Id 160

Effects of Land Degradation
on Farm Output

An Exploratory Analysis

Nigel Hall and Bengt Hyberg

Australian Bureau of Agricultural
and Resource Economics

GPO Box 1563 Canberra 2601

*Farmers' perceptions of land degradation, obtained by survey, are here related
to the levels of output on their farms. It is shown that the perceived existence of
land degradation problems is associated with lower output, but that there is
substantial variation in this relationship in different years and zones. Using a
Cobb-Douglas regression model, an estimate of the total effect of land
degradation on output is obtained, and is shown to be consistent with estimates
made by other methods. Losses in net financial returns associated with land
degradation are also estimated, and these are shown to be less than the gross
output losses estimated. The analysis is preliminary and the estimates are subject
to revision, but the approach used appears to be promising.*

Introduction

Land degradation is a topic widely discussed in Australia (for example, Balderstone, Duthie, Jarrett, Eckersley and McColl 1982; Chisholm and Dumsday 1988). Despite this interest, comprehensive economic data on the extent and impact of land degradation in Australia are lacking. In 1984, to provide a greater understanding of the scope of land degradation, ABARE carried out a survey of farmers' perceptions of their farms' land degradation status (BAE 1986). The survey was conducted by attaching supplementary questions to ABARE's annual Australian agricultural and grazing industries survey (AAGIS), which is designed to collect production and financial data on farms producing wool, meat and cereal crops (which together occupy the bulk of the agricultural land used in Australia). This analysis of the 1983-84 data was carried out in preparation for analysis of further land degradation data collected in a similar manner in 1989-90.

Farmers in the sample in 1983-84 were asked if they considered their properties to be subject to land degradation and, if so, whether they viewed the land degradation as a problem or potential problem. Farmers who answered the first question in the affirmative were asked a further series of questions on their responses to the degradation. These questions concerned changes in planning and management practices as well as the construction of land protection structures.

In 1983-84, 37 per cent of the farmers surveyed thought that they had a problem or potential problem with land degradation. Their farms occupied 31 per cent of the total land area of broadacre farms. (Note that this is not an estimate of the total area of degraded land in the broadacre industries: a farm may have a problem without its whole area being degraded.)

There will be differences in the abilities of individual farmers to recognise land degradation, and in the degrees of damage which they classify as a problem. There is also a possibility that some farmers may tend to assume that inherently poorer land is suffering from land degradation. If that occurs, the output on farms whose operators think they have land degradation will tend to be lower than that on other farms. This possible source of bias cannot be explored in this study, as there is no objective data on the nature of the soil or its past use on survey farms.

The 1978 Joint Study of Land Degradation in Australia (Woods 1984) reported that about half of all land was considered by soil conservation experts to be degraded. The proportion rose to 90 per cent in the pastoral zone. About 30 per cent of the land in total was seen as needing structural works to control and stabilise land degradation. These results are not on the same basis as those in the ABARE study, because soil scientists tend to use non-degraded conditions

as an absolute standard, whereas it is to be expected that farmers will tend to define land degradation in relation to the economic performance of their properties.

Sinden and Yapp (1987), in an effort to test the economic effect: of land degradation, explored the relationship between the Joint Study data and farm output in non-arid New South Wales. Their study suggested that there was a link between levels of land degradation and farm output at the shire level. Their definition of land degradation was the presence, in a shire, of sheet and/or gully erosion, according to the Joint Study, in 1974-75. The area thus affected was 18 per cent of the total non-arid area. The Sinden and Yapp results imply that such land degradation caused a 7 per cent reduction in total output over their study area.

This study is an analysis at the individual farm level using data from the 1984 AAGIS survey of land degradation and the standard data from the main AAGIS survey of that year. The present analysis tests the null hypothesis that 'all other factors being equal, degraded farms [in the sense defined in the next section] will not have lower output than non-degraded farms'. First, the results of the land degradation survey are discussed. The survey data are then used in a production function framework to estimate the farm level output losses associated with the degradation, as a test of the above hypothesis. Finally the production functions are used to estimate the aggregate losses associated with perceived land degradation problems in Australia. The analysis is exploratory and is aimed at testing the suitability of the approach using existing ABARE data, preliminary to a fuller analysis.

A reduction in output or farm incomes related to land degradation is not necessarily a net cost to the economy or to the individual farmer. Land is degraded as a result of farm managers' actions. These actions may be the result of deliberate intention or of a lack of information.

If a lack of information is the cause of loss then farmers have planned on one outcome and obtained another which is less satisfactory. Since information is not costless, the cost of the degradation is partly or wholly offset by the saving in not obtaining the information needed to avoid it. If market or government failure caused underinvestment in information seeking (either by farmers or researchers), there would be a net loss to the economy because of the unexpected land degradation.

Land degradation may, on the other hand, be the deliberate outcome of managers' decisions made with a view to maximising their welfare. In this case the loss of output from the degradation is offset, at least in the manager's mind, by the other benefits which flowed from the decision to degrade land. These might include increased yield in the short run or greater financial flexibility.

Reductions in output or in current farm returns related to land degradation do not therefore represent estimates of the net cost of the land degradation to society, as the costs of overcoming lack of information and the benefits which flowed from the land degrading management must be taken into account in any such estimate. This is attempted later in the paper.

Analysis

The analysis covers the three zones commonly used to categorise broadacre agriculture in Australia: the pastoral zone, covering the low rainfall area of the centre and north; the wheat–sheep zone, covering the mixed and cropping farms in intermediate rainfall areas; and the high rainfall zone, covering the coastal area and tablelands (ABARE 1990).

The data were obtained from the Australian agricultural and grazing industries surveys of 1981-82 to 1985-86 and the land degradation supplementary survey of 1983-84 carried out in conjunction with the 1983-84 AAGIS. For 1983-84 the land degradation data were available for all surveyed farms, allowing the full sample to be used in the analysis. For the other years only the subsample of farms which participated in both that year's AAGIS and in the 1983-84 land degradation survey could be used.

Farm-level estimates of output (defined as the sum of receipts and inventory change, including changes in livestock numbers), native pasture area, improved pasture area, cropland, labour, capital equipment and cash costs were derived from the AAGIS data. The land degradation questionnaire was used to classify farms as 'degraded' or 'non-degraded' depending on whether the operators considered land degradation to be a problem or potential problem on their farms. Thus, the measure of land degradation was subjective, and there was no indication of either its cause or extent.

Model

The null hypothesis that 'all other factors being equal, degraded farms (in the above sense) will not have lower output than non-degraded farms' is tested using a production function approach in which output levels of different farms are explained by using the quantities of major inputs and a dummy variable representing degradation. The null hypothesis can be rejected if the coefficient on the land degradation variable is negative and significantly different from zero, indicating that degraded farms have lower levels of output, *ceteris paribus*.

3

The functional form can be a major determinant of the goodness of fit of a production function and hence of how well it represents the underlying technologies. For reasons given below, a log-linear (Cobb–Douglas) functional form was used. This functional form implies the assumption that the relationship between the dependent variable (Y), the independent variables (X, Z) and the error term (v) is multiplicative:

$$Y = a\, X^b\, Z^c\, v$$

This expression can be linearised by taking logs of the variables to give

$$\ln Y = \ln a + b\, \ln X + c\, \ln Z + \ln v$$

The Cobb–Douglas form has a number of important characteristics:

- Errors are multiplicative, which implies that larger values of Y are associated with larger errors. This is likely to be the case on farms – that is, random error is more likely to be proportionate to farm output than to be a constant absolute amount for all farms.

- If output is held constant and one input is increased, the rate of substitution between inputs changes. For example, as labour intensity is increased, more and more labour must be added to compensate for a unit reduction in capital. This is a broadly realistic assumption in farming.

- The elasticity of output with respect to any given input is constant. This is a fairly restrictive assumption. Other functional forms such as the translog (a quadratic form of the log-linear specification) give more flexibility by allowing the output elasticity to vary in different regions of the data, but this is achieved at the cost of complexity. Examination of the residuals from the regressions showed evidence of heteroscedasticity, particularly in the pastoral zone, as well as evidence that quadratic terms could improve the fit of the model. Experimentally, the data were fitted to a translog model, and this improved the fit but made little difference to the dummy degradation variable unless it was incorporated into the interaction terms in which case it was difficult to interpret. In this preliminary analysis all the interest is focused on the degradation dummy, and the other variables are of less direct interest. The Cobb–Douglas form was therefore adopted.

The initial model fitted was

$$Q = f(K, L, N, C, I, H, D)$$

where:

Q is output defined, as sum of cash receipts and inventory changes, including livestock
($'000 000)

K is farm capital defined as total value of plant, machinery and structures ($),

L is farm labour (weeks),

N is area of native pasture (ha),

C is area of field crops (ha),

. is area of sown pasture (ha),

H is cash costs of services, materials and contracts excluding labour and interest payments ($),
and

D is a dummy for land degradation, with a value of 1 when (in the farm operator's judgment)
the farm has a degradation problem and zero when it has not.

There were serious levels of multicollinearity among some of the variables (capital, labour, cash costs and crop area). This problem was overcome using a partial principal component analysis (Hyberg, Hall and Abt 1991). The four collinear variables were replaced by their four principal components which are orthogonal by definition. (The detailed derivation is described in the paper cited.) Further tests indicated that this treatment eliminated the multicollinearity. The components and the interpretations placed on them by the authors appear in Table 1.

TABLE 1

Interpretations of the Principal Components

Component	Interpretation
$C1$	The size of the farm operation, in a general sense
$C2$	The relative importance of cropping operations
$C3$	A measure of the capital/labour ratio
$C4$	A measure of the ratio of capital to cash expenditure

The revised model is then:

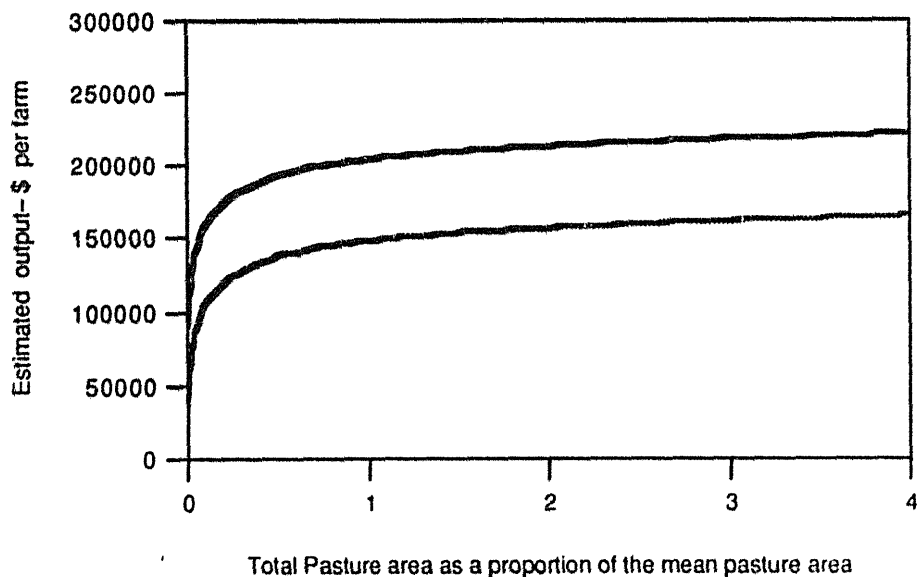$$Q = g \, (\, C1, C2, C3, C4, N, I, D \,).$$

FIGURE 1 — *Output per farm with and without perceived land degradation — Pastoral Zone*
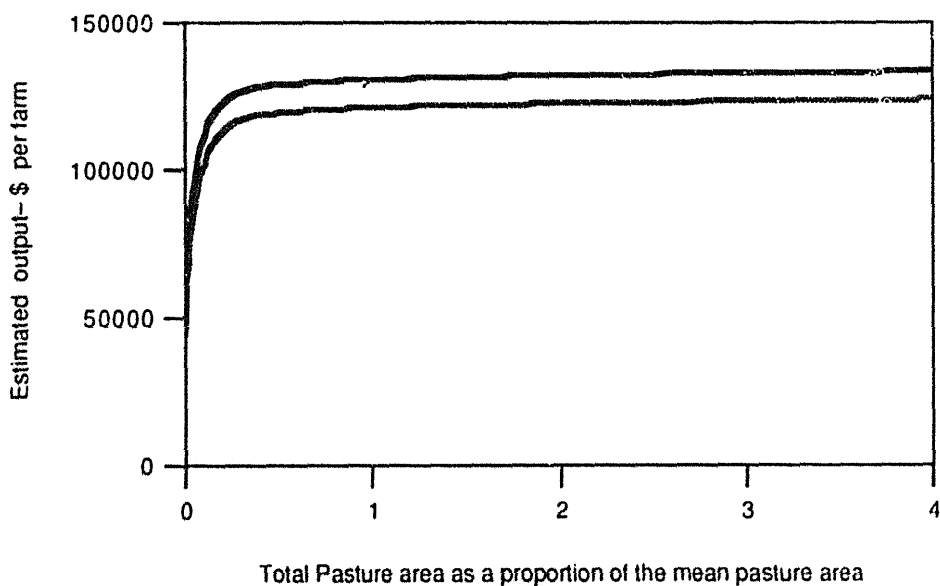

FIGURE 2 — *Output per farm with and without perceived land degradation — Wheat-sheep Zone*
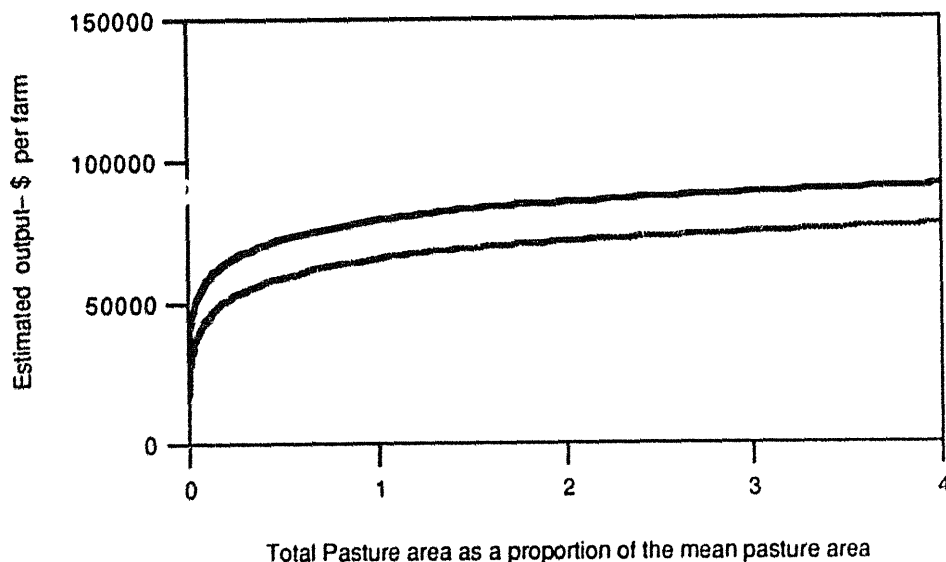
**FIGURE 3 — *Output per farm with and without perceived land degradation —
High rainfall Zone***

The effect of the dummy is illustrated for 1983–84 in Figures 1–3 for the three zones. The two curves are the predicted outputs from the fitted models as the total area of pasture is varied from zero to four times the mean with all other variables held constant. (This variable was chosen because of the composite nature of the others.) The higher line shows the output of farms classified as undegraded and the lower the output of otherwise identical farms classified as degraded. The vertical difference between the curves is the reduction in output per farm attributable to perceived problematic land degradation.

Because data on land degradation were available only for 1983-84, this was the only year for which degradation data and the farm data could be fully matched. The model was also estimated for other years, but the full sample could not be matched because of the changes in sample which occurred each year (both because farms dropped out of the survey and for design reasons). The sample size for each year is given in Table 2. The differences are such that only the 1983-84 data can confidently be regarded as a representative sample of the industry. The other years' estimates are included in the table because they suggest important qualifications to the estimates obtained from the survey year.

7

TABLE 2

Coefficients for the Land Degradation Variable

Year	Pastoral zone	Wheat–sheep zone	High rainfall zone	Sample size
1981-82	0.037 (2.6)	0.005 (0.6)	–0.004 (0.7)	570
1982-83	0.046 (2.6)	0.007 (1.1)	–0.014 (2.8)	716
1983-84	–0.044 (1.9)	–0.009 (1.4)	–0.013 (2.3)	758
1984-85	–0.024 (0.9)	0.01 (1.6)	-0.01 (1.3)	539
1985-86	0.007 (0.3)	–0.002 (0.3)	–0.019 (2.0)	454

Figures in parentheses are t-ratios.

The main qualification is that the effects of the degradation perceived in 1983-84 on any farm may have varied from year to year for climatic reasons. The experience of the high rainfall year when the drought broke (1983-84) may not be typical of other, drier years. Secondly, the levels of land degradation in earlier years may have been different from that in 1983-84 – in particular, some farmers' drought management in the earlier years may have led to increased land degradation in 1983-84.

The variations in degradation coefficients over time are considered in detail in the next section.

Analysis of Degradation Coefficients

The coefficients of the dummy variable for land degradation vary in magnitude and sign between years and zones. Given the limited information content of the variable (whether land degradation is or not seen as a problem) this is not surprising. The limited nature of the data may also account for the low levels of statistical significance. A richer data set with more detail on levels of degradation could be expected to give more statistically reliable estimates. More recently, such a data set has been collected by ABARE.

Variation over time

There are nevertheless some interesting patterns and common features in the estimates of the coefficients. In the years following 1983-84, in which the degradation assessment was made, six out of the nine coefficients are not statistically different from zero at the 5 per cent level, but those which are significant are all negative, so that land degradation in 1983-84 was associated with either reduced output or no measurable change in output in that and the two succeeding years.

The years 1981-82 and 1982-83, in contrast, show significant positive coefficients for land degradation in the pastoral zone. The coefficient for land degradation for the high rainfall zone is negative and statistically significant in 1982-83. The other coefficients are not significantly different from zero.

Looking at the estimates on a zone basis, the pastoral zone has positive coefficients for the drought years of 1981-82 and 1982-83. The wheat–sheep zone has small coefficients which do not significantly differ from zero in any year. The high rainfall zone has negative coefficients in every year, statistically significant in three of the five years.

The results for the pastoral zone may suggest that farms which maintained stocking during the drought may have kept up their level of output at the expense of causing loss of output through land degradation in 1983-84.

The pastoral zone is particularly fragile and susceptible to damage from overstocking, particularly under drought conditions (Young 1987; MacLeod and Johnston 1990; Wang and Lindner 1990). In addition, it is harder to destock gradually in remote areas than in the wheat-sheep and high rainfall zones, because mustering expenses and transport costs are higher. In the wheat–sheep and high rainfall zones, because of higher stocking levels and better access to markets, stock can be sold off at lower cost. Hence, wrong stocking decisions in the pastoral zone are more likely to result in land degradation because an incorrect decision is not so easily reversed. Farms may retain stock too long causing soil damage, or destock too early with consequent loss of income. The optimal point, where stock are kept just long enough to maximise profit net of damage costs from degradation, cannot be determined in advance, and so it is probable that farmers will err on one side or the other. Those who destock too soon will have lower output during a drought but diminished land degradation after it, while those who destock after the optimal time will have higher output from stock sales in the drought period but a greater risk of land degradation. This account of events is speculative but not inconsistent with the data in Table 2.

9

Farmers will be more likely to retain stock in a drought if they are less risk-averse or if government policies favour this course of action. In a study of risk aversion. Bardsley and Harris (1987) found that farmers in the pastoral zone showed partial risk aversion coefficients below those of farmers in other zones. Their measured coefficients were not significantly different from zero – that is, from risk neutrality. Moreover, past drought policies providing transport and fodder subsidies would have tended to encourage farmers to retain stock.

In Table 2, the land degradation coefficients are smallest in the wheat–sheep zone. This may partly reflect the effects of mechanical cultivations (on soil structure) and of fertilisers, which can to some degree overcome the effects of nutrient loss. The results in the high rainfall zone are more consistent from year to year than in the other zones. This may indicate a lack of flexibility associated with lower incomes and a predominance of pasture rather than crop based activities.

The results suggest that the effects of land degradation vary over time. At least in some areas, output may be particularly affected by land degradation in the period after a drought, and may be increased in poor years by practices which lead to increased land degradation. Differences in the effects of degradation in different years may also be due to changes in growing conditions: in some years, good production may be obtained even from degraded land. It is possible that land degradation may affect degraded farms not so much by a regular depression of output in all years but by a more serious effect in years of poor growing conditions.

Further analysis is needed to clarify these relationships but the conclusions of this part of this study are as follows.

- In general, land degradation is associated with reduced output.

- In the pastoral zone, it is possible that farms which had high production in the drought may have suffered increased losses from land degradation in succeeding years.

- In the wheat–sheep zone, land degradation may be compensated on some farms by increased use of other inputs.

Coefficients for 1983-84

Table 3 contains the estimated coefficients of the production functions using the 1983-84 farm-level data. This year's sample is representative of the population, because all of the 758 farms in the sample are included. The coefficients of land degradation shown in Table 2 for the subsamples in the other years, in contrast, cannot be reliably extrapolated to the national farm

population, but their variation provides a warning that an estimate of output losses associated with degradation made from one year's data will not necessarily provide a reliable indication of losses in other years.

<div align="center">TABLE 3</div>

<div align="center">*Regressions of Output with 1983-84 Data*</div>

Variable	Pastoral zone		Wheat–sheep zone		High rainfall zone	
Intercept	14.0	(157)	13.9	(807)	13.9	(793)
C1	0.41	(9.9)	0.54	(25.0)	0.41	(15.8)
C2	_0.03	(0.5)	–0.08	(1.7)	–0.18	(4.6)
C3	0.21	(1.8)	–0.43	(6.6)	–0.18	(3.3)
C4	–0.52	(3.8)	–0.35	(3.7)	–0.33	(3.1)
Native pasture	0.005	(0.7)	0.002	(1.7)	0.004	(3.2)
Sown pasture	0.005	(0.7)	0.002	(1.7)	0.004	(1.9)
Degradation	–0.04	(1.9)	–0.009	(1.4)	–0.013	(2.2)
R^2	0.49		0.69		0.69	
Sample size	148		339		270	

Figures in parentheses are t-ratios.

In 1983-84 the coefficients for land degradation are all negative and are statistically significant at the 5 per cent level for the high rainfall and pastoral zones. The coefficient is not significantly different from zero in the wheat–sheep zone.

Effects of Perceived Land Degradation

The data in Table 3 were used to estimate the reduction in output and in net returns caused by perceived land degradation. It must be recognised that, in this exploratory analysis, the nature of the data is such that these estimates are subject to wide confidence intervals. Nevertheless it is of interest to estimate effects associated with the estimated coefficients.

Gross output

The coefficients in Table 3 were used to estimate expected output for each farm given its present input levels and degradation status. A second estimate of output was then produced with the land degradation effect set at zero. This is equivalent to shifting the farms perceived to be degraded from the lower to the upper curve in Figures 1–3. The weighted average output

<div align="center">11</div>

per farm was then calculated for each case, as well as for the original survey data. These zonal averages of both actual farm output and of the outputs generated by the model, with and without land degradation are presented in Table 4. It is seen that the percentage loss of output is much less in the wheat–sheep zone than in either of the other zones.

TABLE 4

Output Differences Related to Land Degradation – 1983-84

Output	Pastoral zone	Wheat–sheep zone	High rainfall zone	All zones
	$/farm	$/farm	$/farm	$/farm
Average per farm				
Survey estimate	210 815	131 813	78 909	117 837
Model estimates				
– no degradation	213 818	133 918	82 455	120 569
– with degradation	195 707	129 765	77 620	115 355
	$m	$m	$m	$m
Zonal aggregates				
Total output	870	5 779	2 055	8 703
Total loss	80	185	128	393
	(9.3%)	(3.2%)	(6.2%)	(4.5%)

The total loss of output associated with the presence of land degradation is calculated by weighting the per-farm estimates using survey weights. It is estimated that, in the survey population, during 1983-84, about 4.5 per cent of annual output valued at $393 million was lost because of perceived land degradation. The confidence intervals about this estimate are wide. On the basis of the standard errors calculated in the regressions reported in Table 3 the 95 per cent confidence interval is between losses of $840 million and a gain of $60 million.

An estimate was also made of output loss in New South Wales excluding the pastoral zone, for comparison with Sinden and Yapp (1987). This was done by repeating the whole procedure on the subsample of survey farms in the wheat–sheep and high rainfall zones of New South Wales, to approximate the area studied by Sinden and Yapp. The estimated output loss associated with land degradation for this area was 5 per cent. This is below the 7 per cent of Sinden and Yapp, but not greatly different in view of the differences in time period and data used.

An estimate for total losses caused by land degradation of $600 million has been widely reported in the press. This figure is based on a consensus of expert opinion around Australia (L. Nothrop, Department of Primary Industries and Energy, personal communication, September 1989). This estimate was for 1983-84 and amounts to 3.9 per cent of gross value of agricultural production (in which the broadacre industries account for about 60 per cent) in that year.

Thus the approach used in this paper gives results in broad agreement with both the consensus estimate of 3.9 per cent for Australia and Sinden and Yapp's estimate for non-arid New South Wales.

Reduction in income

The analysis above is confined to output reduction associated with land degradation. It is important also to know the effect on net output – that is, the income loss, which will take into account both output and cost variations with land degradation. This net loss of farming income from land degradation was estimated by modelling the effect of the presence of land degradation on a farm's full equity return. This measure is used by ABARE to indicate the investment return on capital and management in the farm sector. It is the return to the capital and management of the farm after taking into account cash costs, unpaid labour (at an imputed cost), inventory changes and depreciation. Interest payments and rent are excluded from costs, to bring all farms to a full equity basis and show the return to all assets and management used regardless of ownership.

TABLE 5

Regression in Coefficients for Full Equity Return – 1983-84

Variable	Pastoral zone		Wheat–sheep zone		High rainfall zone	
Intercept	13.9	(170)	13.8	(963)	13.9	(200)
$C1$	0.10	(2.6)	0.15	(8.0)	0.09	(5.5)
$C2$	0.04	(0.5)	0.12	(2.8)	–0.04	(1.5)
$C3$	0.09	(0.9)	–0.15	(2.7)	–0.10	(2.9)
$C4$	–0.25	(2.0)	–0.00	(0.0)	–0.11	(2.3)
Native pasture	0.003	(0.5)	0.002	(1.8)	0.002	(2.4)
Sown pasture	0.001	(0.1)	0.000	(0.4)	0.002	(1.9)
Degradation	–0.015	(0.7)	–0.012	(2.3)	–0.001	(0.4)
R^2	0.06		0.19		0.27	
Sample size	148		339		270	

Figures in parentheses are t-ratios.

The modelling procedure outlined above for output changes was repeated using full equity return as the dependent variable instead of output. The estimated regression equations are presented in Table 5. The explanatory power, measured by R^2; is lower than for output, especially in the pastoral zone where there are only two significant coefficients. The coefficient of land degradation is statistically insignificant both here and in the high rainfall zone; but it is significance at the 95 per cent level in the wheat–sheep zone. This is in contrast to the estimates for output effects, which are significant in the other zones and not in the wheat–sheep zone.

TABLE 6

Relationship between Full Equity Return and Land Degradation – 1983-84

Full equity return	Pastoral zone	Wheat–sheep zone	High rainfall zone	All zones
	$/farm	$/farm	$/farm	$/farm
Average per farm				
Survey estimate	37 880	21 079	5 846	16 724
Model estimate				
– with degradation	29 910	20 018	5 400	15 472
– no degradation	35 184	25 236	5 879	19 030
	$m	$m	$m	$m
Zonal aggregates				
Total	133	891	142	1 167
Total loss	23	232	13	268
	(17%)	(26%)	(9%)	(23%)

The reduction in full equity return estimated to be related to perceived land degradation (Table 6) is 23 per cent using the estimates of the regression coefficients. Again there is a wide 95 per cent confidence interval, from a loss of $599 million to a gain of $65 million. The largest estimated land degradation effect is that for the wheat–sheep zone, which is also the only zone for which the coefficient is significantly different from zero. This zone accounted for 86 per cent of the estimated net loss for all three zones. The size and significance of the degradation variable in the wheat–sheep zone is consistent with the suggestion that loss of output was being reduced in this zone by the use of additional purchased inputs to overcome the effects of degradation on the productivity of the land.

The central estimate of the full equity return loss, $268 million, can be compared with the corresponding estimate of output loss, of $393 million. The loss of full equity return can be expected to be less than the loss of output because of changes in the use of the other inputs which are combined with land in agricultural production. If it is assumed that these inputs could have been used elsewhere in the economy at the same price, then the economic loss from land degradation is the net loss in returns rather than the gross output change.

Implications and Future Analysis

The estimates presented in this paper support the hypothesis that there is a relationship between farmers' perceptions as to whether land degradation is a problem on their properties, and farm output. Other things being equal, farms whose operators' believed that they had a land degradation problem tended to produce less output than that of other operators. This has important implications for policies designed to manage land degradation, as it suggests that many farmers are aware of the degradation on their own farms and that their concern reflects real loss of output.

The estimates of losses (or gains) associated with land degradation varied from year to year, suggesting that land degradation has a complex effect on farm production. Estimation of the long term effects of land degradation require further research and fuller data. The estimates made in this paper were prepared on the basis of a survey of land degradation perceptions in only one year. In view of the extent of variation found between years, the long term effect of land degradation on output may be either greater or less than that estimated here.

Estimates have also been presented of the change in full equity return – that is, net output – associated with land degradation. This change is less than that of gross output, reflecting the ability of farmers to address land degradation by means of management practices such as increasing the use of other (non land) inputs. If these other factors can be employed elsewhere in the economy at the same price, then this net change is the better indicator of the real economic effects associated with land degradation.

A significant implication of the comparison of losses of output and of full equity return arises from their spatial distribution. The losses of output are statistically significant, and are larger in percentage terms, in the pastoral and high rainfall zones, whereas the loss of full equity return is concentrated in the wheat–sheep zone. That is, on the basis of this analysis, the net loss to the economy is greatest in the cropping zone even though the other two zones show a greater proportion to loss of output.

Not all loss of output or of income from land degradation is economic loss, since some degradation may be an aspect of the optimal use of the land resource over time (Kirby and Blyth 1987) and therefore an appropriate management outcome which does not impose a net cost to society when the associated benefits are taken fully into account. Even where degradation is the result of lack of information, the cost of obtaining information needs to be taken into account in an asses. nent of the net costs of land degradation.

Further research, using this approach but based on additional years of data and a richer data set, might produce estimates of effects over a longer term and at a less aggregated level; and might give some indication of what remedial treatments would be cost-effective.

References

ABARE (1990), *Farm Surveys Report*, AGPS, Canberra, pp. 23–5.

BAE (1986), '1983-84 Australian broadacre industries survey supplementary questionnaire on land degradation', *Farm Surveys Report*, AGPS, Canberra, p. 21.

Balderstone, J.S., Duthie, L.P., Jarrett, F.G., Eckersley, D.P. and McColl, J.C. (1982), *Agricultural Policy and Options for the 1980s*, Working Group Report to the Minister for Primary Industry, AGPS, Canberra.

Bardsley, P. and Harris, M. (1987), 'An approach to the econometric estimation of attitudes to risk in agriculture', *Australian Journal of Agricultural Economics* 31(2), 112–26.

Chisholm, A. and Dumsday, R. (eds.) (1988), *Land Degradation: Problems and Policies*, Cambridge University Press, Sydney.

Hyberg, B., Hall, N. and Abt, R. (1991), Using partial principal component analysis to provide better tests of models with collinear data. ABARE paper presented at the 35th Annual Conference of the Australian Agricultural Economics Society, Armidale, 10–12 February.

Kirby, M. and Blyth, M. (1987), 'Economic aspects of land degradation in Australia', *Australian Journal of Agricultural Economics* 31(2), 155–74.

MacLeod, N.D. and Johnston, B.G. (1990), An economic framework for considering rangeland restoration options. Paper presented at the 34th Annual Conference of the Australian Agricultural Economics Society, Brisbane, 13–15 February.

Sinden, J.A. and Yapp, T.P. (1987), The costs of land degradation in New South Wales: a case study. Paper presented at the 31st Annual Conference of the Australian Agricultural Economics Society, Adelaide, 10–12 February.

Wang, K.M. and Lindner, R.K. (1990), Rehabilitation of degraded rangeland under optimal management conditions. Paper presented at the 34th Annual Conference of the Australian Agricultural Economics Society, University of Queensland, Brisbane, 13–15 February.

Woods, L.E. (1984), *Land Degradation in Australia*, AGPS, Canberra.

Young, M. (1987), 'Land tenure: plaything of governments or an effective instrument?', in A. Chisholm and R. Dumsday (eds), *Land Degradation: Problems and Policies*, Cambridge University Press, Sydney, pp. 175–86.