The Australian Journal of Agricultural and Resource Economics, 41:2, pp. 209–225

Land degradation: links to agricultural output and profitability[†]

Paul Gretton and Umme Salma*

To understand land degradation and assess policy responses, knowledge is needed of the bio-physical causes, the economic effects on farms and the incentives farmers face to avoid or ameliorate the degradation. An empirical study of land degradation in the Australian state of New South Wales is presented in this article. The results suggest that there are incentives for farmers to co-exist with certain forms of degradation, while there are also incentives to avoid some other forms.

This article explores the links between agricultural production, farm profitability and land degradation. In doing so, it draws on the results of a recently completed study on land degradation and the Australian agricultural industry that included an experimental analysis of New South Wales agriculture using a state-wide model (Gretton and Salma 1996). Section 1 provides a definition of land degradation while section 2 conceptualises the links between economic profitability and the level of land degradation. Section 3 highlights the diversity and extent of land degradation. Section 4 presents empirical findings estimated from an integrated environment-economic model of New South Wales agriculture, using information from a New South Wales land degradation study. Section 5 concludes the article with some ideas about future research directions.

1. A definition of land degradation

The development of the agricultural sector has involved progressively more intensive use of land resources for cropping and grazing, and with this,

---

[†] The authors wish to acknowledge the valuable comments received from Philippa Dee, Tor Hundloe, Robert Kerr, Warren Musgrave, Jim Roberts, John Robertson and Richard Snape. Thanks are due to the editors and to two anonymous referees for constructive comments and suggestions. Any errors, opinions and conclusions are the authors and should not be attributed to the organisation they represent.

* The authors are members of the staff of the Industry Commission, PO Box 80, Belconnen, ACT, 2616.

108 Cowley Road, Oxford OX4 1JF, UK or 350 Main Street, Malden, MA 02148, USA.

greater control and pressure on local habitats leading to environmental change. The development of the agricultural sector (along with other sectors of the economy) has therefore involved adaptation to a changing environment. The definition and measurement of land degradation provide one method of monitoring the impact of human activity on the environment and of linking the environment with the economy.

Land degradation has negative connotations that imply the loss of something of value within the environmental–economic system. The lost value may be related to the productivity of the land for agriculture (the concern of this study), the environment as a host to naturally occurring species of flora and fauna or to the environment as a place for other human activities (such as mining, secondary industries, human habitation and waste assimilation). Agricultural land degradation, in particular, is significant because it:

- affects agricultural productivity;
- leads to the clearance of forests and native grasslands as existing land loses productivity;
- places demands on other natural resources to repair the land (lime for neutralising acidity, water for flushing irrigation salinity); and
- leads to off-site pollution and the loss of productivity and amenity values.

For the purposes of this study land degradation has been defined as ‘the decline in the biological productivity or usefulness of land resources in their predominant intended use . . . stemming from human activity’ (Gretton and Salma 1996, p. 27). It encompasses soil degradation and changes in the traditional landscape and vegetation due to human interference. ‘Usefulness’ is a crucial attribute of land degradation.[1] Declining usefulness of land resources indicates that human activity is crowding out pre-existing ecosystems at a rate above what would normally be expected in nature. The changes would be considered to be degradation once they impinge on the intended use of the land resources affected. As land resources have many possible uses, with changes to the landscape having both favourable and unfavourable effects depending on use, the qualification of ‘predominant intended use’ is necessary in order to make the definition of land degradation workable. Under this definition, for example, desertification due to natural climate change would not be

---

[1] See National Soil Conservation Council (n.d.), McTainsh and Boughton (1993), Johnson and Lewis (1995).

regarded as degradation while desert-like conditions due to overgrazing or inappropriate tillage practices would.

2. Farmer incentives and agricultural land degradation

Sustainable land use in agriculture is a two-way process. On one hand, there is a loss of productivity as land resources are used up in current production, while, on the other, conservation and natural regeneration can be used to maintain or renew those resources for future use. This section employs a stylised model of natural resource use to, first, consider the salient features of this two-way process and, second, to show how the biophysical process of land degradation and conservation interrelate with farm outputs and profits.[2]

At the individual farm level, action to prevent or ameliorate degradation is likely to occur if the conservation effort and expense yield a positive stream of farm income benefits. This would generally occur if the net present value of the natural resource to the farmer justified the conservation costs, given commercially applicable discount rates. Economic analysis would suggest that, if such returns were not available, farm investment in conservation would not be warranted.

In the absence of conservation effort, such as when a farmer simply mines land resources, farming would only continue while a normal return on fixed capital could be obtained after all farm running costs have been paid. As land resources were degraded, potential future profits would also be reduced until ultimately, that land would be retired, leaving it for some other land use. As farmers must incur material, labour and capital costs to farm the land, it is unlikely that the land qualities on which farming activities depend would be totally depleted — it would not be profitable for the farmer to permit this. Total depletion would be to the point where regeneration and conservation are no longer possible (all topsoil is lost, soils become poisoned and useless for farming). Nevertheless, some patches of topsoil could be lost, become saline or be otherwise degraded as a result of ignorance, miscalculation, or deliberate sacrifice.

Assuming that individual farms operate in competitive product and input markets, revenue varies in proportion to farm output (see figure 1). The yield obtained by the farmer is jointly determined by his or her effort (E) and the condition of the soil (Z), that is, $Y = f(E,Z)$. The level of effort E is chosen by the farmer, while yield and the resource stock vary

---

[2] We draw on formal presentations by Clarke (1992), Sweeney (1993), Pagiola (1993) and, most particularly, Pearce and Turner (1990).

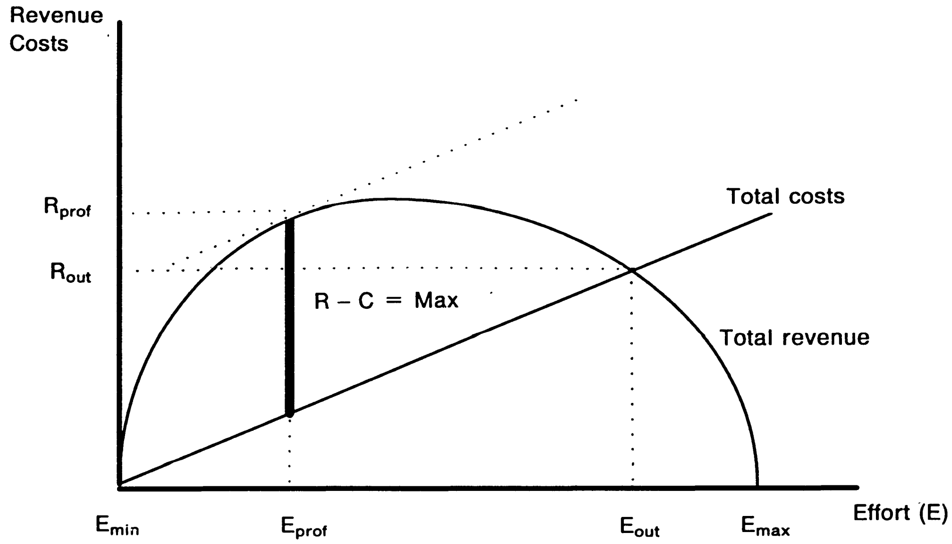


Figure 1 Farm revenue, effort and costs and profit from the use of land resource[ab]

Notes: [a] The profit, or economic yield, to the farmer from the use of land resources is equal to revenue (R) less farm costs (C).

[b] Increases in farmer exploitative effort lead to a decline in land fertility so that without conservation effort or technical change, the higher levels of efforts would actually be associated with declining farm revenues. This is shown as revenue declining on the right-hand side of the figure as effort is increased.

according to that choice. Within the static framework adopted for this illustration, each farmer would set out to achieve the same yield in each year. If nothing else changes, the farmer's profits from land use would not vary from year to year.

Where the effort chosen by the farmer (as measured by inputs of materials, labour and capital) is low (towards E_{min}), so too would be the level of production. If a higher level of effort is chosen, feasible production also increases. However, higher production places more pressure on the land. Ultimately, the repair capacity of the soil would not support higher production, even if the farmer chose a higher level of effort. At some point, feasible production and revenue would be zero (from E_{max}). All points on the spectrum between E_{min} and E_{max} are technically feasible and the farmer must choose where to operate on this spectrum. The level of profit available from alternative levels of farm production and costs would determine the farmer's choice.

In this example, costs also increase in proportion to materials purchased and labour and capital used, while profit from land use resources is the difference between the estimated revenues and input costs. Returns to the farmer from farm-land use would then be at their maximum when farm revenues exceed farming costs by the greatest margin. This profit-maximising outcome is depicted as occurring for farmer effort E_{prof}. In order to gain this maximum economic yield, the individual farmer needs exclusive rights to the use of the land resources relevant to farming. The property rights would enable the farmer to exclude others from the land resource both in the current year and into the future.[3]

Exclusive rights would generally pertain to site-specific land resources and associated site-specific degradation such as soil structure decline and induced soil acidity. Few, if any, spillover effects between farms are likely as a direct consequence of loss of soil condition and fertility due to these forms of degradation. However, excludability does not apply to all land resources relevant to farming. For example, water tables and sub-surface aquifers are rarely confined within the boundaries of individual farm holdings, so that the actions of individual farmers through irrigation farming and land clearing are likely to have spillover effects on other farmers. Where spillovers occur, the capacity of individual farmers to obtain the maximum economic value from their land holding would be limited by the fact that they do not control all resources relevant to the operation of the holding. Farmers would continue in production using open access land resources providing they can cover their material, labour and capital costs. The highest level of farming effort that could be justified on commercial grounds, when there is open access to resources would occur at E_{out} (figure 1). In practice, the true situation is likely to lie somewhere between the two extremes of exclusive land use rights that follow from well-defined property rights, and open access land use that would follow from no or ill-defined property rights.

Importantly, from the perspective of linking the environment with the economy, neither the profit-maximising solution nor the ‘no preservation value’ solution necessarily implies the complete exhaustion of land resources. At points to the right of E_{out}, revenue from further increases in farm effort, given the degraded condition of land resources, would not commercially justify the incurrence of the costs involved. Thus, the model illustrates the reasons why some degradation of land is likely to occur. It also illustrates why it is likely to be too costly for the farmer to completely exhaust the land resources essential for farming.

---

[3] In this context, ‘farmer’ may refer to an individual farmer with exclusive rights to a resource or to a group of farmers acting together to maximise their joint profit.

3. Quantifying the extent of degradation

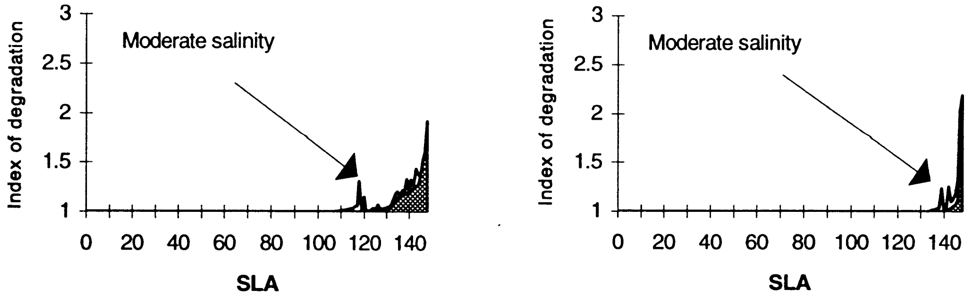
The predominantly location-specific nature of land degradation necessitates a detailed understanding of the incidence and severity of the problem at site levels. With this in mind, we have used data from a survey of farms in the state of New South Wales in 1987–1988 (Graham 1989). The 13 000 data points included in the survey were grouped into 185 Statistical Local Areas (SLAs) and an 'index of degradation' was estimated for each of the 148 SLAs having substantial agricultural activity using a method suggested by Walpole *et al.* (1992). The index of degradation adopted to rank SLAs according to the severity of degradation uses a weighted average of survey points within each SLA. The level of severity at each point provides the appropriate weight. An SLA specific index for each type of land degradation is calculated according to:

$$D = \frac{(1*k) + (2*l) + (3*m)}{n}$$

where there are n data points in SLA*s,* with k points having a degradation weight of 1 (the lowest rating for nil to minor degradation), l points having a weight of 2 (for moderate degradation) and m points having a weight of 3 (for severe degradation). Each type of degradation was measured on its own scale that did not necessarily have three categories or levels of seriousness. So a three-point scale was adopted which generally involved dividing the categories evenly into three groups.

Of the ten types of degradation surveyed, four — irrigation salinity, dryland salinity, induced soil acidity and soil structure decline — were selected for further analysis in this study. For each of these types, separate indexes of degradation were estimated by SLA. In the case of induced soil acidity, this general approach was modified. Problem acid soils were assigned to category three and non-acid or potential acid soils were given the weight of one. A similar treatment was adopted for soil structure decline. This treatment was chosen because the description of the intermediate category in the survey (potential acid and moderate soil structure decline) did not necessarily imply a loss of agricultural productivity. It was therefore most appropriately assigned to category one.

The index results indicate substantial differences in the incidence of degradation across SLAs (see figure 2). For both irrigation and dryland salinity, severe degradation is clustered into a small group of SLAs. In both cases, there is another small group of SLAs with moderate salinity. The most severe dryland salinity extends from SLAs in the Sydney Basin biogeographic region across the South Eastern Highlands region to the South Western Slopes. These biogeographic regions tend to have periodic


Dryland salinity *Irrigation salinity*

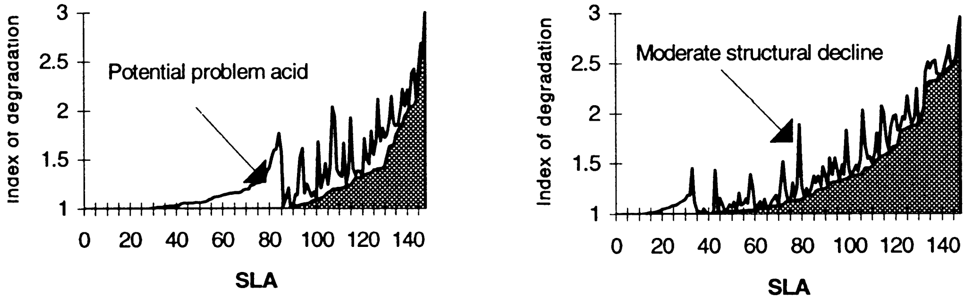

Induced soil acidity *Soil structure decline*

Figure 2 Index of land degradation by type of degradation and agricultural Statistical Local Areas (SLAs) in the State of New South Wales,[abc] 1987–1988

Notes: [a] Nil or negligible degradation in an SLA is indicated by the minimum possible index value of 1. The highest possible value for a degradation index for an individual SLA is 3. At this value, all land degradation survey points in an SLA are rated as having severe degradation.

[b] In each graph, SLAs are ranked according to the contribution of severe degradation to the index for each type of degradation. An individual SLA is therefore likely to have a different rank in each graph. The ranking of SLAs according to severe degradation is indicated by the dark shaded areas and the index value by its upward sloping boundary.

[c] The contribution of moderate degradation (and potential problem acid) to the index of degradation for each SLA is shown by the line above the shaded area, as marked on each graph.

Source: Based on New South Wales-SCS land degradation data.

rainfall, high levels of cleared land and sloping countryside, all of which make them more susceptible to dryland salinity than other regions in the state. Irrigation salinity, as expected, occurs mainly in the Riverina region where there is a concentration of irrigation farming.

The incidence of induced soil acidity and structure decline, on the other hand, is much more widespread. About one-third of SLAs are affected by severe acidity and they fall in the biogeographical regions of the Sydney Basin, South Eastern Highlands, South Eastern Slopes and Riverina. There is, however, a substantial group of SLAs poised with a high incidence of potential problem acid soils. Soil structure decline is even more prevalent and it is focused in areas within the regions of the Sydney Basin, South Western Slopes and Riverina. There is also a substantial group of SLAs with moderate structural decline.

Of these four degradation types, the most widespread are those that are largely farm specific: induced soil acidity and soil structure decline. Irrigation salinity, which could impose substantial external effects on others, is highly concentrated at the regional level.

4. Analysis of the state-wide effects of land degradation

We estimate an econometric model of the state's agriculture, incorporating the land degradation information summarised above. The model uses a snapshot, or cross-section, of the agricultural economy in the early 1990s to study the net effects of the four forms of degradation: irrigation salinity, dryland salinity, soil structure decline and induced soil acidity.

The approach adopted exploits the dual relation between production, costs and profit and assumes that the model's agents choose their input and output mixes to maximise profits, given prices, fixed factors of production and prevailing levels of land degradation. This assumption is suited to the analysis of the Australian agricultural sector, which has many producers each having little control over the input and output prices but with each having the opportunity to vary their input and output mixes.

The profit function approach has been applied to analyse farm behaviour in both Australian and overseas literature (McKay *et al.* 1983; Lawrence and Zeitsch 1989; Fisher and Wall 1990, and Lawrence 1990 for Australia; Shumway *et al.* 1988 for the US; and Nehring 1991 for Bangladesh). Traditionally, the approach has been used to estimate farm price responsiveness, and occasionally to estimate effects of factors such as weather on farm production (Buller and Lin 1969; Hansen 1991). The current study extends this earlier work through the explicit inclusion of land degradation as a factor of production.

The constraints on the level of land degradation and other fixed factors in each SLA give the basic model a short-run focus. In addition, the variability in the level of degradation between SLAs (see figure 2) has enabled the assumption of fixed degradation to be relaxed to give a medium- to longer-run perspective on the effects of land degradation.

For each of 148 SLAs, the model incorporates two commodity output categories: crops and other plant products (crops); and animals and animal products (animal products). It also contains variable inputs divided into four categories, namely: hired labour; fertiliser; water (including water rates); and other materials and services (the numeraire for the model). The fixed factors of production are: the area of agricultural land holdings; and farmer and farm manager labour; while degradation is analysed with reference to the types of degradation listed above.

As the unit of investigation is the SLA, the modelling approach adopted has the advantage that it captures all off-farm effects on agricultural production and profits at the SLA level, that is, intra-SLA effects are internalised. Nevertheless, effects that go across SLA (and State) boundaries are not captured in the model and neither are effects on other industries/activities (such as damage to buildings, roads and other infrastructure).

Ideally, all economic and environmental data relevant to the analysis would be obtained from a single integrated source for a common reference year. Unfortunately, no such data source exists for Australia and it was necessary to draw information from a number of sources. Land degradation information was drawn from the New South Wales survey of land degradation for the years 1987 and 1988, while production, cost and price information was drawn from several sources for the years 1991–92 and 1992–93. Specifically, agricultural production data were drawn from the Australian Bureau of Statistics Agricultural Census (ABS 1995) while agricultural inputs data were drawn from ABS agricultural financial statistics (ABS 1994) and Australian Bureau of Agricultural and Resource Economics farm surveys (ABARE 1995a). Price indexes of commodities produced and farm inputs for New South Wales farms were drawn from ABARE series (ABARE 1995b). The detailed price index information available was weighted together by output and input shares to provide price indexes for the two outputs and four variable inputs for each SLA.

In order to account for differences in production and income due to interregional biogeographic features, each SLA was classified according to the Interim Biogeographic Regionalisation for Australia (IBRA) (Thackway and Cresswell 1995). Using the IBRA, SLAs were classified to one of seven New South Wales regional groupings: North Coast; Central and South coast; Tablelands; Central areas; Central-west areas; Western areas; and Irrigation areas. This information was then taken into account in model estimation.

4.1 The formal model

Farmers make decisions about their output and input mix, given a set of product and input prices and a number of fixed factors of production and land characteristics. Assuming that they exhibit profit-maximising behaviour and that the markets where they operate are competitive, the farmers choose their output and input mix in such a way that their expected variable profit, defined as total revenue net of variable factor costs, is maximised. Thus, a farmer's objective is to maximise

$$\Pi = PY - RX \qquad \text{subject to } Y = f(X;Z) \tag{1}$$

where Π is profit, Y and X are vectors of outputs and variable inputs with P and R being the respective vectors of prices, and Z is a vector of factors that remain fixed in the short run.

The first-order conditions of the problem yield optimal levels of outputs $Y(P, R; Z)$ and of inputs $X(P, R; Z)$. Substituting these expressions for Y and X into (1) yields the indirect profit function Π^*, which has the same arguments as Y and X,

$$\Pi^* = \Pi^*(P, R; Z) \tag{2}$$

By applying Hotelling's lemma, differentiating (2) with respect to the prices gives a set of output supply and negative of input demand equations. Thus,

$$\partial\Pi^*(P, R; Z)/\partial P_i = Y_i(P, R; Z) \qquad i = 1, \ldots, g \tag{3}$$

and

$$\partial\Pi^*(P, R; Z)/\partial R_j = -X_j(P, R; Z) \qquad j = g + 1, \ldots, n \tag{4}$$

Equations (2), (3) and (4) form the basic model representing farmers' choice of output and input mix in any one year when they face a given level of fixed factors of production and land degradation.

From the set of available 'flexible functional forms', this study chooses the normalised quadratic functional form to estimate the profit, input demand and output supply functions. The variable profit function in (2) for this multi-output multi-input case expressed in normalised quadratic functional form is given by:

$$\begin{aligned}\Pi^* = a_0 + \sum_{i=1}^{n-1} a_i \frac{P_i}{P_n} + \sum_{r=1}^{s} \beta_r Z_r + \frac{1}{2} \sum_{i=1}^{n-1} \sum_{j=1}^{n-1} a_{ij} \frac{P_i}{P_n} \frac{P_j}{P_n} + \\ \frac{1}{2} \sum_{r=1}^{s} \sum_{v=1}^{s} \beta_{rv} Z_r Z_v + \sum_{i=1}^{n-1} \sum_{r=1}^{s} \lambda_{ir} \frac{P_i}{P_n} Z_r\end{aligned} \tag{5}$$

where $i, j = 1, \ldots, n$ is for farm outputs and inputs, r and $v = 1, \ldots, s$ is for fixed factors of production and land degradation.[4]

---

[4] See Gretton and Salma (1996) for a detailed description of the empirical model and its estimation, together with the statistical significance of the estimated parameters.

The estimated model was found to have a high degree of explanatory power as tested using the likelihood ratio statistic. With 109 degrees of freedom, the ratio test indicated that variability over the sample period is explained by the model at the 1 per cent level of significance (calculated value of 325 against a 1 per cent critical value of 145). Nearly 30 per cent of the individual parameters estimated were statistically significant at the 10 per cent level or above, while all the five own-price elasticities are statistically significant at the 5 per cent level or above. Among the set of cross-price elasticities, fourteen out of twenty were found statistically significant at the 10 per cent level or above.

In addition to estimating conventional own- and cross-price elasticities mainly to check conformity with existing studies, a comparative static simulation is undertaken to estimate the opportunity cost resulting from a marginal increase in land degradation.[5] By applying the envelope theorem, the partial derivative of (2) with respect to the Z variables will give shadow prices of these variables, so that:

$$\partial \Pi^*(P, R; Z)/\partial Z_q = \omega_q = Z_q(P, R, Z) \tag{6}$$

If, for example, Z_q is the stock of qth type of land degradation, and if the overall sign of ω_q is negative, expression (6) will provide an estimate of the loss from a marginal increase in the stock of degradation. If the sign is positive, it will indicate that profit increases as more land is degraded, and the value given by expression (6) will indicate a magnitude of that gain. When profits are at a maximum, the observed net output must have a level of profit at least as great as the profit at any other net output the firms could have chosen. It then follows that, when degradation is a binding constraint on the increase in net outputs and profit, any further increase in degradation from equilibrium levels would reduce profit and the expected sign would be negative.

Applying the theory to the empirical model in equation (5), the following expression is obtained for deriving an estimate of the loss/gain of additional land degradation:

---

[5] Due to scope or timing differences, those own- and cross-price elasticities estimates are only roughly comparable with other Australian studies using similar approaches. Nevertheless, the estimates from the current study lie within a plausible range established by other studies on Australian agriculture. See Gretton and Salma (1996) for a detailed discussion of the estimates and their comparison with other Australian studies. For those interested in re-estimating the model or undertaking further reviews of the data and methodologies, the estimation database and input files to the SHAZAM econometric package are available from the authors.

$$\partial \Pi^*(P;Z)/\partial Z_q = \omega_q = \beta_q + \sum_{r=1}^{s} \beta_{rq} Z_r + \sum_{i=1}^{n-1} \lambda_{iq} \frac{P_i}{P_n} \tag{7}$$

Using the parameters recovered from the model, the estimated loss/gain from a marginal increase in the stock of land degradation are derived and presented in table 1.

4.2 Results

In the absence of a history of estimation of the state-wide effects of additional degradation on production and profits, the magnitude and even the sign of the estimates reported in this article should be regarded as tentative. They are presented here to encourage discussion and further analysis.

The econometric analysis has indicated that, under the current regime of farm management and technology, agricultural output and profit effects of additional degradation vary depending on the type of degradation. The differences can be linked back to the nature of the individual types of degradation and amelioration possibilities. They suggest, amongst other things, that farmers adapt to changing levels of degradation by changing their mix of activities to either minimise losses or maximise profits. The results are discussed below.

In the cases of soil structure decline and induced soil acidity, degradation tends to be represented in entire farming areas leading to a general decline in productivity. In these circumstances, the basic method of avoiding the productivity loss would be for individual farmers to repair or prevent severe degradation.

Table 1 Estimated responsiveness of current production and profit to changing land degradation[ab] (per cent)

	Dryland salinity	Irrigation salinity	Soil structure decline	Induced soil acidity
Elasticity of production				
Crops and plant products	0.086	0.103	–0.013	–0.164
Animals and animal products	0.091	0.225	–0.007	–0.028
Elasticity of profits	1.22	0.44	–0.29	–0.13

Notes: [a] Responsiveness in this analysis is estimated in terms of estimated elasticities of production and profit to changes in degradation. An elasticity represents the percentage change in production or profit for a 1 per cent change in the New South Wales index of land degradation.

[b] The estimated effects of a change in degradation have a medium to longer-run perspective. The effects are econometrically estimated using a cross-section approach which reflects the ability of the agricultural economy to adjust to changes in degradation.

Consistent with this perspective, the estimated responses to increases in induced soil acidity and soil structure decline indicate that lower levels of production, state-wide, would eventuate with increased degradation. A 1 per cent increase in the index of degradation due to induced soil acidity is projected to lower crop production by 0.16 per cent and animal product output by 0.03 per cent. A 1 per cent increase in the index of degradation due to soil structure decline is projected to lower crop and livestock production by around 0.01 per cent. To read the estimates in a different but more positive way, a reduction in induced acidity or soil structure decline is projected to increase production and profits.

The effects on output and profit due to these forms of degradation have the expected negative sign and provide some rationale for the large groupings of SLAs with moderate soil structural decline and potential induced acidity presented in figure 2. In the case of these forms of degradation, the incentives appear to be against higher levels of land degradation.

A different picture emerges for dryland and irrigation salinity. These forms of degradation tend to be isolated to individual points in otherwise productive farming areas, although the underlying causes may come from underground water tables, aquifer systems and regional, as distinct from farm-specific practices.[6] This confinement of problem salinity would lend support to the notion that farmers could be drawn into high levels of land clearance and to irrigation farming even at the expense of some additional salinity problems, so long as the increased profit due to improved productivity outweighed the negative effect of additional degradation. As the units of the model are SLAs, the model would internalise economic benefits and costs at that level.

However, expansion of degradation is constrained by factors beyond the control of individual farmers, such as the availability of water for irrigation and land for agricultural use in the higher rainfall areas typically subject to dryland salinity. When there are constraints on the expansion of such farming systems, it is possible for the estimated opportunity cost of degradation to be positive. The modelling approach adopted enabled this issue to be investigated.

The econometric estimates indicate that higher levels of production could be achieved by a shift towards farming activities that are characterised by higher levels of dryland or irrigation salinity. A shift

---

[6] The characteristic of these forms of degradation led the New South Wales Soil Conservation Service to publish measures of dryland and irrigation salinity in terms of the percentage of land degradation survey data points affected by degradation rather than in terms of the area affected.

entailing a 1 per cent increase in the NSW state mean of the indexes of degradation due to dryland salinity is projected to raise state-wide crop and animal production by around 0.09 per cent with animal products increasing fractionally more than crops. A 1 per cent increase in the index of degradation due to irrigation salinity is projected to raise crop and animal production by around 0.1 per cent and 0.23 per cent, respectively.

While there may be incentives to move towards farming activities that are associated with higher levels of these forms of degradation, there are also incentives to adapt farming practices to minimise the adverse effects of such degradation in areas where it is most severe. Adaptation to irrigation and dryland salinity involves land management strategies that reduce water accessions and favour salt-resistant crops and pastures.

One way for farmers to achieve this is to vary the mix of crops and livestock in farm output. For example, in the case of irrigation salinity, a substitution from cropping to grazing activities has been estimated to occur as the severity and extent of irrigation salinity increase. This result is consistent with farming strategies that lower water accessions and control water tables by substituting less irrigation-intensive and salt-sensitive grazing activities for more irrigation-intensive and salt-sensitive cropping activities.

The state-wide econometric analysis cannot easily be linked to detailed studies of individual localities or regions within the state. In addition, the state-wide findings for New South Wales may not be representative of possible findings for other states. Nevertheless, the point suggested by the state-wide New South Wales study, that maximisation of economic profit does not necessarily imply zero degradation or even zero growth in degradation is also a result found where cost-benefit techniques have been used to assess degradation amelioration options (see MDBMC 1987 for irrigation salinity; Campbell 1994 and Oram and Dumsday 1994 for dryland salinity; and AACM 1995 for induced soil acidity). For example, the Campbell (1994) cost-benefit analysis of the control of dryland salinity in the Neridup catchment located northeast of Esperence in Western Australia, finds that a negative marginal benefit would be likely as the rate of advance of degradation was targeted to zero (see solid line in figure 3). Assuming that trees planted to aid in arresting salinity could not be harvested commercially, the maximum net benefit to farmers was estimated to occur when the spread of dryland salinity is reduced from 88 hectares per year to around 50 hectares per year. The introduction of commercial forestry was found to reduce the profit-maximising rate of spread of degradation from around 50 hectares per year to around 40 hectares per year (see broken line, figure 3).

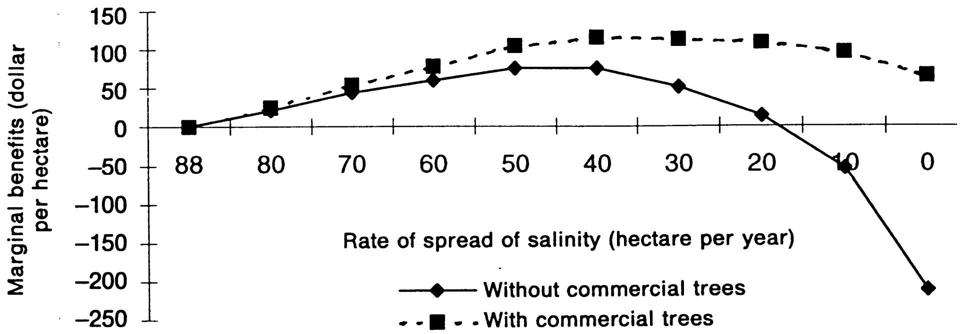


Figure 3 Marginal net benefits from controlling dryland salinity with and without commercial trees[a][b]

Notes: [a] To obtain net benefits, the standard cost benefit approach of comparing cash flows resulting from present farm management practices with cash flows resulting from conservation strategies was adopted.
[b] The reference (or 'current') rate of spread of dry land salinity is 88 hectares per year. This is the benchmark rate of spread for the study.
Source: Campbell (1994).

5. Conclusion

There are numerous forms of land degradation which vary in distribution and intensity. Understanding specific problems and formulating appropriate responses requires a detailed knowledge of the bio-physical nature of prevailing degradation, its economic effects on farms and the community generally as well as the incentives farmers face to avoid or ameliorate the different forms of degradation. Because degradation directly affects farm output and profitability, there are compelling economic reasons for farmers to manage land degradation. Government policies and other economic changes that influence the prices of outputs, inputs and the control farmers exercise over resources are likely to flow through to affect land use and degradation.

The snapshot analysis of New South Wales data suggests that the expansion of some farming systems and associated increased degradation may provide a net increase in profits in the medium term. For others the net effects are negative. The relevant positive and negative effects on profits are not separately analysed in the current study. Further research that enables a separation of the positive and negative effects of changing land use and degradation would improve our understanding of the complex interactions between environmental and economic factors.

Finally, the findings of the snapshot study do not imply that continuing to degrade land is a sustainable activity, given current technologies. Available information does not allow a state-wide analysis of the interaction between environmental and economic factors over time. To investigate these matters further, there is a need to develop regular surveys that integrate environmental and economic information.

References

AACM 1995, *Social and Economic Feasibility of Ameliorating Soil Acidification,* Land and Water Resources Research and Development Corporation, Canberra.

ABARE 1995a, *Farm Surveys*, data provided on special request, Australian Bureau of Agriculture and Resource Economics, Canberra.

ABARE 1995b, *Price Indexes of Commodities Produced and Farm Inputs for New South Wales*, data provided on special request, Australian Bureau of Agriculture and Resource Economics, Canberra.

ABS 1994, *Agricultural Industries Financial Statistics, Australia, 1992–93* (Cat. No. 7507.0), Australian Bureau of Statistics, Canberra.

ABS 1995, *Small Area Agricultural Commodity Data* (Agstats) (Cat. No. 7119.0), Australian Bureau of Statistics, Canberra.

Buller, O. and Lin, W.L. 1969, 'Measuring the effects of weather on crop production', *Canadian Journal of Agricultural Economics*, vol. 17, no. 1, pp. 91–8.

Campbell, C. 1994, 'Economics of salinity management for a catchment in Western Australia', in Webb, A.A. and Price, R.J. (eds), *Procedures for Economic Assessment of Management Options for Dryland Salinity: Report on a Workshop*, Land and Water Resources Research and Development Corporation, Occasional Paper Series no. 6/94, Canberra, pp. 60–7.

Clarke, H.R. 1992, 'The supply of non-degraded land', *Australian Journal of Agricultural Economics*, vol. 36, no. 2, pp. 31–56.

Fisher, B.S. and Wall, C.A. 1990, 'Supply response in the Australian sheep industry: a profit function approach', *Australian Journal of Agricultural Economics*, vol. 34, no. 2, pp. 147–66.

Graham, O.P. 1989, *Land Degradation Survey of New South Wales 1987–1988: Methodology*, SCS Technical Report no. 7, Soil Conservation Service of NSW, Chatswood.

Gretton, P. and Salma, U. 1996, *Land Degradation and the Australian Agricultural Industry*, Industry Commission Staff Information Paper, AGPS, Canberra.

Hansen, L. 1991, 'Farmer response to changes in climate: the case on corn production', *Journal of Agricultural Economics Research*, vol. 43, no. 4, pp. 19–27.

Johnson, D.L. and Lewis, L.A. 1995, *Land Degradation: Creation and Destruction*, Blackwell, Oxford.

Lawrence, D. 1990, *A Generalised McFadden for Australian Agriculture,* paper presented to 34th annual conference of the Australian Agricultural Economic Society, Brisbane.

Lawrence, D. and Zeitsch, J. 1989, *A Disaggregated Model of Australian Agricultural Production Response*, paper presented to 33rd annual conference of the Australian Agricultural Economic Society, Christchurch.

McKay, L., Lawrence, D. and Vlastuin, C. 1983, 'Profit, output supply, and input demand functions for multiproduct firms: the case of Australian agriculture', *International Economic Review*, vol. 24, no. 2, pp. 323–39.

McTainsh, G.H. and Boughton, W.C. 1993, *Land Degradation Processes in Australia*, Longman Cheshire, Melbourne.

Murray–Darling Basin Ministerial Council (MDBMC) 1987, *Salinity and Drainage Strategy*, Background Paper no. 87/1, MDBMC, Canberra.

National Soil Conservation Council n.d., *National Soil Conservation Strategy*, AGPS, Canberra.

Nehring, R.F. 1991, 'Output and input subsidy policy options in Bangladesh', *Journal of Agricultural Economics Research*, vol. 43, no. 2, pp. 29–41.

Oram, D. and Dumsday, R. 1994, 'Evaluating the benefits and costs of dryland salinity control at the farm level: a case study in the Campaspe catchment', in Webb, A.A. and Price, R.J. (eds), *Procedures for Economic Assessment of Management Options for Dryland Salinity: Report on a Workshop*, Land and Water Resources Research and Development Corporation, Occasional Paper Series no. 6/94, Canberra, pp. 42–55.

Pagiola, S. 1993, *Soil Conservation and the Sustainability of Agricultural Production*, Dissertation submitted to the Food Research Institute and the Committee on Graduate Studies of Stanford University in partial fulfilment of the requirements for a degree of doctor of philosophy.

Pearce, D.W. and Turner, R.K 1990, *Economics of Natural Resources and the Environment*, Harvester Wheatsheaf, New York.

Shumway, C.R., Saez, R.R. and Gottret, P.E. 1988, 'Multiproduct supply and input demand in US agriculture', *American Journal of Agricultural Economics*, vol. 70, no. 2, pp. 330–7.

Sweeney, J.L. 1993, 'Economic theory of depletable resources: an introduction', in Knees, A.V. and Sweeney, J.L. (eds), *Handbook of Natural Resource and Energy Economics*, Elsevier, Amsterdam

Thackway, R. and Cresswell, I.D. (eds) 1995, *An Interim Biogeographic Regionalisation for Australia: A Framework for Establishing the National System of Reserves*, Version 4.0, Australian Nature Conservation Agency, Canberra.

Walpole, S.C., Sinden, J.A. and Yapp, T.P. 1992, *The Opportunity Cost of Land Degradation on Agriculture in New South Wales*, Department of Agriculture and Business Management, University of New England, Armidale and New South Wales Department of Conservation and Land Management, Sydney.