Estimating the Cost of Land Degradation

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Abstract

There is considerable policy interest in quantifying the impact that land degradation has on agricultural production yet we have little evidence of the extent of this aggregate impact. In this paper it is shown that estimates of total factor productivity (TFP) can be used to define a conceptually sound measure of the production cost of land degradation. The rate of growth in TFP in agriculture represents the outcome of the combined impacts of technological progress, improvements in both allocative and technical efficiency and land degradation on the agricultural production system. Data for the Australian broadacre agricultural sector are used to investigate the feasibility of decomposing TFP data to derive an estimate of the production cost of land degradation. The approach fails to identify any significant impact from land degradation on aggregate production.

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1. Introduction

The major forms of land degradation experienced in Australia today are water and wind erosion of bare lands, soil salinity, soil fertility decline and rangeland degradation (Hamblin and Williams 1995) It is generally accepted in scientific and policy circles that these and other forms of land degradation have been, and are, a major problem for Australian agriculture This view was recently endorsed by Goss et al (1995) who concluded that unless there were significant changes in the way land was used in agricultural production " a decline in the condition of natural resources will continue and contribute to Australia's economic position becoming more precarious." (Goss et al 1995 p 7) This statement implies that land degradation represents an economic problem in the sense that the extent of land degradation is greater than is optimal from a private and public perspective and that it reflects a significant constraint on agricultural production

The concern of governments, rural industries and the general community with these production implications and other problems associated with land degradation is evidenced in the range of public programs that have been established to address the problems and way these programs have been endorsed and supported by political parties and industry groups Perhaps the most visible of these programs is Landcare. This program involves over 2,000 community groups supported by state and federal resources In 1995/96 the Commonwealth budget for the National Landcare Program alone was over $80 million Other Commonwealth initiatives in the area include the land management functions of the Murray-Darling Basin Commission, the Vertebrate Pest Program, the Feral Pest Program and the financial support of the land management research programs of the various rural industry research and development corporations (Department of Primary Industries and Energy (1995))

Despite the apparent overwhelming agreement in the community on the severity of the land degradation problem and the willingness of governments to commit public funds to the various aspects of the problem, there is very little information on the overall economic impact of land degradation on agricultural production or society in general (Burch, Gratez and Noble (1987)). This information is of interest to policy makers because it provides an upper bound estimate of the gross cost of potential market failures in the land market such as imperfect information and divergences between social and private discount rates. Viewed in this light, estimates of the production implications of land degradation have relevance in the public policy debate on the case for government intervention in the process of private land management.

Attempts at assessing the importance of the agricultural production aspects of the problem have rested on economic measures, such as estimates of the value of lost production and the cost of repairing the degradation, or physical measures, including the area of land affected and tonnes of soil lost The most widely referred to measure of the cost of land degradation to agriculture was prepared by the Australian Soil Conservation Council (ASCC) (1989) They found that the cost of lost production attributable to land degradation was $600 million a year (in 1989 dollar terms).

The basis for this estimate is unclear The figure is reported in the preface to ASCC (1989) with no discussion of the source of the estimate in the body of the document. Hall and Hyberg (1991) investigated the source of the $600 million estimate and found that it represented " a consensus of expert opinion around Australia" (p 13). This could mean that the figure represents a moderation of a number of figures which may have been quite diverse in terms of magnitude and estimation procedure In the absence of some detail on the nature of the individual estimates involved and the rationalisation process involved, it is difficult to place any confidence on the final estimate

However, despite these uncertainties with the estimation procedure, other studies have arrived at very similar figures Hall and Hyberg (1991) used cross sectional survey data to estimate the differences between the production surfaces of farmers who thought their land was degraded and those farmers who were unaware of land degradation on their properties They found that perceived land degradation had a significant impact on production and that for the 1983/84 year this impact was equivalent to a $393 million dollar loss for Australia as a whole (When this figure is indexed forward to 1989 using the prices received index it comes to around $570 million) Hall and Hyberg (1991) reported that their estimate for New South Wales (a 5% loss in production) was in turn broadly equivalent to earlier state estimates derived by Sinden and Yapp (1987) (a 7% loss in production)

One of the most worrying aspects of the estimate of a $600 million loss in production is that it is improbably small Chisholm (1990) has shown that a cost of $600 million in 1989 implies a very small annual incremental production cost He compared this cost with a gain due to the cumulative impact of productivity growth over the previous 30 years of around $10 billion The cost of $600 million reflects the compounded impact of all land degradation on Australian agricultural land Even if one assumes that all degradation has occurred in the last 70 years, a $600 million loss for 1989 is consistent with a steady annual rate of lost production of one tenth of one percent of agricultural production each year

A figure this small appears to be contrary to much of the evidence that exists about the physical dimensions of the problem It has been reported that some 55% of arid land and 45 % of non arid land is suffering from land degradation (Chartres (1987)) These measures of the physical extent of land degradation are likely to be reasonably accurate in that the major forms of land degradation can be measured and monitored fairly reliably given the current technology. Similarly, Hall and Hyberg (1991) found that 37% of farmers surveyed in the ABARE Australian agricultural and grazing industries survey thought that their properties had an actual or potential land degradation problem. While it is possible that such widespread degradation could produce a negligible production impact, this inference is not in line with trial results which suggest that erosion and soil structure decline can have a significant impact on plant growth (For example, see Hamilton (1970) for an analysis of the impact of sheet erosion on NSW wheat yields) It is also inconsistent with the case study and anecdotal information that is available on the impact of the salinisation of some northern Victorian irrigation properties where substantial areas on some farms have either been removed from production altogether, or experienced a marked reduction in the potential for plant growth

Another important problem with this estimate is that its conceptual foundations are unclear A desirable characteristic of a measure of the impact of land degradation is that it comprehensively reflects the production systems involved and allows for substitutability between inputs This comprehensiveness means that changes in all input levels (or costs) are taken into account Blyth and McCallum (1987) argue that there is no case, based in economics, for using a simple measure of the value of lost agricultural production as a measure of the on-farm cost of land degradation Land management involves conservation costs and degradation costs and both need to be considered in assessing the production implications of land degradation

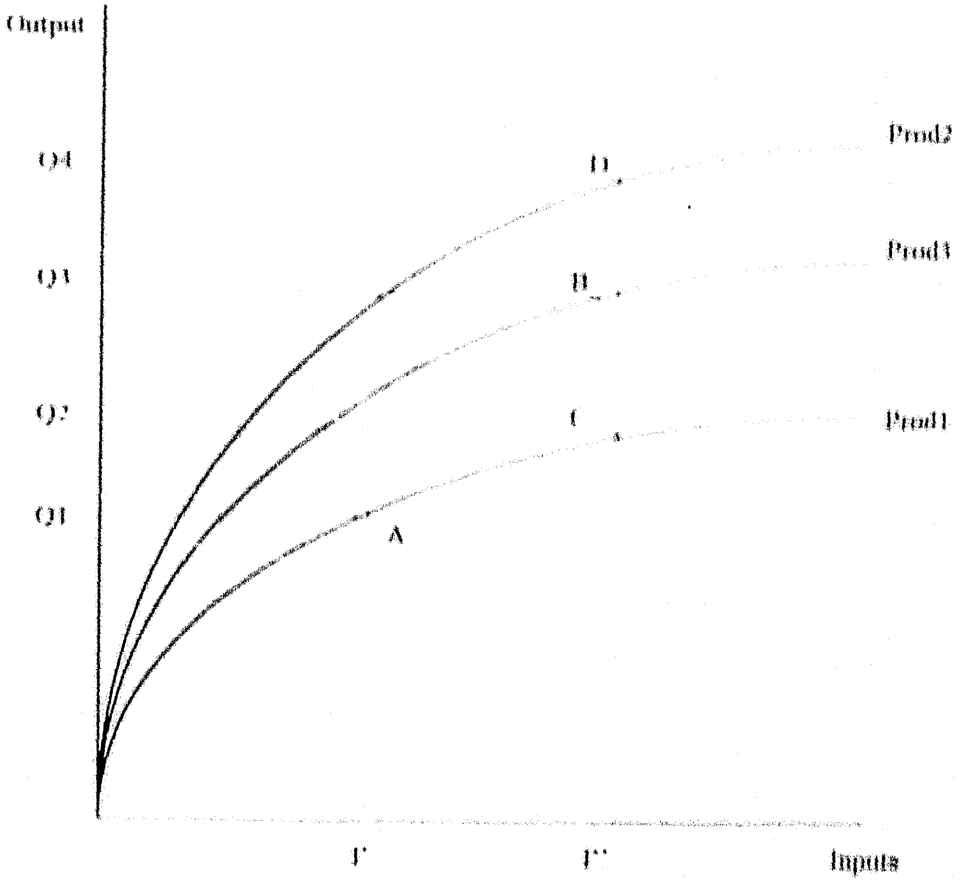
The hypothesis examined in this paper is that, up to this point in time, land degradation has had an insignificant impact on the production of Australian agriculture The magnitude of the impact of land degradation on agriculture is measured econometrically using aggregate production data The model to be tested is based on the relationship between technological progress, total factor productivity (TFP) and the extent of land degradation

2. TFP and Land Degradation

If land degradation has had a substantial and significant impact on agricultural production it will be reflected in lower production levels and/or higher input levels Hall and Hyberg (1991) modeled the impact of land degradation by estimating production functions for farms with and without land degradation problems using cross section data The approach suggests that land degradation can be viewed as a downwards shift in the aggregate production function and so will be revealed as a significant negative coefficient on the land degradation variable in the production function While the approach is conceptually sound, there are significant estimation and data problems associated with the estimation of an aggregate production function In this context the most important problem is the estimation of the extent of land degradation at an individual farm level Individual farmers would find it difficult to quantify the extent of degradation while the use of a dummy variable to reflect whether degradation is present or not loses a lot of information about the relationships involved

An alternative estimation approach can be developed utilising the underlying production relationships as reflected in measures of TFP This approach has the advantage that there is no need to specify the complete production surface and obtain information on the extent of land degradation on individual farms However, it does imply any and all of the assumptions associated with the particular measure of TFP that is used

Figure 1
The Impact of Land Degradation and Technological Change on Production



TFP is a catch-all concept. Changes in TFP reflect all those factors which influence the relationship between inputs and outputs in a production system. Improvements in cost efficiency (technical efficiency, technological progress and increases in allocative efficiency in factor markets) tend to increase TFP while land degradation tends to reduce TFP. The relationship is illustrated in Figure 1. Over time technological progress and the improvement in the efficiency with which resources are used tends to expand the production possibilities as we tend to move from a point like A to some point D on a higher production surface. Land degradation is equivalent to negative technological progress and constrains the industry to some point B on an intermediate production surface. Measured TFP reflects the shift in production from C to B and has two component parts: C to D reflecting improvements in efficiency and technological progress and D to B reflecting the production impact of land degradation

This suggests the following simple model

P = f(CE, LD) (1)

where

P= a conventional measure of TFP

CE = collection of variables determining increases in cost efficiency, and

LD = a measure of the rate of land degradation

The estimation of this model has been made feasible by the work of Mullen and Cox (1995). As part of a study of the returns to research in Australian agriculture they compiled a data series that included estimates of TFP under different modeling assumptions, and most importantly, annual research and extension expenditure for the agricultural sector since 1953. On the basis of the work of Mullen and Cox (1995) it is hypothesised that improvements cost efficiency will be determined by outlays on research and extension, seasonal factors, the level of education of farmers and changes in the profitability of farming as reflected in movements in the terms of trade confronting the sector

A measure of the rate of land degradation is not readily available. A time trend can be used as a very crude proxy for the progress of land degradation. Indirect support for this approach can be found in Mullen and Cox (1994). In attempting to explain changes in TFP this early work reported that after accounting for research outlays, education levels and weather, there was a significant negative time trend. This trend variable was consistent with a 4%pa decline in TFP after accounting for those factors which could explain improvements in cost efficiency. This result is consistent the impact of land degradation. (Mullen and Cox(1995) subsequently removed the time trend variable from their estimation model on the grounds of reducing multicollinearity.)

The use of a time trend in the model is also supported by a test for stationarity of the TFP series. Using the approach suggested by Holden and Perman (1994) it was found that TFP was trend stationary. Under these circumstances the inclusion of a trend term in a model is a valid means of achieving stationarity. Moreover, failure to deal with the non-stationarity of the TFP variable by this, or some other approach, would mean that any results coming from standard OLS models would be unreliable.

The empirical model used as the basis of this work is drawn from Mullen and Cox (1994).

P = f(T, W, E, TOT, RES, EXT) (2)

where
T = time trend
W = weather index
E = education attainment of farmers
TOT = terms of trade for the agricultural sector
RES = research effort
EXT = extension effort

3. Data

3.1 Specification of Variables

The data for TFP, research, extension and education were compiled by Mullen and Cox (1985) The dependent variable, TFP, was computed as a ratio of Divisia indices. The research variable is represented by total State Department of Agriculture, CSIRO and university outlays on agricultural research. This series was adjusted by a research deflator and lagged using an inverted V profile over 8 years. The extension variable was computed by lagging actual agricultural extension outlays over 3 years with a weight of 0.5 for the current year and 0.25 for each of the previous two years. The Education variable is a five year moving average of the ratio of school enrollments to the potential number of students.

The weather and terms of trade variables were also drawn from Mullen and Cox (1985) but were modified in this analysis. The impact of weather on TFP was measured through two variables. The principal variable is the ABARE index of season conditions for grazing areas. This is a regional index of pasture growth weighted, in this case, by sheep numbers in each region. Testing for stability of the model suggested that this variable did not adequately represent the severity of the drought in 1983. To take this into account a 0,1 dummy was included for this year.

The impact of changing profitability on TFP was also measured through two variables: the level of the terms of trade for agriculture and the absolute value of the change in the terms of trade between two periods. The conventional rationale for including the level of the terms of trade in this model is that in periods of improving profitability, farmers undertake investments, often on the basis of a catch-up for some period when capital has been run down. These periods of high investment are characterised by reductions in TFP because there is often a considerable lag between the expansion in the level of capital inputs and the consequent growth in output. Therefore, a negative coefficient would be expected on the terms of trade variable.

However, there is another implication of changing profitability that is not captured by the level of the terms of trade. Any change in output prices, either up or down, will tend to reduce TFP in the short run. Firms maximise their TFP by operating at a level of output which is consistent with a minimisation of their short run average costs. Changes in output prices will tend to shift firms away from the initial long run equilibrium position to levels of output that are not consistent with the lowest level of short run average costs. If prices rise, firms will expand output and experience higher average costs. Similarly, when prices fall firms will contract output and average costs will still rise. In the long run, adjustments to output prices and/or factor prices will tend to move the industry and individual firms back towards a long run equilibrium with an output level that is consistent with the minimum point on the short run average cost curve and the maximum TFP level.

A variable measuring the extent of changes in the terms of trade in an absolute sense would tend to capture these tendencies and could be expected to have a negative coefficient in the estimated model

Following Mullen and Cox (1995) all the variables will be measured in log terms

3 2 Pretesting

Granger and Newbold (1986) have shown that if the variables in a OLS model are non-stationary the estimated equation may be misleading. As noted previously, the dependent variable, TFP, is trend stationary and stationarity is achieved through the inclusion of the time trend term in the estimated model. The stationarity of the explanators in the model was tested using the Augmented Dickey Fuller test and the Phillips-Perron test. All variables were tested in log form. The critical values were taken at the 1% level of significance. The results are presented in Table 1

Only three variables were found to be stationary: the seasonal conditions index of weather conditions, the education variable and the variable representing the absolute value of the change in the terms of trade. The lagged research variable required second differencing before stationarity was achieved. All other variables were stationary after first differencing. There were no conflicts between the results from Augmented Dickey Fuller and Phillips-Perron tests

The variables included in the estimated models are all specified in there stationary form. For example, the reported coefficients on research refer to the impact of the second difference of the research variable on TFP

4. Results

The initial estimation model with all variables expressed in log terms and in there stationary form is given by Equation (3).

$$TFP = C + a1.W + a2.DW + a3.E + a4.RES + a5.EXT + a6.TOT + a7.ATOT + a8.T + a9.T^2 + \varepsilon \quad (3)$$

where:

DW = 0,1 dummy for the 1983 drought

ATOT = absolute value of the change in the terms of trade index

RES = research outlays lagged by 8 periods

The procedure followed in estimating the model was to estimate equation (3) and then delete insignificant variables in turn re-estimating following the deletion of each variable.

Table 1
Pre-Testing of Data for Stationarity

Variable	Test Augment Dickey Fuller	Phillips- Perron
Weather Seasonal Index	I(0)	I(0)
Education	I(0)	I(0)
Terms of Trade	I(1)	I(1)
Change in Terms of Trade	I(0)	I(0)
Research	I(2)	I(2)
Extension	I(1)	I(1)

I(0) = stationary in levels
I(1) = required first differencing to achieve stationarity
I(2) = required second differencing to achieve stationarity
Critical values for the tests were based on the 1% level of significance.

The equations were estimated using OLS in the RATS statistical package. The results from all regression runs are presented in Table 2

The model that appears most appropriate given the nature of the data is Model 6. All the variables are significant and the signs on the coefficients are not unreasonable. The diagnostics for the equation also appear acceptable

One of the key points to come out of this estimation exercise is the difficulty in isolating the impact of individual factors on measured TFP. It is of particular concern that the lagged research and extension variables were not significant. In Model 7 the trend term is replaced with the lagged research variable and the deterministic trend is removed from TFP by prior regression on a trend variable. These changes did not improve the performance of the research variable as the relevant coefficient was still clearly insignificant. It is important to remember that the research variable used in this exercise is derived from, but not the same as, the research variable used by Mullen and Cox (1994) and (1995)

A Chow test was carried out to test for the stability of the coefficients over the sample period. The sample was effectively broken into two 18 year periods with 0,1 intercept and slope dummies included in the model. The results indicated that the null hypothesis of stable coefficients between the two sub-sample periods could not be rejected (Chi-Squared (3) coefficient of 3.06 with a significance level of 0.38)

The positive and highly significant trend term in Model 6 highlights the difficulty involved in identifying the contributions of the individual explanators to the level of measured TFP. The most obvious interpretation that can be placed on the estimated trend coefficient is that it captures the net impact on TFP of a number of variables including research, extension and land degradation. The positive coefficient confirms the accepted belief that, up to this point in time, the impact of research and development has outweighed the negative effect of land degradation. In effect this result does little more than confirm that the underlying rate of growth of TFP has been around 2% pa

An alternative formulation of the model was also estimated based on a comparison of the rate of growth of TFP in the agricultural sector with that achieved in manufacturing where natural resource degradation is unlikely to have a significant impact. If one makes the bold assumption that the underlying rate of technological progress is similar between the two sectors, it could be expected that a substantial level of land degradation would tend to reduce the ratio of agricultural TFP compared to manufacturing TFP

To test this relationship, the ratio of TFP in agriculture to TFP in manufacturing was regressed against a time trend and the two weather variables. (The new dependent variable was found to be stationary.) It is assumed that the weather variables account for the sector specific differences in the changes in TFP other than land degradation which is captured in the trend term. In this case the expected sign on the trend term is negative. The variables other than the trend were again expressed in logs

The results of this test (see Table 3) also failed to show any evidence of a substantial impact of land degradation on agricultural production

Table 2
Regression Results for TFP Model: Sample Period 1956 to 1988

Variable	MODEL 1*	2	3	4	5	6	7**
Constant	13.85	-6.57	-6.11	-6.89	-7.07	-7.16	-10.40
	(0.92)	(1.00)	(1.09)	(1.32)	(1.88)	(1.92)	(1.56)
T	0.004	0.022	0.023	0.021	0.02	0.02	
	(0.18)	(2.05)	(2.34)	(2.37)	(14.23)	(14.36)	
T^2	0.0003	-0.000	-0.000	-0.000			
	(0.61)	(0.16)	(0.26)	(0.05)			
W	0.20	0.19	0.19	0.18	0.18	0.18	0.30
	(2.47)	(3.64)	(3.83)	(3.93)	(4.10)	(4.15)	(4.77)
DW	-0.11	-0.07	-0.07	-0.07	-0.07	-0.08	-0.07
	(2.45)	(2.35)	(2.41)	(2.54)	(2.62)	(2.75)	(2.08)
EDUC	-2.28	2.37	2.26	2.45	2.49	2.51	-2.70
	(0.66)	(1.55)	(1.72)	(2.01)	(2.89)	(2.95)	(1.74)
TOT	-0.04	-0.07	-0.07	-0.07	-0.07		
	(0.28)	(0.57)	(0.57)	(0.65)	(0.66)		
ATOT	0.03	0.003	0.003				
	(1.15)	(0.18)	(0.20)				
EXT	-1.09	0.072					
	(1.01)	(0.14)					
RES	-2.29						-6.97
	(0.12)						(0.46)
Durbin-Watson	2.11	1.97	1.98	2.00	2.00	2.00	2.20
R^2	0.85	0.92	0.92	0.93	0.93	0.94	0.52

* Model 1 was run over the shorter sample period 1964 to 1988

** The dependant variable in Model 7 is the residual of a regression of TFP on a linear trend

"t" statistics are in parenthesis

Table 3
Regression Results for the TFP Ratio Model: Sample Period 1955 to 1982.

Variable	Coefficient
Constant	3.80
	(16.15)
Time	0.0007
	(0.49)
W	0.18
	(3.45)
DW	-0.05
	(1.47)
Durbin-Watson	1.84
R^2	0.34

"t" statistics are in parenthesis

A more robust test of this model would involve a re-estimation of the TFP ratio equation with appropriate research and development measures for both sectors. Unfortunately the data for research and development expenditure in the manufacturing sector is even more difficult to obtain than is the case for agriculture.

5. Conclusion

The objective of this paper has been to test the notion that land degradation has been minor in terms of production losses Two models were investigated as devices to isolate the impact of land degradation one involved a direct assessment of the relationship between land degradation and TFP in agriculture while the other attempted to model the relationship indirectly by examining the ratio of TFP in agriculture to TFP in the manufacturing sector On the basis of these models, and the available data, it was not possible to reject the null hypothesis that, up to this point in time, land degradation has had a negligible impact on grazing industry production systems.

More sophisticated econometric techniques and longer data sets are probably necessary to decompose the underlying rate of growth in TFP into those positive components due to technological progress and the negative impact of land degradation This decomposition is worth pursuing not just for the insights it could offer on the overall impact of land degradation, but also because it would provide a clearer picture of the impact of research and development on production. For example, given the available data the best we can say about the impact of research and development is that the underlying 2% pa growth in TFP probably represents a lower bound estimate of the impact of R+D and that the greater the impact of land degradation on production, the greater is the true underlying impact of R+D. If one accepts the estimate of $600 million as the land degradation impact, the lower bound estimate is probably very close to the true value

If the results of this and previous analyses of the production impact of land degradation are broadly correct there are potentially significant implications for public policy formulation in the land management area. Most importantly, there would appear to be little justification for significant increases in public funding to correct market failures due to high private discount rates and sub-optimal information on the on-farm implications of land degradation. It also raises the question as to whether the current funding may be excessive.

At a more general level an estimate of a negligible production impact from land degradation casts some doubt on claim that land degradation has imposed a significant production constraint upon society. However, it is important to remember that this, and other attempts at the measurement on-site impact of land degradation, are in terms of "up to now". These estimates tell us nothing about what will happen to production in 10 years time if critical soil quality thresholds are breached.

Finally, an indirect policy implication of this work is that the public policy focus on land degradation should be directed towards the off-site/externality issues which have not been considered in this analysis.

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