993).

[b] Department of Primary Industries and Energy (1993).

To take another example, salinity was found to have a negative but not significant influence in Zone 2, a zone in which neither private expenditure nor Landcare grants were dominant. This suggests a prima facie case of resource misallocation that should be tested to discover whether the current allocation to salinity is justified on grounds not considered here. For example, dryland salinity is becoming an increasing problem in some areas where it may not have been detected at the time of the 1987-88 Land Degradation Survey. The expenditure in Zones 1 and 3 may have been undertaken on preventative measures in areas identified as areas of potential hazard, rather than trying to repair areas already damaged by dryland salinity. An economic association was established between induced soil acidity and levels of agricultural output in Zone 3. Is acidity receiving the attention it deserves relative to other forms of degradation which would appear to have a lesser economic impact?

There appears to be an emphasis on salinity reduction and control expenditure at the State and national level. Stone, Andriotis and Chamley (1994) examined Commonwealth grants allocation to State government bodies for soil conservation and salinity reduction between 1977-88 and 1993-94. According to their estimates, specific-purpose payments to NSW total $26 m for soil conservation, and $42.5 m for salinity reduction and control during this time. During the same time payments for salinity reduction and control more than doubled allocations to soil conservation in Victoria and Western Australia. Stone *et al.* (1994) note the absence of a comprehensive and consistent framework for determining the basis for funding allocation.

(b) Farm

At the farm level, the landholder may make a decision to invest in management practices to control or prevent a particular land-degradation problem, or a number of landholders as part of a Landcare group may identify a particular problem they wish to address. Their motivation to undertake such practices may not necessarily be driven by purely economic incentives; however, guiding information of this nature is lacking.

Results at this scale of management indicate that it is possible to produce both farm-level and landscape-level economic information to guide the allocation of limited resources. It was not the intention of this study to provide actual management solutions for individual landholders in the study area, due to the confidential nature of the data. The analysis was more an exercise to show the type of information that can be produced at this scale, and the ability to assess economic priorities for management programs according to bio-physical and land-use attributes. However, general observations in Chapter 7 reveal that there are profitable opportunities for investment in soil-conservation practices for the farm study area. The predictive modelling further enhances these results through the extrapolation of the BCRs across conventional management and ownership boundaries, enabling the recognition of economic benefits on the basis of bio-physical attributes that occur in the landscape. For example, two farms surveyed in the bottom right-hand corner of the map sheet (Figure 7.1) were estimated to have BCRs less than 1.0. The results of the predictive modelling (Figure 7.2) reveal that while some parts of these farms record BCRs below 1.0, other areas have BCRs that indicate profitable investments can be made. Given that the BCRs are aggregated from individual values into classes that represent a range of values (eg. 1 — <2), this may lead to some loss of accuracy in the predicted results, particularly for the classes where BCRs are <1, and above 5.

The study has highlighted that there is still an element of risk involved in soil-conservation investment, even if information is provided to guide expenditure decisions to control or prevent land degradation. Therefore, landholders need to be given an indication of the probability of a particular BCR occurring, as in Chapter 7. Landholders unable to afford the range of management practices required to return degradation to negligible levels can also be provided with BCRs associated with alternative management practices.

As well as guiding future funding allocation, the results can also be interpreted in terms of past expenditure on land degradation. The study area falls within the Namoi River catchment, and information is available on activities funded by external sources for Landcare groups within the catchment (Donaldson Planning and Management Services 1996). Despite the availability of adequate technology for the control of soil erosion in the catchment, there still appears to be doubt about the economic feasibility of projects. However, investment in Landcare activities by external sources has been substantial (Table 9.2). One Landcare group occurs within the study area, with 11 of the landholders surveyed being members. For the period 1992-95 the group received \$23 300 for erosion control and watercourse management, \$5800 for salinity reduction and \$53 750 for tree planting, for a total of \$82 850 (Donaldson Planning and Management Services 1996). Results from the landholder survey undertaken for this study indicate that most farmers are also implementing land-degradation management practices at their own expense, but these investments are not large. The average loss in agricultural output for each landholder from sheet and rill erosion is \$19.60/ha/year, or

Table 9.2

Summary of expenditure on Landcare activities funded from external sources in the Namoi River Catchment 1990-95 ($)

Landcare activity	1990	1991	1992	1993	1994	1995	Total
Catchment planning	12 480	10 060	20 000	72 411	101 950	93 890	310 791
Soil erosion	0	54 500	10 000	9500	346 832	264 431	685 263
Pasture degradation and scalding	600	57 500	10 500	9000	16 000	15 489	109 089
Salinity	15 406	53 056	21 450	16 620	145 644	150 718	402 894
Streambank erosion	700	0	17 500	85 490	112 279	150 145	366 114
Tree decline	0	3700	28 973	33 235	87 405	449 415	602 728

Source: Donaldson Planning and Management Services (1996).

around $0.5 m/year for the entire study area. This would, of course, be the gain from investment in treatment. Therefore, it can be concluded that there is significant under-investment in land-degradation management in the study area at present.

(c) Paddock

As with the farm results, analysis at the paddock level was an exercise to show the type of information that can be produced at this scale. This research has highlighted that landholders in the chosen study area do not find it necessary to keep detailed production records at the paddock level for their current management purposes. It is unclear whether the incentive of improved economic information for conservation management purposes would encourage landholders to begin recording this data.

9.4 Market failure

The framework developed in this study does not attempt to analyse the market failures associated with the off-site effects of land degradation, however the importance of such effects is acknowledged in Chapter 3. These off-site effects of land degradation include damage to water courses and infrastructure, the occurrence of dryland salinity, and loss of wildlife habitat.

The results of this study suggest that on-farm market failure is occurring too, as there appear to be many profitable opportunities for landholders to undertake programs to ameliorate or prevent land degradation, which are not being taken up. This market failure could result from a lack of information on the potential profitability of undertaking conservation works, or the potential effects that land degradation may be having on levels of agricultural output and the type of programs and funding available to address the problem. The market failure could also result from uncertainty. The risk analysis undertaken in Chapter 7 indicates that despite the apparent profitability of undertaking particular management programs, there is still a certain level of uncertainty attached to the decision, which may relate to the variability of crop and livestock prices.

9.5 Assessment and limitations of the research

9.5.1 The findings and contributions

The main findings and contributions of this research can be summarised as follows.

(a) A general procedure has been developed that uses a production function containing a land quality variable to estimate the influence of land degradation on agricultural output. This procedure can be applied at various scales of management, depending on data availability.

(b) A method has been developed to determine the bio-physical and management factors that are most influential in changing BCR levels. A BCR can then be predicted for an area on the basis of a combination of the influential factors.

(c) The predictive analysis has been enhanced through the use of GIS. The GIS enables the predicted BCRs to cross conventional boundaries of management and vary according to bio-physical attributes that exist in the landscape as well as management factors. By providing the results in a mapped output, it is also possible for specific areas requiring particular management attention to be identified.

(d) Various forms of land degradation have been found to have a significant negative influence on agricultural output at the regional, farm and paddock level. As the inputs of fertiliser and chemicals consistently have a positive influence on the value of output, they may be masking the negative effects of land degradation to a certain degree. The availability of more detailed bio-physical and management data such as slope, soil type and presence of soil-conservation works at the farm and paddock level enabled their inclusion in production functions, and some were found to be influencing agricultural output along with more conventional inputs.

(e) The BCRs estimated at the regional, farm and paddock level indicate that there are many profitable opportunities for undertaking land-management programs to control and prevent land degradation. The results also highlight that it may not always be economically worthwhile to invest in conservation projects or changes in land-management practices. For landholders unable to achieve optimal low levels of degradation because of financial constraints, some benefits may still exist from undertaking a certain degree of conservation management. A risk analysis of the BCRs at the farm level revealed that there is a high probability (up to 35 percent) that conservation measures will be unprofitable. This level of risk may deter farmers from investing in conservation practices.

9.5.2 Limitations and directions for future research

(a) Limitations of the research

There are a number of factors related to the production function specification and estimation that may be viewed as limitations to the study. The estimation of a Cobb-Douglas model rather than a more flexible functional form involves restrictive properties: the returns to scale have the same value across all firms in the sample, and the assumption exists that the elasticity of substitution is equal to one, which must be taken into account when interpreting the results. The inclusion of a climatic variable was attempted at the regional level but was not shown to have statistical significance. Due to the unpredictable and seasonal nature of rainfall it would be better suited to a time-series rather than cross-sectional analysis. The regional models were also restricted to using secondary data not collected specifically for the purposes of this study. This meant that a reliable capital variable could not be included in the production function models, and bio-physical information was limited to broad categories of slope and soil type. Analysis at the farm and paddock level relied on GIS data collected for other purposes. Additional GIS data such as land capability and suitability would have been useful for the analysis.

The inclusion of other forms of economic information in the GIS would also have been desirable. This study has relied on the BCR as an indicator of profitability of land management programs. Other measurements such as net present value or total investment required may have also been useful for predictive modelling purposes.

(b) Scope for further research

The main advantage with the approach adopted is the estimation of an opportunity cost of degradation, which provides an indirect measure of the benefits associated with various amelioration and conservation measures However, the heterogeneity in production and bio-physical characteristics may limit the accuracy of this indirect measure of benefits at the farm and paddock level. At the regional level the general approach is based on agro-ecological regions which are relatively homogenous regions of climate, geography and land use. Therefore, the models developed at this scale are more likely to provide accurate opportunity cost measures.

Furthermore, at the farm and padddock levels, the approach will compete with other, more direct, though possibly more subjective, measures of the benefits of particular conservation or amelioration measures, such as the budgeting approach. At the regional level, there are no such alternative approaches to provide the type of information generated in this study, suggesting that the approach is especially suited to the regional level.

The general method of analysis has potential for application in other States and regions, provided that adequate data are available. Such applications would allow the provision of consistent information to guide decisions for land-degradation prevention and control. A useful exercise would be to compare these results with those from other estimates of the influence of land quality on agricultural output, such as changes in total factor productivity (TFP). Changes in TFP are an indication of technological change, with any changes in land quality being reflected in the input/output ratio that TFP measures (Chisholm and Hone 1996). Further exploration of the application of frontier production functions is also warranted, with this type of analysis being enhanced by the availability of time-series data on production and degradation. However, data on land-degradation trends over time is difficult to obtain.

The estimation of offsite benefits and costs was outside the objectives of this research. Nevertheless, conservation has been shown to make a positive contribution to welfare in many cases, even without the added benefit of reductions in these offsite costs. A further area for research must concern the estimation of social BCRs.

There is scope for the farm-level results to be extrapolated to other map sheets in the surrounding area. GIS information exists for the entire Namoi catchment, therefore the predictive results could be extended to other areas in the catchment with similar land-use and bio-physical attributes.

9.7 Concluding comments

Economic information should be combined with bio-physical information when estimating benefits and costs, as illustrated by the results in Chapter 6,7 and 8, where bio-physical factors are also having an important influence on BCR levels. However, at present decisions regarding land management New South Wales have very little detailed integrated economic and bio-physical information to guide them. This research provides a consistent method of analysis, by indicating where degradation is having the most significant effect on agricultural output, estimating BCRs and relating the profitability of undertaking land-management programs to various bio-physical attributes and management attitudes. This process of data integration using GIS technology allows the BCR results estimated at the farm and paddock level to be disaggregated and extended to include both surveyed and non-surveyed areas. This, therefore, combines economic and bio-physical information at a scale that is useful for both landholders policy makers in a decision-making process.

Due to some limiting assumptions and a lack of data for some potentially-important factors, the models estimated in this study only go part way towards describing the dynamics of the real world. However models that incorporate bio-physical and spatial factors are likely to outperform those that do not. Therefore, there is potential for further applications of this method both in Australia and elsewhere, provided suitable data exist.