6. Regional results

6.1 Introduction

Several kinds of information concerning land quality are needed to guide the allocation of resources to address the problems of land degradation at the regional level. State conservation agencies need to answer several kinds of questions. Given an annual budget, should any resources be allocated to reduce land degradation? If resources are to be allocated, which kinds of degradation should be addressed? What resources should be allocated to each project within a specified program? Information is needed on the benefits and costs of degradation, and the increased output from soil conservation for each kind of project, land type and degradation type. The increased output will, of course, vary according to the quality of the land to which the resources are applied.

The aims of this chapter[4] are therefore to:

(1) apply the general approach developed in Chapter 4 to analyse the effects of land degradation on a regional basis by agricultural and ecological zones,

(2) derive regional information about the benefits and costs for the treatment of land degradation for particular land-management situations,

(3) determine the bio-physical and management factors that most influence these costs and benefits, and

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[4] Walpole (1994) and the author's contribution to Walpole, Sinden and Yapp (1996) form the basis for this chapter.

(4) disaggregate regional benefit-cost ratios (BCRs) according to bio-physical and management factors to give a higher resolution of information.

The method follows the general approach developed in Chapter 4. This approach consists of specifying a production function that relates changes in land quality to changes in output, estimating the empirical models, and then calculating the costs of degradation and benefits of conservation from the empirical results. Estimates of the costs of treatment are then made in order to calculate a benefit-cost ratio. To increase the resolution of the estimated BCRs below the scale of the original management unit, the bio-physical and management factors that are most influential in changing benefit-cost ratio levels are then determined. This information can be presented in a form that will enable a rapid appraisal of sites where conservation may be required, giving an indication of the economic merits of particular projects.

The only set of statewide degradation data available is for New South Wales, so the scope of the analysis is limited to degradation of agricultural land in that State. But the general approach and underlying principles can be well illustrated with these data. As described in Chapter 5, the NSW Land Degradation Survey (Soil Conservation Service of NSW 1989; Graham 1989, 1992) provides the most comprehensive land-degradation data in Australia. The survey collected state-wide information on ten degradation types, as well as other bio-physical and management attributes. The local government area (LGA) is the smallest government administrative unit in Australia, and agricultural input and output data are aggregated to this level by the Australian Bureau of Statistics in their Annual Agricultural Census. Therefore, the LGA was chosen as the basic unit for State and regional applications of the general approach. For the purposes of analysis, LGAs were aggregated into zones to represent particular regions of the State.

The economic information available at the regional level, coupled with the bio-physical data from the Land Degradation Survey, allows for a more detailed examination of the factors influencing the benefits and costs associated with land degradation.

6.2 Estimation of models

Cobb-Douglas models, estimated on the basis of Equation 4.8 for the seven NSW zones specified in Chapter 4, are presented in the following sections. The estimated equations show the influence of degradation on the value of agricultural production, and a significant negative coefficient shows that increases in degradation are associated with decreases in production. In the estimation process, the form of the degradation variable must be specified, the problem of reversibility should be addressed, and the nature of the shift in the production function must be specified. Furthermore, the possibility of spatial correlation must be examined. The questions of returns to scale and the functional form are also discussed as part of the results of this chapter. A number of statistical and diagnostic tests were applied to the models to examine the potential problems outlined in Chapter 4, and to determine the preferred models for further analysis. The tests are the t-ratio test of coefficients, the goodness-of-fit statistics R^2 and adjusted R^2, the Durbin-Watson (DW) test for autocorrelation, and the Breusch-Pagan-Godfrey (BPG) test for heteroskedasticity. The model variables reported in this section are defined in Section 5.2.

All functions have been fitted with ordinary least squares (OLS). Attempts were also made to estimate the stochastic frontier regression described in Chapter 4 in order to depict the production/degradation relationship in terms of technical efficiency. However, these attempts were unsuccessful.

6.2.1 Zone 1 — Temperate semi-arid slopes and plains

The preferred Cobb-Douglas models estimated for Zone 1, together with the relevant test statistics, are shown in Table 6.1 (Equations 6.1, 6.2 and 6.3). The total amount of degradation per LGA is the ideal specification of this variable, and the three significant degradation variables in the Cobb-Douglas models are of this form. A linear or arithmetic specification of the degradation variable (SUMGUL; Equation 6.1) is preferred, due to the implications for the shift of the production function. However models with logarithmic degradation variables are also presented (LSUMGUL; Equation 6.2 and LSUMTON; Equation 6.3). All the estimated coefficients in Equation 6.1, 6.2 and 6.3 are significant. The diagnostic tests suggest that the estimated models are statistically sound. The DW statistics for Equation 6.2 and 6.3 are inconclusive in that H_0 is neither accepted nor rejected according to the Durbin-Watson test (Griffiths *et al.* 1993), indicating the absence of autocorrelation.

A translog model was also estimated for Zone 1, and is shown in Table 6.2 (Equation 6.4). The model reduces to a Cobb-Douglas function if the restriction described in

Table 6.1

Estimated models for the relationship between agricultural inputs and gross value of agricultural production for Zone 1[a]

	Zone 1		
Regressor variable	Equation 6.1	Equation 6.2	Equation 6.3
LAREA	0.219 (4.3)***	0.229 (4.4)***	0.226 (4.2)***
LLABOUR	0.290 (2.7)***	0.270 (2.4)**	0.301 (2.6)***
LTFERT	0.568 (6.5)***	0.579 (6.4)***	0.579 (6.1)***
SUMGUL	-0.138E-06 (2.5)***		
LSUMGUL		-0.036 (2.1)**	
LSUMTON			-0.044 (1.6)*
n	36	36	36
Constant	1.346	1.346	1.561
R^2	0.782	0.772	0.759
Adj R^2	0.754	0.742	0.728
DW Statistic	1.832	1.659	1.546
BPG Statistic	6.231	3.499	4.795

[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.

Table 6.2

Translog model for the relationship between agricultural inputs and gross value of agricultural production for Zone 1^a

Regressor variable	Coefficient	Equation 6.4
LAREA	ß$_2$	-0.101
		(0.1)
LLABOUR	ß$_3$	-1.223
		(0.3)
LTFERT	ß$_4$	-1.094
		(0.2)
LSUMGUL	ß$_5$	0.654
		(0.8)
$\frac{1}{2}$(LAREA)^2	ß$_6$	-0.026
		(0.2)
$\frac{1}{2}$(LLABOUR)^2	ß$_7$	-1.344
		(2.0)**
$\frac{1}{2}$(LTFERT)^2	ß$_8$	0.012
		(0.03)
$\frac{1}{2}$(LSUMGUL)^2	ß$_9$	-0.020
		(0.9)
(LAREA .LLABOUR)	ß$_{10}$	0.346
		(1.4)*
(LAREA.LTFERT)	ß$_{11}$	-0.209
		(1.2)
(LAREA.LSUMGUL)	ß$_{12}$	0.018
		(0.4)
(LLABOUR.LTFERT)	ß$_{13}$	0.726
		(1.7)**
(LLABOUR.LSUMGUL)	ß$_{14}$	-0.046
		(0.7)
(LTFERT.LSUMGUL)	ß$_{15}$	-0.045
		(0.7)
	n	36
	Constant	12.353
	R^2	0.869
	Adj R^2	0.782

[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.

Chapter 4 is met. An F-test was undertaken to choose whether the Cobb-Douglas or the translog is the appropriate functional form. This test supports the validity of the Cobb-Douglas restriction ($F_{(10,21)} = 1.399$). In addition, the translog model does not appear to offer any further insights than the Cobb-Douglas estimations into the relationship between land degradation and agricultural output.

6.2.2 Zone 2 — Temperate highlands

The preferred Cobb-Douglas model for Zone 2, together with the relevant test statistics, is shown in Table 6.3 as Equation 6.5. Equation 6.6 is also presented, although the estimated degradation coefficient LDRYSAL is not significant at the 10 percent level. It was included to show that a negative relationship exists between agricultural output and dryland salinity, but not at a high enough level of significance to warrant further analysis in this study.

In regard to the specification of the acidity variable in Equation 6.5, the significant degradation variable is an average value of a hazard classification rather than the ideal total measurement. Acidity could only be represented in the model this way, because of the way in which it was originally recorded in the NSW Land Degradation Survey. Degradation represented as a linear or arithmetic variable is also preferred; however, Equation 6.5, with a logarithmic degradation variable LACID, was the only significant model. All the estimated coefficients in Equation 6.5 are significant except for LCHEMHA. The diagnostic tests for Equation 6.5 suggest that the estimated model is statistically sound. The DW statistic for Equation 6.5 is inconclusive in that H_0 (no autocorrelation) is neither accepted nor rejected according to the Durbin-Watson test.

6.2.3 Zone 3 — Sub-tropical highlands

The preferred Cobb-Douglas models estimated for Zone 3, together with the relevant test statistics, are shown in Table 6.3 (Equations 6.7 and 6.8). As with Zone 2, the significant degradation variable is an average class value. Degradation represented as a linear or arithmetic variable is preferred (ACID; Equation 6.8); however, Equation 6.7, with a logarithmic degradation variable (LACID) is also presented. All the estimated coefficients in Equation 6.7 and 6.8 are significant. The diagnostic tests for both equations suggest that the estimated models are statistically sound.

Table 6.3

Estimated models for the relationship between agricultural inputs and gross value of agricultural production for Zone 2 and Zone 3[a]

	Zone 2		Zone 3	
Regressor variable	Equation 6.5	Equation 6.6	Equation 6.7	Equation 6.8
LLABHA	0.599 (7.7)***	0.593 (7.0)***	0.746 (8.4)***	0.751 (7.9)***
LFERTHA	0.526 (3.0)***	0.513 (2.7)**	0.275 (3.4)***	0.260 (3.3)***
LCHEMHA	0.062 (1.3)	0.070 (1.4)*	0.120 (2.6)**	0.123 (2.6)**
LACID	-0.264 (1.7)*		-0.489 (1.9)**	
LDRYSAL		-0.330 (1.3)		
ACID				-0.313 (1.8)**
n	16	16	24	24
Constant	2.783	2.624	3.468	3.776
R^2	0.926	0.919	0.874	0.871
Adj R^2	0.899	0.890	0.847	0.843
DW Statistic	2.697	2.521	2.048	2.062
BPG Statistic	5.512	2.484	2.198	2.000

[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.

6.2.4 Zone 4 — Coastal and tablelands zone

No models are presented for this zone, as none of those estimated were statistically significant, recording low t-values and R^2 values. An explanation for this failure could be the heterogeneity of land use and bio-physical factors that occur within this region.

6.2.5 Zone 5 — Wheat-sheep zone

The preferred Cobb-Douglas models estimated for Zone 5, together with the relevant test statistics, are shown in Table 6.4 (Equations 6.9, 6.10 and 6.11). The three significant degradation variables in the Cobb-Douglas models are all total measurements per LGA. Degradation is represented as a linear or arithmetic variable (SUMGUL; Equation 6.9), and logarithmic degradation variables are also presented (LSUMGUL; Equation 6.10 and LSUMTON; 6.11). All the estimated coefficients in Equation 6.9, 6.10 and 6.11 are significant at the 10 percent level. The diagnostic tests for all equations suggest that the estimated models are statistically sound.

6.2.6 Zone 6 — Western zone

The preferred Cobb-Douglas model estimated for Zone 6, together with the relevant test statistics, are shown in Table 6.4 (Equation 6.12). The significant degradation variable (WSHRUB) is an average class value. All the estimated coefficients in Equation 6.12 are significant. The diagnostic tests for both equations suggest that the estimated models are statistically sound. The DW statistic for Equation 6.12 is inconclusive in that H_0 (no autocorrelation) is neither accepted or rejected according to the Durbin-Watson test. Interpretation of the coefficients from this model should be treated with more care than the other regional models, since the adjusted R^2 value is significantly lower than those estimated for other models.

6.2.7 Zone 7 — Extended wheat-sheep zone

The preferred Cobb-Douglas models estimated for Zone 7, together with the relevant test statistics, are shown in Table 6.5 (Equations 6.13, 6.14, 6.15 and 6.16). The four

Table 6.4

Estimated models for the relationship between agricultural inputs and gross value of agricultural production for Zone 5 and Zone 6[a]

Regressor variable	Zone 5		Zone 6	
	Equation 6.9	Equation 6.10	Equation 6.11	Equation 6.12
LAREA	0.295 (3.0)***	0.298 (3.0)***	0.251 (2.6)***	0.610 (3.0)***
LLABOUR	0.537 (4.0)***	0.541 (4.1)***	0.596 (4.3)***	0.574 (2.3)**
LTFERT	0.336 (3.1)***	0.313 (2.9)***	0.327 (3.0)***	0.088 (1.5)*
SUMGUL	-0.620E-07 (2.1)**			
LSUMGUL		-0.047 (2.2)**		
LSUMTON			-0.052 (1.5)*	
WSHRUB				-0.379 (1.6)*
n	45	45	45	16
Constant	0.826	1.507	1.658	-1.155
R^2	0.806	0.809	0.796	0.634
Adj R^2	0.787	0.790	0.776	0.500
DW Statistic	2.111	2.044	2.087	1.423
BPG Statistic	8.601	7.199	6.634	4.300

[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.

Table 6.5

Estimated models for the relationship between agricultural inputs and gross value of agricultural production for Zone 7[a]

	Zone 7			
Regressor variable	Equation 6.13	Equation 6.14	Equation 6.15	Equation 6.16
LAREA	0.341 (5.3)***	0.346 (5.5)***	0.322 (4.9)***	0.317 (4.9)***
LLABOUR	0.609 (5.1)***	0.607 (5.1)***	0.648 (5.2)***	0.664 (5.4)***
LTFERT	0.199 (2.5)***	0.183 (2.4)**	0.204 (2.4)***	0.204 (2.5)***
SUMGUL	-0.679E-07 (2.5)***			
LSUMGUL		-0.054 (2.8)***		
SUMTON			-0.112E-06 (1.5)*	
LSUMTON				-0.071 (2.3)**
n	51	51	51	51
Constant	1.008	1.712	0.934	1.724
R^2	0.806	0.813	0.792	0.803
Adj R^2	0.791	0.797	0.774	0.786
DW Statistic	2.191	2.143	2.297	2.127
BPG Statistic	7.239	3.625	6.214	2.817

[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.

significant degradation variables in the Cobb-Douglas models are total measurements per LGA. Degradation is represented as a linear or arithmetic variable (SUMGUL; Equation 6.13 and SUMTON; Equation 6.15) and logarithmic degradation variables are also presented (LSUMGUL; Equation 6.10 and LSUMTON; 6.16). All the estimated coefficients in Equations 6.13, 6.14, 6.15 and 6.11 are significant at the 10 percent level. The diagnostic tests for all equations suggest that the estimated models are statistically sound.

6.2.8 Preferred models

For the Cobb-Douglas production function, the elasticities of the individual inputs are given by the estimated coefficients in the regression equation. These individual elasticities can be summed to determine the scale coefficient (ε), which indicates the percentage by which output will be increased if all factors are increased by one percent. Thus, $\varepsilon < 1$ is taken to imply decreasing returns to scale, and $\varepsilon > 1$ increasing returns to scale, while $\varepsilon = 1$ implies constant returns to scale. It is important to acknowledge that in some of the models, the sum of the output elasticities is greater than one, possibly reflecting the use of a limited subset of inputs being included in the models (Heady and Dillon 1961). Models that display explosive use of inputs to exploit increasing returns ($\varepsilon < 1$) will provide the most accurate estimates.

The estimated Cobb-Douglas models show a consistent pattern where various types of land degradation have a significant negative influence on agricultural output. The preferred models are those with degradation represented as a total measurement and a linear variable, and where the diagnostic tests indicate that the estimated model is statistically sound. Therefore, the preferred models are Equations 6.1, 6.8, 6.9, 6.12, 6.13 and 6.15.

6.3 Benefit-cost ratios

The benefits and costs for each zone are calculated according to the procedures outlined in Chapter 4 and are presented in Table 6.6. These ratios give a broad indication of overall profitability levels for investment in land degradation control and prevention. The BCRs were recalculated with discount rates of 3 and 7 percent. The ratios for acidity did not change because the benefits and costs are equal annual flows. At the lower rate, the ratios

Table 6.6

Per hectare benefit-cost ratios for the treatment of land degradation

Degradation type/Zone ($/ha)	PVB ($/ha)	PVC	BCR
Acidity			
Sub-tropical Highlands (Zone 3)	280	300	0.9
Gully erosion			
Temperate and semi-arid slopes and plains (Zone 1)	200	325	0.6
Wheat-sheep zone (Zone 5)	280	325	0.9
Extended wheat-sheep zone (Zone 7)	220	325	0.7
Sheet and rill erosion			
Extended wheat-sheep zone (Zone 7)	180	325	0.6
Woody shrub infestation			
Western zone (Zone 6)	200	175	1.1

for gully erosion increased from 0.6, 0.9 and 0.7 to 0.8, 1.1 and 0.9 respectively. At the higher rate, the ratios for gully erosion decreased to 0.5, 0.7 and 0.6. The ratio for woody-weed infestation was 1.1 at 3 percent, 1.1 at 5 percent and 1.2 at 7 percent. The results suggest overall that, even ignoring external benefits, there are profitable opportunities for investment in soil and land conservation in New South Wales. The limitations of the data used to obtain these results, outlined in Chapter 5, should also be kept in mind when interpreting these results.

It is also possible to determine BCRs for individual LGAs and particular degradation types, following the method outlined in Chapter 4. This allows for a disaggregation of information below the zone level. Using Equation 6.9 from Table 6.4, BENPH and PVB values were estimated for 12 LGAs in the northern part of the Wheat-Sheep Zone (Zone 5) for gully erosion. Using cost data PVCMAINT, PVCREST, PVCCHANGE and PVC were also estimated for each LGA. Using these results, BCRs for each LGA can also be calculated. These values are recorded in Table 6.7. In addition, the total area in agricultural production and the total length of gullying per LGA and per 100 ha are also recorded in Table 6.8 for the same LGAs.

The size of the LGAs ranges from 105 936 ha (Nundle) to 1 634 512 ha (Moree Plains), with an average of 445 022 ha. The presence of gully erosion was recorded as metres/100 ha, and has been converted to a total amount for the entire LGA. As an intensity measure, Moree Plains had the lowest average levels of gully erosion (98.58 m/100 ha), while Barraba recorded the highest levels (1770.20 m/100 ha). As an absolute measure, Nundle had the lowest total length of gullying (436 691 m), while Yallaroi had the highest (6 403 426m). The average figure across all LGAs was 749.62 m/100 ha and 2 660 869 m in total.

The estimated BCRs for repairing gully erosion range from 0.36 for Nundle to 2.63 for Yallaroi, with an average across the 12 LGAs of 1.16. This is slightly higher than the BCR estimated for the whole of Zone 5 (0.9; Table 6.4), reflecting a higher incidence of gully erosion in the northern part of the State (Walpole *et al.* 1992; Soil Conservation Service of NSW 1989).

Table 6.7

Comparison of benefits and costs for treating gully erosion for LGAs in the northern part of the Wheat-sheep zone (Zone 5)

Local Government Area	Area (ha)	Total gully length for LGA (m)	Mean gully length (m/100 ha)	BENPH ($/ha)	PVB ($/ha)	PVC MAINT ($/ha)	PVC REST ($/ha)	PVC CHANGE ($/ha)	PVC ($/ha)	BCR
Barraba	222070	3931083	1770.20	30.78	615.56	179.90	695.26	20.42	895.58	0.69
Bingara	209096	2489158	1190.44	15.28	305.63	193.99	301.37	39.89	535.25	0.57
Coonabarabran	435456	2635208	605.16	18.07	361.42	263.56	54.30	72.46	390.32	0.93
Gunnedah	171188	1016857	412.04	29.12	582.37	386.79	34.02	187.01	607.82	0.96
Inverell	598795	7009618	1170.62	62.27	1245.40	271.49	143.96	73.13	488.58	2.55
Manilla	170629	1101769	645.71	6.88	137.64	196.22	58.77	59.30	314.29	0.44
Moree Plains	1634512	1611302	98.58	21.95	438.97	322.19	2.31	102.23	426.73	1.03
Narrabri	758480	2521037	332.38	41.06	821.26	298.07	21.57	109.76	429.40	1.91
Nundle	105936	436691	412.22	5.88	117.55	249.60	24.54	50.27	324.41	0.36
Parry	310766	1522474	489.91	24.28	485.58	278.57	57.24	102.81	438.62	1.11
Quirindi	263983	1251809	474.20	25.64	512.71	444.20	51.87	151.40	647.47	0.79
Yallaroi	459350	6403426	1394.02	84.85	1696.94	352.62	160.26	133.37	646.25	2.63
Average	445022	2660869	749.62	30.50	610.08	286.43	133.79	91.84	512.06	1.16

6.4 Site-specific benefit-cost ratios

The estimated BCRs for all 45 LGAs in the Wheat sheep zone (Zone 5) 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 are most influential in changing the BCR levels. This increases the resolution of the BCRs by allowing the BCR results from the LGA level to be disaggregated below the LGA level. The estimated models are shown in Table 6.8. The model variables reported in this section are defined in Section 5.2.

The dependent variable BCR = the benefit-cost ratio. The independent variables are: GULLY = length of gullies (m/100 ha); CROP = proportion of cropping land use; SLOPE = average slope across the LGA SOILG = soil group class (three classes, where class 1 = sandy soils [coastal and inland , class 2 = length-textured brown soils, skeletal soils, red brown earths, and class 3 = heavy-textured grey and brown soils, black earths, coastal peats); NTH = dummy variable (north area), where 1 = north, 0 = central or south; STH = dummy variable (south area), where 1 = south, 0 = north or central. These dummy variables were included to determine whether there was any significant difference in the data provided from the northern, central and southern parts of the zone. Of the 45 LGAs in the Wheat-sheep zone, four outlying LGAs with very high gully lengths were excluded, as it was felt that the extreme levels of degradation recorded in these LGAs were not representative of the region as a whole. Also, five LGAs had gully lengths that were already lower than the 'negligible' rate, therefore a BCR cannot be estimated. This left 36 LGAs in the estimation.

Equation 6.17 indicates significant relationships between the level of BCRs and length of gullying, the proportion of cropping, and soil type. Equation 6.18 indicates significant relationships between BCRs and length of gullying, the proportion of cropping, and slope. Thus, increases in BCRs to repair gullying appear to be associated with increases in the amount of gullying and decreases in the proportion of cropping, and the degree of slope. Due to the way the opportunity costs (benefits) are calculated, areas recording the largest gullies stand to gain the most in terms of increased agricultural output when these gullies are repaired. Areas of land with lower slopes and less cropping are also less costly to undertake soil conservation works, so the combination of these three factors leads to higher BCRs.

Having determined these equations, it is then possible to use them to predict BCRs for different levels of the regressor variables. Significant relationships between the

Table 6.8

Preferred models for the relationship between benefit-cost ratios, and land use and biophysical factors[a]

Regressor variable	Equation 6.17	Equation 6.18
GULLY	0.003 (5.6)***	0.003 (5.3)***
CROP	-1.01 (1.9)**	-0.89 (1.7)**
SOILG	0.72 (1.4)*	
SLOPE		-0.089 (2.5)***
NTH	-0.93 (3.1)***	0.71 (2.8)***
STH	-0.20 (0.8)	-0.47 (2.1)**
n	36	36
Constant	-0.834	1.310
R^2	0.65	0.69
Adj R^2	0.59	0.64

[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.

dependent variable and GULLY, CROP and SLOPE indicate that these variables are likely to provide the most useful estimates of ratios. Thus, for Equation 6.18 SLOPE, NTH and STH were set at their mean values, and BCRs were generated, given particular values of GULLY and CROP. The predicted BCRs are shown in Table 6.9. Similarly, with CROP, NTH and STH set at their mean values, BCRs were generated, given particular values of GULLY and SLOPE. The predicted BCRs are shown in Table 6.10.

These values are the basis of a rapid appraisal method, developed by Walpole (1994). Using this method it is possible to predict a BCR that indicates whether a proposal to repair gully erosion will be profitable at a specific site with its given combination of land attributes. For example, in Table 6.9 gully repair becomes profitable (BCR > 1.0) when levels of gullying are at 350 m/100 ha and there is 10 percent cropping (BCR = 1.05). From Table 6.10 gully repair becomes profitable when levels of gullying are at 300 m/100 ha and slope is 1 percent (BCR = 1.14).

6.5 Discussion

6.5.1 The effect of land degradation

Perhaps the most interesting result concerns the separate significance of the regressor variables in the models. The statewide survey of land degradation in 1987-88 indicated that 25 percent of New South Wales was affected by moderate to very severe levels of wind erosion, 11.9 percent of the State was affected by moderate to extreme levels of gully erosion, and 18.3 percent of the State had moderate to severe levels of soil structure decline. So a major policy question can be asked: has this degradation had a significant effect on output, or has its effect been masked by improved practices or improved technology ?

In each of the models the inputs of area, labour, fertiliser, chemicals and degradation separately influence the value of output. Thus, while increases in land area, labour, fertiliser and chemicals increase output degradation decreases it. Increases in fertiliser and chemicals, therefore, appear to counter the effects of degradation but degradation continues to reduce output, even while these inputs increase it.

Table 6.9

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

Proportion of cropping (%)	Gully length (m/100 ha)									
	50	100	150	200	250	300	350	400	450	500
10.0	0.12	0.27	0.43	0.58	0.74	0.89	1.05	1.20	1.35	1.51
20.0	0.02	0.17	0.33	0.48	0.63	0.79	0.94	1.10	1.25	1.41
30.0	-	0.07	0.22	0.38	0.53	0.69	0.84	1.00	1.15	1.31
40.0	-	-	0.12	0.28	0.43	0.59	0.74	0.90	1.05	1.20
50.0	-	-	0.02	0.18	0.33	0.49	0.64	0.79	0.95	1.10
60.0	-	-	-	0.07	0.23	0.38	0.54	0.69	0.85	1.00
70.0	-	-	-	-	0.13	0.28	0.44	0.59	0.75	0.90
80.0	-	-	-	-	0.03	0.18	0.34	0.49	0.64	0.80
90.0	-	-	-	-	-	0.08	0.23	0.39	0.54	0.70
100.0	-	-	-	-	-	-	0.13	0.29	0.44	0.60

Table 6.10

Benefit-cost ratios given particular gully lengths and degrees of slope

Slope (%)	Gully length (m/100 ha)									
	50	100	150	200	250	300	350	400	450	500
1.00	0.32	0.48	0.65	0.81	0.98	1.14	1.31	1.47	1.64	1.80
3.00	0.14	0.30	0.47	0.63	0.80	0.96	1.13	1.29	1.46	1.62
5.00	-	0.13	0.29	0.46	0.62	0.79	0.95	1.12	1.28	1.45
7.00	-	-	0.12	0.28	0.45	0.61	0.78	0.94	1.11	1.27
9.00	-	-	-	0.10	0.27	0.43	0.60	0.76	0.93	1.09
11.00	-	-	-	-	0.09	0.26	0.42	0.59	0.75	0.93
13.00	-	-	-	-	-	0.08	0.24	0.41	0.57	0.74
15.00	-	-	-	-	-	-	0.07	0.23	0.40	0.56
17.00	-	-	-	-	-	-	-	0.06	0.22	0.39
19.00	-	-	-	-	-	-	-	-	0.04	0.21

6.5.2 Estimates of opportunity cost

The opportunity costs of degradation for all the models are shown in Table 6.11. The costs were calculated as the change in LGVAP if all degradation is reduced to negligible levels (see Chapter 4, Section 4.4). Gully erosion, through the SUMGUL variable, is associated with opportunity costs of $174m in the Temperate semi-arid slopes and plains (Zone 1). Using the two classifications of the wheat-sheep zone (Zones 5 and 7), gully erosion is associated with a total opportunity cost of $214m in the former and $255m in the latter larger region.

The per hectare opportunity costs vary by type of degradation. Using the arithmetic degradation variables (SUMGUL, SUMTON, ACID, WSHRUB) we have the following per hectare opportunity costs.

Gully erosion	$10 - $14
Sheet and rill erosion	$9
Acidity	$14
Woody shrub infestation	$10

In terms of the general approach, the results show that land degradation has been associated with a measurable, negative impact on agricultural production and income. In many cases, these impacts are technically reversible through conservation works and changes in land use or management. In some of these cases, conservation will be rewarded by increases in income which will exceed the costs. Equally, the results demonstrate that this will not always be the case.

6.6 Summary

The general approach developed in Chapter 4 is based on estimating a production function that includes a land-quality variable. This is in contrast to other recent studies that have attempted to explain the influence of land degradation on agricultural productivity through examination of the residual term of agricultural production relationships (Chisholm and Hone 1996; Gretton and Salma 1996). It is only possible to estimate models of this type in NSW given the availability of statewide land-degradation data. Successful analysis at

Table 6.11

Opportunity costs (OC) of land degradation for various zones within NSW and for different types of land degradation

Zone	Description	Degradation Variable	Total OC($m)	OC/LGA($m)	OC/ha($)
1	Temperate semi-arid slopes and plains	SUMGUL	174	4.8	10
		LSUMGUL	111	3.1	6
		LSUMTON	178	5.0	10
2	Temperate highlands	LACID	101	6.4	34
3	Sub-tropical highlands	ACID	86	3.6	14
		LACID	108	4.5	18
5	Wheat-sheep zone	SUMGUL	214	4.8	14
		LSUMGUL	359	8.0	23
		LSUMTON	358	7.9	23
6	Western zone	WSHRUB	289	18.1	10
7	Extended wheat-sheep zone	SUMGUL	255	5.0	11
		LSUMGUL	424	8.3	18
		SUMTON	210	4.1	9
		LSUMTON	499	9.8	21

the regional scale is also dependent upon the models being based on areas of homogenous in terms of agricultural practices, climate and geography.

In this chapter, Cobb-Douglas production functions have been successfully applied to all but one of the regions defined in Chapter 4. The estimated models show a consistent pattern where various land degradation types have a negative, significant influence on agricultural output. The preferred models are those with a total degradation measurement, represented as a linear variable, and where the diagnostic tests indicate that the equation is statistically sound.

Benefit-cost ratios calculated for selected zones give a broad indication of overall profitability levels for investment in land degradation control and prevention. The results from the general approach can be further developed, as illustrated in Table 6.7, to provide more detailed information for management units within particular zones across the State. For example, the estimated BCR for gully erosion repair for Zone 5 was 0.9. Closer examination of LGAs in the northern part of the zone reveal BCR estimates ranging from 0.36 to 2.63, indicating that some areas may have the opportunity to undertake soil conservation works profitably, while it may not be economically worthwhile in other areas. Therefore, it is also possible to guide policy decisions regarding resource allocation at this scale through disaggregation of information.

The rapid-appraisal approach then goes a step further by providing detail at a site-specific level, and makes the important link between economic information and bio-physical and management factors. The results show that variations in management practices and bio-physical characteristics of land will determine the profitability of a particular project. For example, the BCR values in Table 6.9 indicate that as the degree of slope increases, gully erosion repair will become less profitable. An issue to consider when examining these ratios is that they have been estimated from statewide data, which was not originally collected with the intent of being interpreted at such a detailed scale. Thus, it is important to realise that these results should only be used as a guide for decision-makers, and should be used in conjunction with other more detailed information, such as at the farm or paddock level. Therefore, the general method of analysis will now be applied to the farm level in Chapter 7.

7. Farm results

7.1 Introduction

At the farm level, maintenance of land quality is just one of a number of management issues requiring attention from the landholder. Each farm may be faced with a variety of land-degradation types of different intensity and scale. Most landholders now have access to information from various management agencies about the types of programs that may be undertaken to combat a particular land-degradation problem, and the emergence of Landcare has assisted in the dissemination of this information. Certainly, there appears to be an increasing will among the agricultural community, encouraged by increased government funding, to undertake land-management programs such as tree planting, gully stabilisation and conservation tillage. However, is this conservation work warranted on a financial basis? Does information exist at the farm or sub-catchment level about the profitability of particular land-management projects? If so, how can this information be integrated with more broadly based information systems?

Estimates of the benefits of land-management programs at the farm level are important for the landholder both for short and long-term management decisions. If a landholder is able to undertake a whole-farm planning program, the knowledge that specific forms of land-management activities on particular soils and slopes will generate a certain level of benefit is certain to be of assistance. Alternatively, if a group of landholders within a sub-catchment is able to identify areas of greatest agricultural loss and potential benefit from conservation programs, this information should assist its claims for funding from government agencies.

The area chosen to examine these issues is located in the Namoi River catchment in north-western NSW, and is based on a 1:25 000 map sheet near Gunnedah. This area falls within the two wheat-sheep zones described in Chapter 4 and 6. There is a documented history of serious sheet and rill soil erosion in the area (Junor, Marston and Donaldson 1979; Anonymous 1991; Donaldson Planning and Management Services 1996), and the regional results in Chapter 6 indicate that this erosion is having a significant, negative impact on agricultural productivity. Many landholders in the region have implemented major soil-conservation earthworks, although some of these are now in need of further maintenance.

In this context, the objectives of this chapter[5] are to:

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

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

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

Farm-level BCRs can then be disaggregated according to bio-physical and management factors. The higher level of resolution of the benefit-cost information, and its display through GIS, should provide a useful planning tool for landholders.

The impact of land degradation on agricultural production, and the profitability of land management programs, were estimated at the regional level in the previous chapter. The issues facing individual landholders are somewhat different. However, it is possible to apply the general method of analysis, described in Chapter 4, at this scale. Analysis at the site-specific level is further enhanced by the availability of GIS data, enabling predictive modelling of the data to derive BCRs that are disaggregated below the farm level.

As described in Chapter 5, farm-level information was collected through individual landholder surveys. The data included input and output values for livestock and cropping, socio-economic characteristics of the landholder, land degradation estimates, and past and future expenditure on soil conservation works. The estimated relationship between inputs and outputs may be enhanced through additional information available in GIS form for the study area. Details of the GIS data are given in Chapter 5. In addition

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[5] The author's contribution to Walpole and Sinden (in press) forms the basis of this chapter.

to providing information for land management, these land quality attributes are likely to have a significant influence on levels of agricultural production.

The economic information available at the farm level from the survey, coupled with the detailed bio-physical data from the GIS, allows for a more detailed examination of the factors influencing the benefits and costs associated with land degradation.

7.2 Estimation of models

Estimated Cobb-Douglas models based on Equation 4.8 of the farm-level relationship between degradation and output are now presented. The various issues related to the model specification outlined in Chapter 4 are again examined when estimating the models. The model variables reported in this section are defined in Section 5.3.

At the regional level the preferred models included sheet and rill erosion and gully erosion as land-degradation variables (Equations 6.9, 6.12, 6.13 and 6.15). Their inclusion reflected the importance of these land-degradation types in reducing agricultural output over the wheat-sheep zones. The preferred Cobb-Douglas models estimated at the farm level, together with the relevant test statistics, are presented in Table 7.1 (Equations 7.1 and 7.2). Sheet and rill erosion were found to have a significant negative effect on the gross value of agricultural output in Equations 7.1 and 7.2. Unlike the regional models, labour did not have a significant influence on the gross value of agricultural output, with the majority of farms having one full-time and one part-time worker. Therefore, labour was constant across all farms. The degree of slope was found to be significantly related to the gross value of agricultural output in Equation 7.1, while the area of lucerne and soil type had a moderate influence in Equations 7.1 and 7.2 respectively.

All the estimated coefficients in Equations 7.1 and 7.2 are significant at the five percent level apart from SOIL, which is significant at the ten percent level. The diagnostic tests for Equations 7.1 and 7.2 suggest that the estimated models are statistically sound. The DW statistics for Equations 7.1 and 7.2 are inconclusive in that H_0 is neither accepted nor rejected according to the Durbin-Watson test (Griffiths *et al.* 1993), indicating the absence of autocorrelation.

An attempt was made to calculate models using per hectare variables; however, equations with this type of alternative specification could not be successfully estimated, as the

Table 7.1

Estimated models for the relationship between agricultural inputs and gross value of agricultural production[a]

Regressor variable	Equation 7.1	Equation 7.2
LAREA	0.797 (4.0)***	0.609 (3.8)***
LALUC	0.058 (1.4)*	
LTFERT	0.118 (2.4)**	0.155 (3.3)***
LCHEM	0.119 (3.9)***	0.122 (4.1)***
LSLOPE	-0.235 (1.8)**	
SOIL		0.278 (1.4)*
SUMTON	-0.771E-04 (2.4)**	-0.937E-04 (3.0)***
n	31	31
Constant	5.751	6.704
R^2	0.793	0.772
Adj R^2	0.741	0.727
DW Statistic	1.723	1.650
BPG Statistic	9.367	9.282

[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.

important variables were not significant at the ten percent level. Soil type was included in the original specification but was not significant, so was dropped from the model. It was suspected that LSLOPE might be a surrogate for soil type or soil erosion. However, examination of the correlations between LSLOPE and the soil-type/soil-erosion variables did not reveal any significant relationships. Rainfall is not included in the model, as it is constant across all farms for the given year of analysis.

For the purposes of further analysis, Equation 7.1 is the preferred model. This model has the standard inputs of land, fertiliser and chemicals and degradation, as well as an improved pasture variable and an additional bio-physical variable of slope. The statistical results are also more favourable for this model.

7.3 Benefit-cost ratios

The benefits and costs for each farm are calculated according to the procedures outlined in Chapter 4. BCRs are then calculated for each farm. The results of these calculations are given for each farm in Table 7.2. The area, amount of erosion on cropping and pasture areas, and additional soil conservation works required are given to provide a profile of each farm in the study area. Farm areas range from 178 to 1345 ha, with an average of 719 ha. The annual soil loss from sheet and rill erosion per farm ranges from 282 to 4876 t, with an average of 1684 t per farm, or 3.67 t/ha/year. Areas of additional soil conservation required ranges from 0 ha to 891 ha, with an average of 164 ha. The values of PVB, PVCMAINT, PVCCHANGE, PVC and BCR for each farm in the study area are recorded in Table 7.2. It is interesting to note that the PVBs are of the same order of magnitude as those calculated for sheet and rill erosion in the corresponding zone (Zone 1) at the regional level (Table 6.6).

The BCRs across the 31 farms range between 0.01 and 66.04, with an average of 7.06. Some of the results from individual farms require further explanation before discussing the overall results. According to the GIS data, Farm 6 does not require any additional soil conservation works, and has no crops. Therefore PVCMAINT and PVCCHANGE are both zero, leading to an infinite BCR value. Farm 18 had soil-loss levels that were already lower than the 'negligible' rate, therefore a PVB and hence a BCR cannot be estimated.

Table 7.2

Comparison of benefits and costs for treating sheet and rill erosion

Farm No.	Area (ha)	Soil loss (t/year)	PVB ($/ha)	Add soil cons(ha)	PVC MAINT($/ha)	PVC CHGE($/ha)	PVC ($/ha)	BCR
1	1003	2319.43	185.91	19.7	2.44	14.92	17.36	10.71
2	752	2620.96	272.74	0	0.00	4.13	4.13	66.04
3	178	1434.64	724.89	36.3	28.80	101.96	305.25	2.37
4	486	343.38	17.77	47.3	13.74	61.47	158.49	0.11
5	685	674.32	73.39	102.6	28.26	37.93	66.19	1.11
6	834	805.26	49.99	0	0.00	0.00	0.00	-
7	1000	1227.84	57.76	198.2	32.21	8.82	41.03	1.41
8	1093	2340.59	167.28	79.5	9.29	8.37	17.66	9.47
9	450	3649.92	218.94	135.3	70.21	28.68	98.90	2.21
10	467	1311.88	99.35	205.3	156.37	116.86	273.23	0.36
11	1246	2318.00	450.17	536.6	43.98	87.20	131.19	3.43
12	405	1120.14	83.45	19.1	22.21	8.47	30.69	2.72
13	800	3353.70	685.96	0	0.00	32.47	32.47	21.13
14	1154	414.72	-23.05	79.8	22.09	18.12	40.21	-
15	900	1049.68	126.12	0	0.00	52.10	52.10	2.42
16	335	3697.22	1227.95	7.4	4.68	64.87	69.55	17.66
17	520	3566.46	1404.33	8.9	1.94	194.76	196.69	7.14
18	1226	628.46	4.28	832.9	170.76	118.57	289.32	0.01
19	429	779.12	185.55	10.5	8.53	120.35	128.89	1.44
20	1113	1556.67	92.96	2.8	0.11	5.58	5.69	16.34
21	630	4876.28	2166.10	454.1	161.82	122.15	283.98	7.63
22	643	3845.00	1250.74	95.9	22.41	109.78	132.19	9.46
23	417	282.00	12.59	33.3	16.93	53.29	70.22	0.18
24	892	1330.19	142.29	198.8	35.05	32.24	67.29	2.11
25	1345	2143.84	421.68	433.2	85.86	73.37	159.23	2.65
26	364	2542.59	1183.04	145.6	57.97	154.75	439.80	2.69
27	607	815.40	37.92	192.6	13.56	0.00	13.56	2.80
28	1200	661.60	16.13	891.1	109.57	121.73	231.30	0.07
29	291	2149.72	206.61	112.2	89.65	83.10	172.75	1.20
30	312	4849.73	484.20	23.1	1.43	61.80	63.23	7.66
31	500	881.52	151.62	130.8	38.57	27.45	66.02	2.30
Ave	719	1684.16	386.99	164.3	55.91	62.11	118.12	7.06

A number of farms have very high estimates of PVB and BCR, indicating that the potential benefits of undertaking soil conservation are very high. Furthermore, their estimated costs of soil conservation are sometimes quite low, according to the areas of additional soil conservation required. The costs of maintenance and land-use changes were given by local soil conservation experts and are based on purely bio-physical grounds. On the basis of these results, soil-conservation works and changes in land use are highly profitable options for the majority of farms in this area.

Landholders generally perceive heavy rainfall events as being the only times of high levels of erosion damage, and thus may only manage for these events. The high levels of potential benefit suggest that low yet regular levels of erosion damage, which are less evident, may also have a significant effect on agricultural output. Also, some soil-conservation works undertaken in the past now require significant maintenance work.

Therefore, the full costs of land management in both bio-physical and economic terms may have been underestimated by the local experts. Therefore, the BCRs were re-estimated to include a maintenance cost for the entire farm area under agricultural production. These results are shown in Table 7.3. Only 13 farms now have BCRs higher than 1.0, compared to the 24 farms in Table 7.2. The PVCMAINT estimates are considerably higher, thus reducing the BCR values. Therefore, the BCR estimates in Table 7.3 are considered to be a more realistic reflection of the true benefits and costs associated with sheet and rill erosion in the study area.

The BCR estimates in Table 7.3 are based on the assumption that a reduction in soil erosion from present levels to a level of 0.5 t/ha/year reflects a 100 percent achievement of soil-conservation targets. This is an acknowledgment that reduction of sheet and rill erosion to zero levels is not a realistic expectation. However, with appropriate soil-conservation measures and management practices, a 'negligible' level of erosion is likely to be achieved. In the event that a 100 percent achievement of soil-conservation targets is not possible because of particular financial and/or management constraints, it would be useful to know the BCRs for lower levels of effectiveness. Therefore, sensitivity analyses were undertaken to reflect a 95, 85 and 75 percent achievement of soil-conservation targets in terms of tonnes of soil lost. The results are shown in Table 7.3. A lowering to 95 percent achievement of soil-conservation targets has only a small impact on BCRs, with no additional farms dropping to values of less than 1.0. However, a decrease to 75 percent achievement of soil-conservation targets leads to an increase in the number of farms with BCRs less than 1.0. For a number of farms a decrease in target

Table 7.3

Comparison of benefits and costs for treating sheet and rill erosion, with BCR estimates for achieving 100, 95, 85, and 75% of soil conservation targets

Farm No.	PVB ($/ha)	PVC MAINT($/ha)	PVC CHGE $/ha)	PVC ($/ha)	BCR (100%)	BCR (95%)	BCR (85%)	BCR (75%)
1	185.91	122.88	14.92	137.80	1.35	1.22	0.97	0.74
2	272.74	115.36	4.13	119.49	2.28	2.15	1.89	1.64
3	724.89	142.25	01.96	244.21	2.97	2.90	2.77	2.64
4	17.77	131.32	61.47	192.78	0.09	0.02	-	-
5	73.39	139.05	37.93	176.98	0.41	0.28	0.00	-
6	49.99	99.03	0.00	99.03	0.50	0.33	-	-
7	57.76	134.48	8.82	143.30	0.40	0.31	0.13	-
8	167.28	89.63	8.37	98.01	1.71	1.53	1.18	0.86
9	218.94	201.25	28.68	229.94	0.95	0.93	0.88	0.84
10	99.35	246.81	16.86	363.67	0.27	0.25	0.21	0.18
11	450.17	71.79	87.20	158.99	2.83	2.48	1.79	1.14
12	83.45	112.12	8.47	120.59	0.69	0.64	0.54	0.45
13	685.96	124.58	32.47	157.05	4.37	4.16	3.74	3.35
14	-23.05	134.03	18.12	152.15	-	-	-	-
15	126.12	127.00	52.10	179.10	0.70	0.53	0.19	-
16	1227.95	132.42	64.87	197.29	6.22	6.12	5.90	5.70
17	1404.33	77.74	194.76	272.49	5.15	5.01	4.72	4.44
18	4.28	207.36	118.57	325.93	0.01	-	-	-
19	185.55	234.33	120.35	354.68	0.52	0.46	0.33	0.21
20	92.96	94.64	5.58	100.22	0.93	0.76	0.42	0.11
21	2166.10	226.05	122.15	348.21	6.22	6.06	5.74	5.43
22	1250.74	177.50	109.78	287.27	4.35	4.21	3.92	3.65
23	12.59	126.27	53.29	179.56	0.07	0.01	-	-
24	142.29	146.73	21.70	168.43	0.84	0.70	0.43	0.17
25	421.68	177.90	73.37	251.28	1.68	1.42	0.92	0.45
26	1183.04	158.21	154.75	312.96	3.78	3.68	3.48	3.28
27	37.92	88.41	0.00	88.41	0.43	0.35	0.18	0.03
28	16.13	218.69	121.73	340.42	0.05	-	-	-
29	206.61	179.22	83.10	262.32	0.79	0.77	0.73	0.69
30	484.20	32.01	61.80	93.81	5.16	5.10	4.97	4.84
31	151.62	841.85	27.45	869.30	0.17	0.15	0.11	0.06
Ave	386.99	164.62	61.88	226.50	1.86			

levels means that the minimum soil loss required becomes higher than the actual soil loss, therefore a PVB and BCR cannot be calculated.

7.4 Site-specific benefit-cost ratios

The preferred BCRs can now be regressed against land use and bio-physical factors, following Equation 4.15, to determine the factors that are most influential in changing the BCR levels. This allows the BCR results to be disaggregated below the farm level, thus increasing their resolution. The estimated model is shown in Table 7.4. The model variables reported in this section are defined in Section 5.3.

Farm 14 had sheet and rill erosion levels lower than the 'negligible' rate. This implies that there is no benefit to be gained from changing erosion rates from their current levels, hence a BCR cannot be estimated. This left 30 farms in the estimation. The results from Table 7.4 indicate that levels of erosion, slope, soil type, area of additional soil-conservation required and 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.

In GIS terminology, the BCR values estimated in Section 7.4 are known as ground-surveyed data. These data can be incorporated into the GIS database as a new layer. Once this information is in the database, maps can be produced of BCRs (Figure 7.1). These results give an indication of the profitability of land-management programs at the farm level. The ground-surveyed BCR data does not have complete geographical coverage of the 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 erosion, slope, soil type and area of additional soil conservation (identified from Equation 7.3).

Once the decision-tree model has been built in the GIS, the predictive modelling module is instructed to run the model, 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 7.2. This provides the information at a higher level of resolution than

Table 7.4

Preferred model for the relationship between benefit-cost ratios, and land-use and bio-physical factors[a]

Regressor variable	Equation 7.3
SUMGUL	0.001 (10.1)***
SLOPE	-0.156 (2.0)**
EUCH	0.825 (1.9)**
TREES	0.004 (1.4)*
n	30
Constant	-0.058
R^2	0.835
Adj R^2	0.808

[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 7.1

Estimated benefit-cost ratios of restoring sheet and rill erosion to negligible levels for surveyed farms

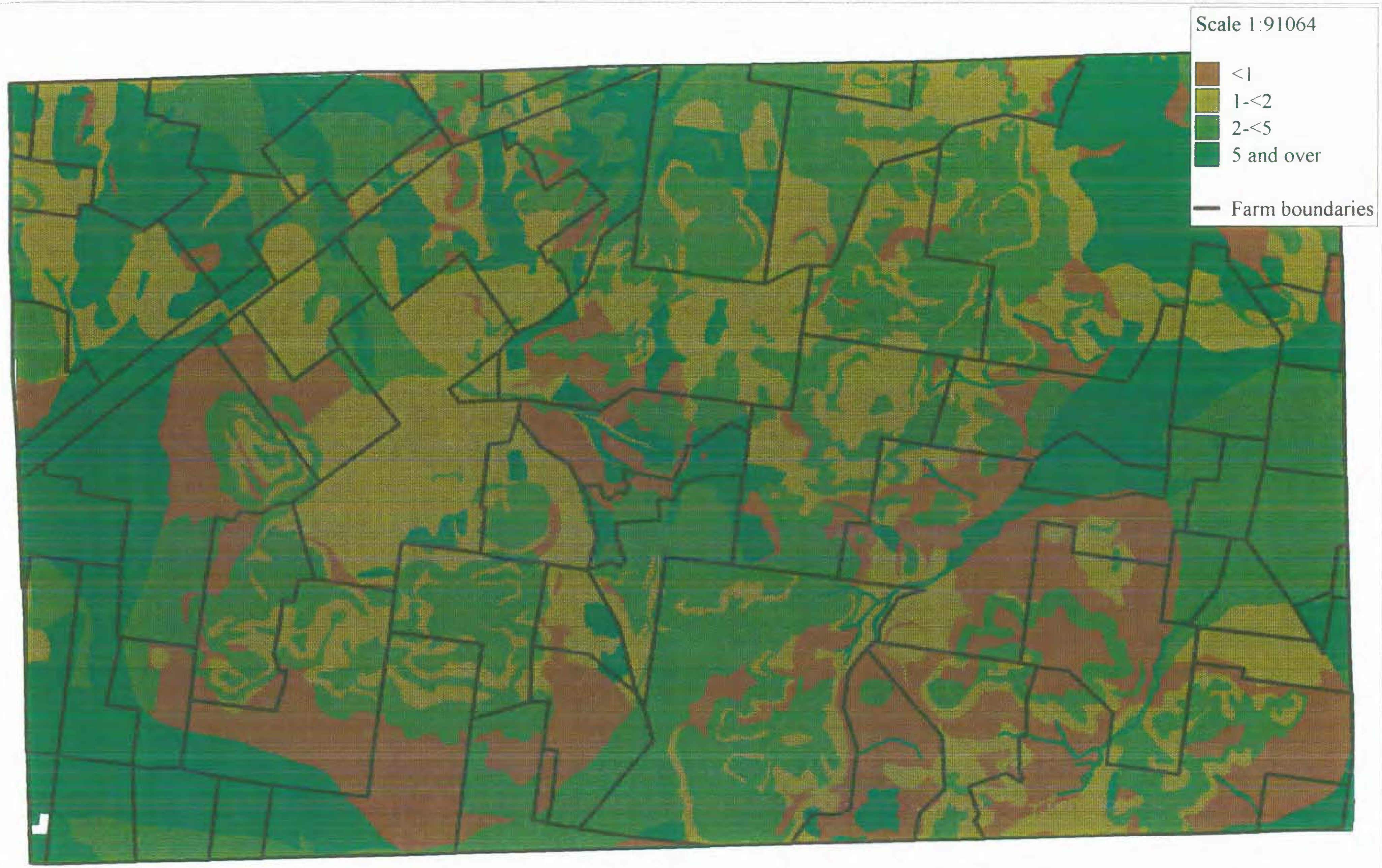

Figure 7.2

Predicted benefit-cost ratios of restoring sheet and rill erosion to negligible levels for the farm survey area at the farm level (Figure 7.1), thus allowing landholders to make decisions at a more relevant management level.

It is also possible to test the predictive accuracy of the derived BCR models. This can be done by making a comparison between a 'training data set' and a 'validation data set', a random split of the farms into two sets. A model is then derived from the training data set, and the predictions compared with the modelled BCR variable. Results from this test indicate that the derived BCR models have a high level of predictive accuracy.

7.5 Discussion

The estimated and predicted BCRs indicate that there are many profitable opportunities for managing sheet and rill erosion in the study area. Why, then, are more farmers not recognising the financial advantages and undertaking land-management programs? The reason may be that some factors that would negatively influence the BCR values have not been included in the analysis thus far. Hence, further examination is warranted.

Correlations between BCR values and the bio-factors of age, membership of a Landcare group, whether the landholder intends to sell in the future, and whether trees have been planted did not reveal any significant relationships. However, correlations between BCR and present value cost and benefit estimates were more revealing. The correlation between BCR and PVB was (0.95), indicating, as expected, the major influence of the benefit estimates on the BCR.

The BCRs range from 0.01 to 6.22 for a 100 percent achievement of soil conservation targets across the whole farm. They show that further soil conservation measures on some farms are profitable (above 1.0) and greatly profitable (greatly above 1.0). They also show that further measures on some farms are unprofitable. The economically rational farmer could be expected to have already undertaken the profitable measures, so why are there still profitable opportunities? One reason may be lack of information. Another, perhaps more relevant, reason is the uncertainty attached to the benefits and costs. Accordingly, a risk analysis was undertaken to determine the sensitivity of the BCRs to changes in the benefits and costs.

Risk analyses were undertaken for all 61 farms and for the top 20 farms using @RISK (Palisade Corporation 1992). The top 20 landholders are likely to act in the most economically rational manner when making decisions in regard to soil conservation, so a specific analysis was undertaken for these farms. The difference in BCRs not only reflects managerial skills, but also reflects the different bio-physical characteristics of the farms. The representative farms for the risk analyses were based on mean benefit and cost values from Table 7.2 for all farms and the top 20 farms.

The benefits and costs were assumed to follow a normal distribution, truncated to include observations within one standard deviation above and below the mean. This will, of course, include 95 percent of the observations of a normal distribution. The minimum values of benefits and costs were set at $0. The time period was changed from perpetuity to 15 years to more properly reflect the farmers' expectations that the measures will actually yield the given benefits that were modelled. The mean likelihood, that actual yield equals predicted yield, was set at 0.95 with minima and maxima of 0.75 and 1.00. A five percent discount rate was used.

The cumulative probability distribution results are given in Table 7.5. The mean BCR was 2.00 for all 31 farms, and 2.18 for the top 20 farms, assuming 100 percent effectiveness in controlling soil erosion. The high means of 2.00 and 2.18 are accompanied by a 35.2 and 24.8 percent chance, respectively, that the measures will actually be unprofitable (BCR < 1). A risk-averse farmer might well choose to invest elsewhere.

The sensitivity of the BCR values to absolute and relative crop and livestock prices can also be interpreted from these results. For all farms, a shift in the BCR value from 1.0 to 1.2 reflects a 20 percent rise in the crop/livestock price, with six percent more of the farms achieving this increase.

The potential benefit of increased agricultural production through the reduction of land degradation is clearly a difficult value for a landholder to estimate. Landholders often perceive a loss in output due to erosion. but find this difficult to quantify in dollar terms. The BCR estimates are based on the assumption that a reduction in soil erosion from present levels to a level of 0.5 t/ha/year reflects a 100 percent achievement of soil conservation targets. Sensitivity analyses were also undertaken on these data to reflect a 95, 85 and 75 percent achievement of soil conservation targets. The results reveal that when the adjustments are made from 100 percent effectiveness to 75 percent effectiveness the average reduction in BCR values is 0.55, from 1.85 to 1.30. Therefore, landholders

Table 7.5

Cumulative probability distribution of benefit-cost ratios for all farms and the top 20 farms

	Percentage of observations at or below the ratio	
Ratio	All farms	Top 20 farms
0.8	29.3	19.0
1.0	35.2	24.8
1.2	41.2	28.9
1.4	47.8	34.4
2.0	62.7	50.8
2.2		55.5

who do not have the resources to reduce erosion to 'negligible' levels may still benefit from undertaking some degree of soil-conservation measures.

Other issues in relation to the estimation of Equation 7.1 and 7.2 require further examination. One is whether reductions in soil quality necessarily lead to a decline in output — that is, can non-land inputs such as fertiliser and other technologies be a substitute for land quality, and therefore maintain output while degradation continues to occur. Examination of the separate significance of the regressor variables in Equations 7.1 and 7.2 indicate that the inputs of area, area of lucerne, fertiliser, chemicals, slope, soil type and degradation separately influence the value of output. Thus, while increases in land area, lucerne area, fertiliser, chemicals, and soil type increase output, increases in degradation and slope decrease it. Therefore, non-land inputs may in some way be masking the negative effects of decreased land quality.

Another issue is the omission of capital and labour variables from the estimated equations. Capital proved to be a difficult figure for landholders to determine, therefore fertiliser and chemicals were used as partial measures of capital. A labour variable was included in earlier estimations of the model, but did not display any levels of significance. The models are based on a single production year. It could therefore be argued that other factors such as climate may be having an influence on output in that particular year. Examination of ABS farm survey figures for Gunnedah Shire for a number of years either side of the 1992-93 period indicate that it was an 'average' year; this is supported by landholders' remarks during the survey, indicating that it was a normal production year.

Issues in relation to the estimation of Equation 7.3 also require examination. In the original model specification, management factors such as the intention to undertake soil conservation works, membership of a Landcare group and intention to sell the property in the future were included. These variables were not significant, so were dropped from the model, thus the primary source of variability between properties appears to be related to bio-physical factors. As a bio-physical factor, it might be expected that hydrological regimes may have some significance and variation over the study area; however, these data were not available at the time of the study. Other factors such as land tenure may also be important, but were not included in the model for the same reason.

7.6 Summary

In this chapter, Cobb-Douglas production functions have been successfully applied at the farm level. The estimated models show a consistent pattern where various land degradation types have a negative, significant influence on agricultural output. The preferred model has the standard input variables as well as an improved pasture variable and slope.

Benefit-cost ratios were calculated for each farm, with the chosen BCR estimates ranging from 0.01 to 6.22, indicating that some areas may have the opportunity to undertake soil conservation works profitably, while it may not be economically worthwhile in other areas. Sensitivity analysis were also undertaken to reflect that the reduction of sheet and rill erosion to zero levels may not be a realistic expectation for all landholders.

Predictive modelling makes the important link between economic information and bio-physical and management factors, and allows the extrapolation of economic information beyond 'normal' boundaries of management. The results show that variations in management practices and bio-physical characteristics of land will determine the profitability of a particular project. These results could be further enhanced and reinforced through the application of the same method at the paddock level, which is the basic management unit for landholders. Therefore, the general method of analysis will now be applied to the paddock level in Chapter 8.