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ESTIMATION OF OPPORTUNITY COSTS OF LAND DEGRADATION IN NEW SOUTH WALES: PRELIMINARY FINDINGS.

J.A SINDEN and T.P YAPP
Department of Agricultural Economics and Business Management,
University of New England, Armidale, N.S.W.;
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There are several different processes of land degradation, each of which can change the biophysical characteristics of the land. These changes can lead to a reduction in agricultural output, and so impose opportunity costs on the agricultural community and society. The objective of this paper is to report the preliminary results of a study to estimate such costs for New South Wales, on a state-wide basis. Data from the Department of Conservation and Land Management, and the Australian Bureau of Statistics, are combined in production functions with land quality (land degradation) as an input. To this stage, preliminary functions have been estimated for crops, and for agricultural output as a whole. A variety of measures of degradation has been included in the crop models, and work is proceeding on a pasture model.

1 INTRODUCTION

There are several different processes of degradation, each of which can change the biophysical characteristics of the land. They are natural processes, which human action sometimes accelerates and can sometimes retard. Ecologists regard any degradation as a undesirable, when judged against their goal of maintenance of land condition. Economists regard degradation as undesirable when it imposes net costs on society. In this sense, too much degradation may impose social costs just as too much conservation may impose social costs.

The economic costs comprise on-site effects, such as lost agricultural output and higher production costs, as well as the off-site effects such as reductions in downstream water quality and increases in costs of road and creek maintenance. In this research, we concentrate on the loss in agricultural output and this is an opportunity cost of degradation.

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The existence of degradation raises two broad questions. What is the opportunity cost and what is the cost of control? In this paper, we report a method to address the first question, as a basis for considering the second later in the project. More specifically, the objectives of this paper are to

(a) present a model to assess the lost agricultural output due to degradation, and

(b) present preliminary results from applications of the model.

An opportunity cost is the income forgone in the best alternative use of a resource. When the best alternative is another way to manage the same land, opportunity cost is the loss in income under the present use. For analytical purposes, income may be interpreted as output, revenue or economic surplus. The alternative use may be interpreted as the conventional marginal change in degradation, or as a specific or complete restoration of the land -- depending on the policy context. A detailed discussion of the intricacies of the opportunity cost concept, in the context of soil erosion, is provided by the exchange between van Kooten, Weisensel and de Jong (1989) and van Vuuren and Fox (1989). Following their discussion, output and input levels are held constant as appropriate in the calculations opportunity cost. But in the present cross-sectional analysis, changes refer to an annual differences in output and input between producing units, rather than to flow over time.

2 LITERATURE REVIEW

Losses in agricultural production have been estimated for specific case studies, particular regions and single shires(Sinden 1990). But apart from the initial contribution by Sinden and Yapp (1987), there exist no estimates of these opportunity costs on a statewide basis. This lack of knowledge is unfortunate because the state is the basic administrative unit of soil conservation activity.

Cameron and Elix (1991) summarise estimates of losses for the cropping region of the northwest slopes of New South Wales and the pastoral areas of the Queensland mulga lands. Alcock (1979) estimated the decline in value of production due to soil erosion on the Darling Downs. Dumsday and Oram (1990) estimate the lost income due to salinity in northern Victoria and Greig and Devonshire (1981) estimate costs borne by households in Kerang if salinity is not controlled. Cary, Ferguson and Belin (1982) cite a gain of $680 per year from increased agricultural output if salinity is controlled in the upstream of Merbein near Mildura.

With data from ABARE surveys, Hall and Hyberg (1991) estimate the effect of degradation on output for the pastoral, wheat-sheep and high rainfall zones of Australia. Income on farms where farmers perceived there was degradation was less than income on farmers where farmers perceived there was no degradation. The reduction due to degradation was 23 per cent on average, although there was a wide 95 per cent confidence interval around this figure.

Molnar (1965) undertook another analysis of the impact of degradation covering a very wide region. - - half of Victoria in fact. As he concluded, his was the first attempt to measure quantitatively the impact of erosion on a regional basis. Wheat yields showed a 40 per cent reduction between shires of high and low erosion, and changes in rainfall and fertiliser must be included in the analysis.

Losses in output may differ between production in the field, in plots, and in simulated models. Watt (1990) derives a relationship between yield loss and soil loss from a series of experimental plots maintained by the Soil Conservation Service of New South Wales. Overall, crop yield decreases by 2.3 per cent for every tonne of soil loss.

Production over time, with the cumulative effects of soil loss on production, were simulated by Syaukat, Pandey and Sinden (1992) for a case study crop farm in northern New South Wales. Data on yields, prices, costs and the yield/loss relationship were collected from local experts and combined by dynamic programming. The change from conventional tillage to minium or no tillage, to conserve the soil, imposed opportunity costs between $11 and $43 of net present value per mm of soil saved.

Woody weeds in the Wanaaring district of New South Wales greatly reduce the livestock carrying capacity of the land. Jackson, in Booth (undated), believes that property areas must increase by two thirds of the current sizes to maintain a sufficient sheep flock for a viable living.

Attempts are sometimes made to estimate opportunity costs in other ways. For example, Lipsett and Dann (1983) argue that replacement of minerals lost through wheat production would cost $18 per tonne of grain exported. Drynan (1986) argues that the argument does not recognise the price relationships, substitutability between inputs, and the desirability of maintaining mineral levels.

3 THE DEGRADATION PROBLEM

3.1 The Welfare Model

Changes in agricultural output are caused by several factors -- even if land area, labour and management are held constant. Following Crosson with Stout (1983), supply curve S_1 in Figure 1 represents the actual marginal costs of production in time 1, and S_2 represents the lower actual costs in time 2. The changes between these times include technological advance, changes in input and activity mix, as well as degradation – induced increases in cost. If there were no technological advance but degradation did occur, the supply curve would have risen from S_1 in time 1 to S_2^a in time 2. If there were no degradation but the actual technological advance did occur, the supply curve would have fallen from S_1 to S_2^b. The effect of degradation is therefore captured as the difference between curve S_2^b (actual technological change and no degradation) and curve S_2 (actual technological change and actual degradation). The loss in economic surplus, or welfare, derives from this difference which is shaded in Figure 1.

The welfare loss, for an export product, can be defined as the change in producers surplus and calculated by introducing product prices of P_1 in time 1 and P_2 in time 2. Price P_2 is lower, indicating a decline in real price over the time period. In time 1, actual output is Q_1 and the producers surplus is area A P_1 ,B. In time 2, actual output is Q_2 and so producers surplus is D P_2 E. Thus

$$\text{actual change in surplus} = AP_1B - DP_2E \qquad (1)$$

In time 2, the potential output without degradation would have been Q_2^b with a potential surplus of CP_2F. Thus

$$\text{potential change in surplus} = AP_1B - CP_2F \qquad (2)$$

The welfare loss, or opportunity cost, due to degradation alone is therefore the difference between the actual and potential change.

$$\begin{aligned} \text{Welfare loss} &= (AP_1B - DP_2E) - (AP_1B - CP_2F) \qquad (3) \\ &= CP_2F - DP_2E \\ &= \underline{CDEF} \end{aligned}$$

An estimate of this loss requires data on, inter alia, the shift in quantity Q_2^b to Q_2, and an estimate of this shift requires an analysis of production and the effects of degradation on production.

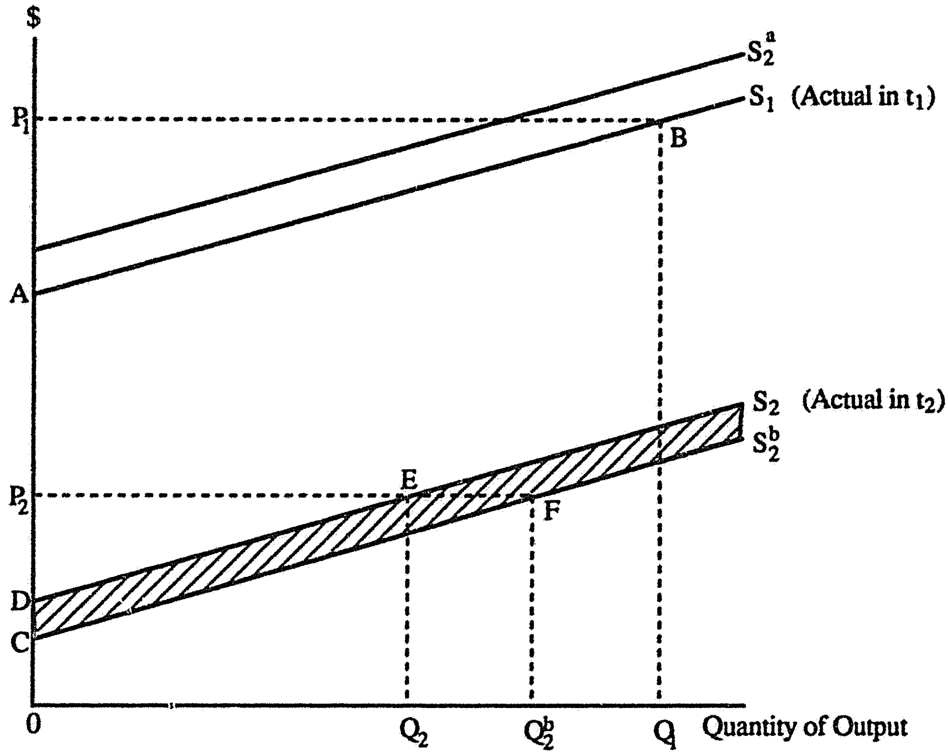

Figure 1: The welfare loss due to degradation

3.2 A Model of Production

Land is a traditional input to production, and if all land were homogeneous the following simple production function would apply.

$$\text{Output} = f(\text{Land, labour and capital}) \tag{4}$$

In a given area, the quality of the land will influence output and several reformulations of the function may accommodate this. In one reformulation, a separate function may be estimated for each quality of land. Without the necessary field-level data, a cross-sectional analysis may be undertaken with function of the following form.

$$\text{Output}_i = f(\text{Land area}_i, \text{land quality}_i, \text{labour}_i, \text{capital}_i, Z_{ij}) \tag{5}$$

where i is the spatial unit of analysis, and Z_{ij} are the other j variables that affect output.

The Cobb- Douglas form

$$\text{Log } Yi = a + \sum_{i=1}^{n} bi \text{ Log } Xi + Ui \qquad (6)$$

allows for decreasing productivity from each input, for diminishing rates of substitution between inputs, but does not allow for substitution rates to change between inputs.

The following partial logarithmic function

$$Y_i = a + \sum_{i=1}^{n} b_i L_n X_i + U_i \qquad (7)$$

also allows for diminishing marginal product from each input, and for substitution between each.

If additional units of input always produce a given quantity of output,regardless of input mix or level, and if there is no reason to expect diminishing marginal products in the particular data, then a linear specification is more useful.

$$Y_i = a + \sum_{i=1}^{n} b_i X_i + U_i \qquad (8)$$

This specification presumes, perhaps usefully for analytical and policy purposes, that the quantity and relationship of one input can be varied without affecting the quantity or relationship of the other inputs.

The information from estimates of such models will be useful in itself, and will provide basic data for the estimation of opportunity costs and welfare changes.

3.3 The Frontier Production Function

The conventional production function, like equation (8), implies that output is a function only of the X_i variables, and all other possible variables are fixed or unimportant. The conventional OLS estimation assumes the disturbance term U_i to be normally distributed. The estimated model would then be a best fit trend "between" the individual observations.

Regression models of production functions should typically characterise a frontier, which defines the maximum possible (or frontier) output which can be produced from given inputs. The random disturbances would then be presumed to follow a one-sided distribution ($U_i \leq 0$), and to be independently and identically distributed. Frontier functions have been the subject of considerable research over the last decade (Aigner and Schmidt 1980), particularly in the context of the concept of efficency (Sengupta 1989). They have been estim⁻ ⁼d in a deterministic manner, using corrected ordinary least squares, or in a stochastic manner.

Corrected ordinary least squares (COLS) is a convenient deterministic means to estimate the production function. In the first step, OLS procedures are used to estimate a conventional function. In the second, the estimate of the intercept is corrected by shifting the function until no residual is positive. To do this, the largest positive residual is added to the intercept.

A stochastic frontier regression, from which production functions can be derived, was developed by Aigner, Lovell and Schmidt (1979) and Meeusen and van den Broeck (1977). In the basic equation,

$$Y_i = a + b_i X_i + e_i \qquad (9)$$

the term e_i comprises two random disturbances which are assumed to be independent. One disturbance is non-positive and allows for output to be on or below the frontier. Any deviation here is under the entrepreneur's control and is attributable to differences in technical efficiency. The other disturbance allows for things the entrepreneur cannot control such as climate, and topography. This formulation permits an improved ability to model actual situations while assessing technical efficiency.

Measures of technical efficiency can readily be derived from the frontier function. Russell and Young (1984), use the deterministic COLS procedure and follow Timmer (1971) and Kopp (1981) to estimate:

(a) output efficiency (the ratio of actual output to potential output, given the existing level of inputs), and

(b) input efficiency (the ratio of potential input use to actual use, given the existing level of output and proportions of inputs).

These measures appear to be useful ways to measure the impact of degradation, in addition to the standard interpretations of the coefficients of the regression models.

4 DATA

The opportunity costs and welfare losses are to be estimated on a state-wide basis. Data on agricultural outputs and inputs were taken from standard sources of the Australian Bureau of Statistics (ABS), and rainfall information was obtained from Bureau of Meteorology publications. The data on degradation were obtained from the 1987-88 Land Degradation Survey undertaken by the Soil Conservation Service of New South Wales. The general trends in degradation are reported in Soil Conservation Service of New South Wales (1989), and the survey procedures are documented by Graham (1989). The interprepration of such degradation data, in the context of agricultural productivity, is discussed by Walpole (1992).

The local government areas (LGA) is the smallest spatial unit for which ABS data are available whereas the degradation survey was based on observations at many points within an LGA. Data from the survey were therefore aggregated up to the LGA level (Walpole 1992), and all LGAs with more than 14 survey points were included. There were 113 LGAs with more than 14 survey points. Most of these were shires but some were very large municipalities.

The independent variables were defined as follows.

AREAS	=	the total area in agricultural production in an LGA, in hectares, as a three-year average 1987/88 to 1989/90.
AREAC	=	the total area in crops of all kinds in LGA, in hectares, as a three year average 1987/88 to 1989/90.
FERT	=	total quantity of all fertilizers applied to all land in tonnes, as a three year average 1987/88 to 1989/90.
FERTHA	=	the total quantity of all kinds of fertilizer applied to crops in tonnes per thousand hectares, as a three year average 1987/88 to 1989/90.
LABOUR	=	the total number of farmers, managers, farm labourers and farm workers in each LGA in 1986.
RAIN	=	the total rainfall per LGA, mm, as a four year average 1987 to 1990.
GULLY	=	gully erosion, as the total length of gullies, in metres per 100 hectares.
STRDEC	=	structural decline of the soil, coded as 1 for undisturbed land, 2 for intermediate decline,and 3 for severe decline.
SHRILL	=	sheet and rill erosion, as tonnes of soil lost per hectare per year.
WIND	=	wind erosion, as 1 for a low hazard to 4 for the highest hazard.
DRYSAL	=	dryland salinity, as 1 for no obvious sign, 2 some sign, and 3 for extensive areas.

The degradation variables of GULLY,STRDEC, SHRILL, WIND and DRYSAL were the mean values per LGA(See Walpole 1992).

Several types of degradation occur in most LGAs, and all these types must be included in any model which includes all kinds of agriculture. Thus, two interactive variables and one aggregate degradation variable were defined. The interactive variables were:

DEGB = mean gully class x mean sheet and rill class x STRDEC x WIND.

DEGC = mean gully class x mean sheet and rill class x STRDEC

In these two variables, gully class is derived from GULLY, but now coded 1 to 7 in its original 7 classes. Similarly, sheet and rill class is derived from SHRILL, coded 1 to 5 in its original 5 classes. The mean value across all survey points in a shire is taken for the gully class and sheet and rill class components of these two variables. We had converted these original classes into arithmetic numbers (metres and tonnes respectively) for GULLY and SHRILL, from the basic procedure and information of the degradation survey (Graham 1989).

To reflect policy and popular exhortations to restore all land, the aggregate degradation variable was defined in terms of the target of a negligible level of all the types of degradation.

$$\text{TARGET} = \sum_{j=1}^{7} \frac{\text{actual level of degradation type j}}{\text{target level of degradation type j}}$$

for the of seven types of degradation (j) namely gully, mass movement, dryland salinity, irrigation salinity, scalding, shrub infestation and sheet and rill erosion. The target levels were negligible levels of erosion in each case. Each actual level in the above formula is an average for all degradation survey plots per LGA.

The two dependent variables are as follows:

CROP = total crop output per LGA, in tonnes, as a three-year average 1987/88 to 1989/90.

TOTAL = total gross value of all agricultural production, in $000 dollars, as a three year average 1987/88 to 1989/90.

The crop and total models are estimated for the 92 LGAs which had at least some cropping.

5 RESULTS

A crop model was estimated for each of the degradation variables.

$$CROP = f(AREAC, FERTHA, RAIN, D_j) \tag{10}$$

where D_j is each of the defined degradation variables, from GULLY to TARGET, derived from survey points on cropland.

The function for agricultural output as a whole was specified as follows:

$$TOTAL = f(AREAS, FERT, LABOUR, TARGET) \tag{11}$$

where TARGET is derived from all survey points on agricultural land.

The crop models, following equation (10), are estimated by conventional OLS procedures. The total model, following equation (11), was estimated with OLS, and then with COLS, and stochastic procedures to obtain the frontier functions.

5.1 The crop models

The set of crop models are presented in Tables 1 and 2. All models include the land area (AREA), fertilizer (FERTHA) and rainfall (RAIN) variables. Those in Table 1 include the separate degradation variables, and those of Table 2 contain the combined degradation variables.

The equations of Table 1 suggest that

(a) some three quarters of the variation in quantity of crop output is associated with variations in area, fertilizer and rainfall alone,

(b) declines in crop output are associated with increases in degradation in four of the models (gully erosion, structural decline, sheet and rill erosion, and wind erosion and rill erosion), but

(c) the addition of the degradation variables adds less than one per cent to the explanatory power of the equations.

The four significant degradation types (GULLY, STRDEC, SHRILL, and WIND) are all widespread throughout the state, and are all associated with crop production. The difficulty of the choice between them invites the use of a joint variable, hence the models of Table 2.

Table 1
Cropping models with individual degradation variables

Independent Variables	EQUATION					
	12	13	14	15	16	17
AREAC	1.922 (16.2)***	1.903 (16.2)***	1.967 (16.2)***	1.887 (15.8)***	1.946 (16.5)***	1.916 (15.9)***
FERTHA	99.070 (1.6)*	70.690 (1.2)	105.900 (1.8)**	82.314 (1.4)*	122.604 (2.0)**	97.938 (1.6)*
RAIN	80.379 (2.9)***	90.945 (3.3)***	72.593 (2.6)***	85.290 (3.1)***	58.108 (2.0)**	80.152 (2.9)***
GULLY		–28.401 (1.8)**				
STRDEC			–31 074.872 (1.6)*			
SHRILL				–3 474.321 (1.7)**		
WIND					–21 103.259 (1.9)**	
DRYSAL						–19 348.121 (0.3)
Constant	–63 802.768 (2.6)***	–56 579.281 (2.6)***	15 180.558 (0.2)	–48 939.046 (2.1)**	–862.630 (1.9)*	–43 265.067 (0.6)
R^2	0.747	0.756	0.754	0.754	0.757	0.747
$\bar{R}^2$	0.738	0.745	0.743	0.743	0.745	0.735

a The levels of significance are denoted as * for ten per cent or better, ** for 5 per cent or better, and *** for 1 per cent or better.

Table 2

Cropping models with aggregate degradation variables

Independent variables	EQUATION 18	19	20
AREAC	1.895 (16.4)***	1.894 (16.2)***	1.884 (16.1)***
FERTHA	69.571 (1.2)	78.670 (1.3)*	72.281 (1.2)
RAIN	86.693 (3.3)***	85.141 (3.2)***	90.436 (3.4)***
TARGET	–15 383.652 (2.6)***		
DEG B		–776.996 (2.4)***	
DEG C			–1992.387 (2.4)***
Constant	–85 667.504 (1.4)*	–41 592.828 (1.8)*	-43 167.918 (1.9)*
R^2	0.765	0.762	0.762
$\bar{R}^2$	0.754	0.751	0.752

In Table 2, all three degradation variables are significantly associated with crop output and once more show that increases in degradation are associated with decreases in output. Further, all three degradation variables are significant at the one per cent level -- instead of 10 per cent and 5 per cent as for those of Table 1. However, in equations 18 and 20, FERTHA has now slipped below 10 per cent in its significance and this change may correspond to the change in significance of the degradation variables.

Direct interpretation of the models provides the following opportunity cost information.

(a) Model 13 indicates that a one unit increase in gully degradation results in a 28 tonne reduction in crop output per LGA. A one unit increase is an increase of one metre of gully length per 100 hectares.

(b) Model 15 indicates that a one unit increase in sheet and rill erosion results in a loss of 3,474 tonnes of crop output per LGA. A one unit increase is a one tonne increase, on average, over all the 44,421 cropped hectares of the "mean" LGA. On this basis, a loss of one more tonne of soil per hectare is associated with a loss of 0.08 tonnes (3474/44,421) of crop output per hectare, on average. The average crop yield (CROP/AREAC) was 2.09 tonnes per hectare. So a loss of one more tonne of soil is associated with a decrease of 3.8 per cent (0.08/2.09) in crop yield, rather higher than Watt's (1990) estimate of 2.3 per cent from experimental plots.

Soil conservation measures attempt to reduce degradation and enhance the productive capacity of the land. The potential increases in crop output, associated with specific reductions in different kinds of degradation, are therefore of some interest. The elasticities of crop output (CROP) with respect to specific reductions in the different types of degradation were calculated from the models of Tables 1 and 2, and are shown in Table 3.

The meaning of the values of Table 3 may be interpreted in terms of an example. The mean gully length for all surveyed points in Gunnedah shire is 508 metres per 100 hectares. A decrease in gully length of one per cent (or 5.08 metres) is therefore associated with an increase in crop output of 0.11 of one per cent. Total crop output for the shire is 260, 967 tonnes, so the increase is 287 tonnes (0.0011 times 260,967) over the shire as a whole.

The mean loss of soil through sheet and rill erosion is 3.19 tonnes per hectare per year. A decrease of one per cent (from 3.19 to 3.16 tonnes) is associated with an increase in crop output of 0.82 of one per cent which is 418 tonnes over the shire.

Table 3
Increase in crop output, for specific reductions in degradation, for different types of degradation[a]

Type of degradation		For a 1 per cent reduction Per cent	Tonnes[b]	For a reduction to to negligible levels Per cent
Gully erosion	GULLY	0.11	287	10.8
Structural decline	SDTRDEC	0.82	2140	48.6
Sheet & rill erosion	SHRILL	0.16	418	12.1
Wind erosion	WIND	0.55	1435	32.2
Overall	TARGET	1.61		36.3

a For example the 0.11 for gully erosion indicates that a one per cent reduction in gully degradation leads to an increase in crop output of one eleventh of one per cent.

b Tonnes of increase of output for Gunnedah Shire.

Structural decline and wind erosion are measured as qualitative variables. A one per cent reduction in structural decline is equivalent to two survey points being improved from severe status, (coded at 3), to intermediate status, (coded at 2). This improvement is associated with an increase of 0.82 of one per cent which is 2140 tonnes. A one per cent decrease in wind erosion is equivalent to degradation at two survey points being improved from moderate hazard, (coded as 3), to low hazard, (coded as 2). This would be associated with an increase in output of 1435 tonnes for Gunnedah shire.

Changes in soil structure are associated with the highest responses in crop output, perhaps because a stable soil structure is important for water infiltration, aeration, root growth and for reducing erodability over entire paddocks. Perhaps therefore land with structural decline should be restored first. The LGA's, with substantial cropping areas, and the worst levels of sturctural decline, are 'Narrandera, Parkes, Coonamble Culcairn and Coolamon shires.

5.2 The total output models

The OLS model for total output is equation (21) in Table 4, and the deterministic (or COLS) and stochastic frontier functions are equations (22) and (23). The deterministic model was derived by the corrected ordinary least squares procedure. The highest positive residual from the OLS model, 68,649.0, was added to the OLS constant to give the COLS model. The stochastic model was estimated with Greene's LIMDEP package.

The coefficients of all the functions are similar. Total output per LGA increases with increases in area, fertiliser applied, and labour. Each extra unit of degradation reduces the value of shire output by some $4,530,000. Each extra unit of conservation will increase output by $4,530,000. If all degradation were eliminated, it appears that the value of output would rise by $7.3m per LGA or about $12 per hectare. For these 92 LGAs, the rise is about $672m in total (7.3x92).

The parameters estimated in the LIMDEP frontier model include the regression constant, coefficients, and lamda and sigma parameters. Lamda is the ratio of (the standard deviation of the dependent variable due to the non-positive (or efficiency) disturbance) to (the standard deviation of the dependent variable due tot he random disturbance). Sigma is the sum of the variances due to each kind of disturbance. When lamda is zero, the frontier estimates are equivalent to OLS estimates because the random disturbance comprises the total disturbance. When lamda approaches zero, the producing units are approaching technical efficiency because the differences between them are due mainly to random disturbances. When lamda approaches infinity, the differences are due mainly to technical efficiencies.

An advantage of the frontier model, in addition to its intuitive and theoretical advantages, is it's information on the proportion of the disturbance due to technical inefficiency (non-positive disturbances) and to random causes. The lamda and sigma parameters enable calculation of this proportion. The parameters were 3.89 and 34 993.3 respectively for Equation 23, which indicated that 93.9 per cent of the disturbance can be attributed to differences in technical efficiencies. The inefficiencies are now explored, for simplicity through the deterministic model.

Table 4
Models for total output

Independent variables	EQUATION 21	22	23
	OLS function	Frontier: deterministic	Frontier: stochastic
AREA	0.014 (6.5)***	0.014 (6.5)***	0.015 (7.4)***
FERT	1.749 (3.6)***	1.749 (3.6)***	1.918 (7.6)***
LABOUR	53.733 (7.0)***	53.733 (7.0)***	46.828 (7.3)***
TARGET	-4532.30 (1.7)*	-4532.30 (1.7)*	-4531.03 (1.6)*
CONSTANT	37,771.1	106,420.1	11,570.5

a The R^2 statistics for models 21 and 22 are both 0.603, and adjusted R^2 statistics are both 0.585. The maximum log-likelihood for equation 23 is highly significant at -1049.0.

5.3 The efficiency results

The importance of degradation can also be assessed in terms of its impact on output and input efficiency. The 92 LGAs were ranked by their co-efficient of output efficiency and the top and bottom five shires are shown in Table 5. The corresponding coefficients for the chosen measure of input efficiency are also shown, together with the relative level of degradation. The relative level for shire is ($TARGET_i/TARGET^*$), where $TARGET^*$ is the level for the least degraded shire (Maclean).

(a) The measure of output efficiency is the ratio of actual output (TOTAL) to potential output for a particular producing unit, given the actual levels of inputs for that unit. By the nature of the method, actual and potential output are deemed to be identical for the top-ranked LGA which is on the frontier. So the value of this measure is 1.00 for this LGA

Consider, the average shire with an efficiency value of 0.43. Actual output is now only 43 per cent of potential output - - given the level of inputs of the average shire, and presuming the potential could be achieved by the management and other conditions of the most efficienct LGA. In these conditions, the most efficient LGA would produce 57 per cent more output (1.00 – 0.43 converted to a percentage) with the same inputs.

(b) The measure of input efficiency is the ratio of the potential level of use of an input to the actual level - - given the actual output of the producing unit, actual levels of all other inputs, and constant ratios of input use for all units. By the nature of the method, once more, actual and potential input use are deemed identical for the top-ranked LGA. So the value of input efficiency for this measure is 1.00.

The measure has been computed just for the single input of degradation. As Table 5 shows, the values of this measure of input efficiency range from 1.00 to 0.29, with an average of 0.38. These indices measure the relative decrease in degradation alone which would raise a shire onto the production frontier, ceteris paribus. For the average LGA, the change is 62 per cent (1.00 – 0.38). Thus a 62 per cent decrease in degradation is needed, with no change in the other inputs, for the average LGA to be on the efficient frontier.

Table 5

Measures of output and input efficiency[a]

Rank order	LGA	Output efficiency	Input efficiency	Relative level of degradation
1	Warren	1.00	1.00	1.04
2	Narrabri	.98	.89	1.11
3	Griffith	.93	.72	1.18
4	Narromine	.92	.75	1.11
5	Walgett	.86	.60	1.04
21	Gunnedah	.52	.38	1.24
88	Hastings	.16	.23	1.06
89	Tallaganda	.15	.32	1.20
90	Maclean	.14	.26	1.00
91	Nymboida	.11	.29	1.04
92	Greater Lithgow	.12	.29	1.04
Average		.43	.38	
Standard deviation		.20	.12	

a The shire of Moree Plains was excluded from this analysis, because its total value of output was at least double that of shires of similar size.

b If the production function exhibited constant returns to scale, the coefficients of output and input efficiency would be identical. If the function exhibited mildly-decreasing returns to scale, the input efficiency measures would be slightly smaller than the output ones. In this case, there appears to be decreasing returns at the 'top end', and increasing returns at the bottom end where input efficiency exceeds output efficiency.

The distribution of the necessary decreases is as follows.

Reduction in degradation required %	Number of LGAs
76 to 71	18
70 to 61	43
60 to 51	22
50 to 41	4
30 to 21	3
10 to 1	1
0	1
	92

The large proportion of LGAs, 83 out of 92, require a decrease in their degradation of more than 50 per cent to allow them to become efficient -- given their existing levels of area, labour and fertiliser.

(c) Another measure of input efficiency is the reduction in agricultural area that could be made if degradation were reduced to negligible levels - - but output maintained at the frontier level and with other inputs at their existing levels.This index of efficiency is the ratio of the potential reduction in area to the actual total agricultural area. The three LGAs with the lowest reductions are as follows.

Walgett	0.06
Carathool	0.06
Central Darling	0.08

Elimination of degradation in Walgett and Carathool would allow the frontier output to be produced on 6 per cent less land, given the same levels of other inputs. In Central Darling, the output could be produced on 8 per cent less land.

The relative levels of degradation are shown for each LGA in Table 5. Observation of the relative levels of Table 5 suggests that output efficiency bears no particular relationship to the level of degradation. Indeed, Gunnedah shire has 24 per cent more degradation than Maclean but is nearly four times more efficient.

6 DISCUSSION

In this final discussion, we summarise the main findings so far, and review potential developments of the analysis.

6.1 The main preliminary findings

The main preliminary findings may be summarised as follows.

(a) Land degradation has been shown to be statistically related to decreases in agricultural output.

(b) Increases in fertiliser and labour could mask the effect of increase in degradation on total value of output. When the effects are separated out as in Table 4, increases in degradation by themselves do lead to decreases in output.

(c) Structural decline and wind erosion appear to lead to larger losses of crop output than gully or sheet and rill erosion-- although all four types of degradation are associated with losses in crop output.

(d) An increase of one tonne of soil lost per hectare per year through sheet and rill erosion appears to be associated with a loss of 3.8 per cent in crop yield per hectare.

(e) If all degradation were eliminated, the value of total agricultural output per LGA would rise by some $7.3 million (or 13 per cent) per year. This corresponds to some $672 million over the state, or $12 per hectare.

(f) A 62 per cent decrease in degradation is needed to shift the average LGA back onto the production frontier, given its output and mix of other inputs.

(g) Elimination of degradation would reduce the area of an LGA needed to produce the given output from its other given inputs. The "equivalent increase in area" would be at least six per cent.

6.2 Potential developments in the analysis

At this stage in the project, it is appropriate to conclude with the caveats that surround the data and analysis, and the further work that is already underway.

(a) Further data are being sought on farm capital, climatic indices, and feral animals. The degradation data are being revised to access the data already collected on gully length and sheet and rill erosion.

(b) The measures of efficiency are useful concepts to assess the importance of degradation and to help define policies to resolve degradation. They provide information to supplement that from the coefficients in the regressions. The analysis to derive the measures could be developed to improve the usefulness of the efficiency measures.

(c) The analysis has used TOTAL, the gross value of all agricultural production, as the output measure. Some LGA's like Narrabri and Griffith may have high levels of output efficiency because they have special, localised outputs such as cotton and horticultural crops. Analyses by separate outputs is desirable.

(d) The analysis has covered 92 LGAs, and so covered widely different conditions. Analyses by groups of LGA's, with more consistent conditions in each group, would improve the policy relevance of the estimates.

(e) The indicies of efficiency (Table 5) are based on a single observation (LGA) on the production frontier, which automatically rates at 1.00. Moree Plains is excluded because its value of output is a clear outlier but perhaps more LGAs should be excluded. Whilst relative orderings may remain when more outliers are excluded, the absolute efficiency values change and perhaps become more relevant.

(f) The multiple regression models are all linear, allowing for constant rates of output response. This allowance may reflect the response for changes in the degradation input, but other models may be worth investigating.

(g) Some kinds of land degradation were not measured in the survey, and so their effect is not reflected in the analysis. For example, chemicals used in horticulture or cotton production, may degrade the land and water resource. Apart from salinities and acidities, this pollution is not included.

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