36th Annual Conference of the Australian Agricultural Economics Society, Canberra,
10-12 February 1992.

THE MEASUREMENT OF LAND DEGRADATION TO ASSESS LOSSES IN AGRICULTURAL PRODUCTION

S.C. WALPOLE
Department of Agricultural Economics and Business Management,
University of New England, Armidale, N.S.W.

THE MEASUREMENT OF LAND DEGRADATION TO ASSESS LOSSES IN AGRICULTURAL PRODUCTION*

S.C. WALPOLE
Department of Agricultural Economics and Business Management
University of New England, Armidale, NSW 2351

With increasing awareness and understanding of the various forms and processes of land degradation, assessment and measurement techniques have been refined, especially in relation to intensive land uses such as agriculture. This paper examines data from the 1987-88 Land Degradation Survey of New South Wales undertaken by the Soil Conservation Service of New South Wales, and the ways to include the data in an agricultural production function model. The ten forms of land degradation included in the Survey are examined in terms of the way they were measured, and the usefulness of these measurements are assessed in respect to various management applications. Methods to develop an overall degradation index are discussed, and regions displaying extreme levels of land degradation are identified.

1 INTRODUCTION

1.1 The Study

The work reported in this paper has been undertaken as part of a project to estimate the opportunity cost to agriculture of land degradation (see also Sinden and Yapp 1992). The project is being undertaken to attempt to estimate a production function to express agricultural production as a function of the quality of land, as well as the quantity of land, labour and capital. The study is being carried out for the entire state of New South Wales (NSW). The Local Government Area (LGA) has been chosen as the basic unit of analysis because

* The author wishes to acknowledge the Land and Water Resources Research Development Corporation for their financial assistance, and the Department of Conservation and Land Management for making the Land Degradation Survey Data available, as well as the provision of further assistance by Jeremy Black and Owen Graham. Associate Professor Jack Sinden and Mr Tim Yapp must also be thanked for their helpful comments on this paper and for their constant support and encouragement throughout the project. This paper should be read in conjunction with Sinden and Yapp's paper to this conference.

agricultural data are readily available on an LGA basis from the Australian Bureau of Statistics.

1.2 Land Degradation

Land degradation is defined for our purposes as the decline in condition or quality of land as a consequence of human use. The two key features of land degradation are that it is a human-induced process, or a natural process that has been accelerated through human actions, and that it may result in a decline in productivity of the land. Degradation can be measured in terms of physical parameters such as tonnes of soil loss and length of gullies, or biological parameters such as loss of vegetation. An economic measurement of land degradation can be made in terms of the values of reduced output associated with the decline in productivity due to reductions in land quality.

Changes in the condition of the land must be viewed in relation to the particular land use being considered. In order to assess the effects of degradation on agriculture, the following problems and related degradation issues must be examined:

(a) changes in soil condition,
- soil loss due to wind and water erosion and mass movement
- decline in fertility including acidification and salinisation
- soil structure decline,

(b) rising water tables resulting in salinisation and waterlogging,

(c) changes in vegetation composition in pastures,
- weed invasion
- reduction of palatable species,

(d) loss of native vegetation/biodiversity,
- land clearance,
- tree dieback,

(e) invasion of feral animals,
- vegetation and soil loss due to overgrazing and disturbance.

An ideal measure of land degradation will be objective, relevant to the concept of degradation as defined, capable of systematic application, and specific to the time and region.

1.3 Land Degradation Data

For the purposes of this study, data were taken from the recent Land Degradation Survey of NSW, undertaken by the Soil Conservation Service of NSW (SCS) (Graham 1989 and SCS 1989). The survey was restricted to forms of degradation which affected the productive capacity of the State's agricultural, pastoral and forested lands, and only land degraded as a consequence of European management was included. Measurements of decline in productivity associated with land degradation were not incorporated.

The survey plots, at which measurements were undertaken, were selected on a 5km x 10km grid of geographic coordinates in the Eastern and Central Divisions, and on a 10km x 10km grid in the Western Division, giving around 13,000 sample points in total. The information required to assess each type of degradation was derived from aerial photograph interpretation, specialist knowledge, current data, and field checking. Ten forms of degradation were assessed (Table 1). The presence of perennial bush and tree regrowth were also recorded. These measurements were not assessments of degradation as such, but gave an indication of past land use and the present stability and susceptibility of the area to degradation, thus providing a benchmark for future surveys.

Having chosen LGA's as the appropriate unit for analysis, it was necessary to aggregate the survey data to this level. This was undertaken at the Gunnedah Research Station of the Department of Conservation and Land Management (C&LM) using a Geographical Information System (GIS). A map overlay process was used to define which survey points fell within each LGA. In NSW there are 178 LGA's, of which 113 have a large enough area to incorporate fifteen or more survey points within their boundaries. Any LGA's with less than fifteen survey points were excluded from the analysis, with these mainly being municipalities and cities where agricultural outputs were minimal.

For the purposes of this project, the data provides the most comprehensive state-wide information on the status of land degradation in New South Wales. These data were more detailed than the information from the Commonwealth/State Collaborative Soil Conservation Survey (Woods 1984), which was a qualitative inventory of land damage assessed in terms of the required land treatment. The methodology of this Australia-wide survey inevitably left

Table 1: Forms of Degradation and their Assessment

Form of Degradation	Basis of Assessment	Method of Measurement	Comment
Sheet and Rill Erosion	Hazard 0.1ha – USLE estimate quantity of soil loss t/ha	5 classes negligible to very severe	Existing land use basis for USLE factors
Mass Movement of Soil	Status 100ha	2 classes, evidence as yes/no	
Wind Erosion	Hazard 0.1ha	4 classes, low to–high	Depends on existing land use soil group ground cover
Gully Erosion	Status as length of gullying m/100ha	7 classes none appreciable to extreme	
Dryland Salinity	Status 100ha	3 classes nil,minor and severe	Not converted to area affected
Irrigation Salinity	Status 100ha –severity	3 classes none obvious, present, extensive	Not converted to area affected
Scalding	Status 100 ha –percentage scalded	3 classes 5% & less 5 to 50% over 50%	
Acidity	Status 4ha – 'problem acid'	3 classes none potential severe	Incorporates existing land use
Soil Structure Decline	Status 4ha –severity	3 classes undisturbed, intermediate, severe	Incorporates existing land use
Woody Shrub Infestation	Status 4ha –loss of ground cover	4 classes absent to dense	

scope for subjectivity and inconsistency in the assessment both within and between states. The SCS degradation survey was not designed specifically for the purposes of this project, so any problems encountered in its use arose from our manipulation of the data, and not the original data set.

1.4 Aims of the Paper

In the context of the SCS land degradation data available, and the objectives of the overall project, this paper aims to:

(a) examine the application of land degradation data, as measured by the SCS,
(b) assess the usefulness of different ways to measure land degradation,
(c) identify whether areas where land degradation occurs at its extremes differ under different measures of degradation, and
(d) explore the development of a degradation index that describes overall levels of land degradation.

If all of the above aims are achievable, then it will be possible to devise a satisfactory means of including a land degradation variable in a production function model.

2 MEASUREMENT OF LAND DEGRADATION

There are several initial issues to be considered in the way degradation is measured in the SCS survey, and the interpretation of these measurements. These include measurement of existing or potential degradation, the unit of measurement, and the statistical interpretation of measurements. These are now considered in turn.

2.1 Existing and Potential Land Degradation

The ten degradation variables measured in the SCS survey can be grouped according to the way in which they were measured:

(a) Gully length, mass movement, dryland salinity, irrigation salinity, scalding and woody shrub infestation were all direct measurements of the existing status of degradation, with assessment being based on the condition of the land at the time of the survey.

(b) Induced soil acidity and soil structure decline were indirect measurements of existing degradation that required more detailed forms of measurement, with assessment being based on a combination of land use, soil characteristics, farming practices and climate.

(c) Wind erosion and sheet and rill erosion were measured in terms of potential degradation levels, with both being estimated on the basis of hazard, which predicts the estimated level of soil loss given particular land use and soil type parameters. Hazard is the basis of assessment for these types of soil erosion because the effects of their occurrence can be obliterated soon after they occur, making a status assessment difficult, if not impossible (Graham 1989).

Although the direct measurements of degradation may provide an accurate representation of the degradation at the time of the survey, the measurement of degradation hazard takes into account a number of factors over a period of time. For some purposes, such as a long-term inventory, these predictive measurements may hold more relevance.

2.2 The Unit of Measurement

Degradation may be assessed in terms of:

(a) a cardinal measure, such as tonnes of soil loss per hectare,

(b) a direct ordinal or qualitative measure, such as a ranking from 1 to 5, relating to the degree of severity of the degradation,

(c) a dichotomous variable, which simply records the presence or absence of a particular degradation type, or

(d) a proxy variable, which is an indirect measure of the quantity of degradation.

Six of the degradation types in the SCS survey were recorded simply as ordinal classes; wind erosion, dryland salinity, irrigation salinity, acidity, soil structure decline and woody shrub infestation. The measurement of mass movement and scalding were dichotomous assessments. Two degradation types recorded are represented in the data both in terms of a cardinal and ordinal measurement:

(a) The gully erosion variable is the most precise degradation variable recorded. As well as being measured in terms of actual metres of length in each 100 ha plot, the gully lengths were also assigned into ordinal classes from 1-7.

(b) Estimates of soil loss were made by applying the Universal Soil Loss Equation (USLE), which combines a number of causal factors involved in the sheet and rill erosion process to predict soil erosion trends. This equation was used in a modified form, suitable for the Australian environment. Estimates were made in tonnes of soil loss per hectare, and then converted into classes, numbered from 1-5.

The systematic way in which the survey was undertaken and the checking procedures employed ensures that there was a high degree of consistency in the way each degradation type was evaluated across the state (Graham 1989). The use of direct quantitative degradation data rather than qualitative or standardised values, may have a number of advantages. In particular, they accurately describe the occurrence of individual degradation types, and the interpretation of coefficients derived from a production function that uses these variables is straightforward. Alternatively, the arrangement of degradation types into classes with an ordinal number for each class may provide more scope for comparison between degradation types, once the numbers are converted into a standardised value.

2.3 Minimum, Maximum, Median, Mode, Mean, and Standard Deviation

There are a variety of ways in which the degradation variables can be interpreted through statistical measurements such as minimum, maximum, median, mode, mean and standard deviation. The minimum and maximum describe the range of values of the variable. The median is the value which divides the distribution exactly in half, and the mode is the value at which the peak of the distribution occurs. The mean is the value of the variable which is the point of balance or centre of gravity of the distribution, while the standard deviation measures the dispersion of the observations about this mean (Karmel 1959). The question is, which of these measurements provides a useful representation of the degradation type for inclusion in a production function? Table 2 shows the statistical values that have

Table 2

Minimum, maximum, median, mode, mean and standard deviation values for two degradation variables: Gunnedah Shire

	Measurement					
Degradation type	Minimum	Maximum	Median	Mode	Mean	Standard Deviation
Sheet and rill[a]	1	25	2	1	2.47	2.75
Gully[b]	10	3750	10	10	479.28	831.00

[a] t/ha

[b] m/100 ha

Table 3

Elasticities for Mean, Median and Mode Degradation Variables[a]

Degradation type	Statistical measurement	Mean (X)	Coefficient (b_i)	Elasticity[b] (e)
	Mean	1.91	-22566.00	-0.46
Sheet and rill	Median	1.95	-11152.88	-0.23
	Mode	1.69	-17674.23	-0.32
	Mean	2.08	-18991.89	-0.43
Gully	Median	1.93	-13814.91	-0.28
	Mode	1.66	-11232.16	-0.19
	Mean	2.41	-21103.30	-0.54
Wind	Median	2.48	-17167.15	-0.46
	Mode	2.37	-10081.40	-0.26
	Mean	2.45	-31074.87	-0.80
Structure Decline	Median	2.53	-22755.66	-0.61
	Mode	2.50	-21206.37	-0.57

[a]The basic model was:
tonnes of crop production = f(area, fertiliser, rain, degradation type)
[b]Each elasticity was calculated as follows:
$e = b_i (X/Y)$ where,
b_i = coefficient of degradation variable
X = mean of the independent variable (degradation type)
Y = mean of the dependent variable (tonnes of crop production/LGA)

been derived from the Length of Gully and Tonnes of Soil Loss variables, for Gunnedah Shire. Initial examination of the data did not reveal an obvious choice, although the median, mode and mean all appear to provide a beneficial means of describing important characteristics of the data.

In order to evaluate the possibilities of using a median, mode or mean of a degradation variable, each type was included in a cropping enterprise model with degradation types of sheet and rill erosion, gully erosion, wind erosion, and soil structure decline. To test the differences in the coefficients generated for each variable, elasticities were calculated (Table 3). The elasticity describes the percentage change in the output (tonnes of crop output) resulting from a one percent change in the degradation variable. The mean statistic consistently records the highest elasticity, but the median and mode do not follow the same pattern. It can be seen that there are some large differences in the elasticity values for mean, median and mode variables for each degradation type, so on the basis of these values it is difficult to say which would be the most suitable for inclusion in a production function model.

The fact that the mean is capable of algebraic treatment implies that it has great advantages as a measure of central value. The mean can also be used in some cases where a median and mode cannot, such as obtaining a weighted mean. Unlike the mean, the median is virtually unaffected by extreme values so may be a useful measurement when the distribution of the data is highly skewed, while the mode has advantages in the treatment of discrete variables in presenting representative values of the data. For the purposes of this project, the mean was chosen to represent the data, as it appears to be the most useful statistical value for dealing with both quantitative and discrete degradation measurements in the SCS survey.

3 INTERPRETATION OF MEASUREMENTS

Even if the degradation were measured perfectly, there remain several interesting issues of interpretation in the use of the data. These include causality and circularity, interdependence and double counting, and an overall index of degradation. These issues are addressed in turn.

3.1 Causality and circularity

Problems of causality and circularity may arise with respect to the inclusion of sheet and rill erosion, wind erosion, acidity and soil structure decline as explanatory variables in a production function. This is because the measurement of these degradation types is based on land use and soil group factors. Both of these factors are major direct determinants of output, as well as having indirect influence through direct determinants of these degradation variables.

i.e	output is a function of	- land area - land use - soil characteristics - climate - labour - degradation
	degradation is a function of	- land use - soil characteristics

The relationship between agricultural output and degradation, as measured through regression analysis, provides a measure of association. Whether or not this is a causal association is a matter for judgement based on knowledge of the biophysical processes involved.

3.2 Interdependence and double counting

The similarity in the method of measurement of sheet and rill erosion, wind erosion, acidity and soil structure decline implies that the degree of relationship, or interdependence between these degradation types may be an important consideration when including two or more of them as individual variables in a production function. To test for interdependence, correlation coefficients were obtained between sheet and rill erosion, wind erosion, acidity and soil structure decline, using mean values for each of 113 LGA's. The matrix of Pearson Correlation Coefficients is shown below in Table 4.

The high correlations between sheet and rill erosion and wind erosion, sheet and rill erosion and soil structure decline, and wind erosion and soil structure decline suggests that these degradation types may be highly related to each other. There may therefore be double counting involved if two or more of these degradation types are included in a production function.

Table 4
Pearson Correlation Coefficient Matrix for sheet and rill erosion, wind erosion, acidity and soil structure decline.

Degradation Type	Degradation Type			
	Sheet and rill	Wind erosion	Acidity	Structure Decline
Sheet and rill	1.00	0.72	0.27	0.70
Wind erosion		1.00	0.32	0.89
Acidity			1.00	0.42
Structure decline				1.00

3.3 Derivation of an Overall Index

To obtain comparable estimates of opportunity cost between LGA's, an index of the overall level of degradation occurring within LGA's would be helpful. As well as the difficulty of creating a standardised value for each degradation type, the problem that arises is how to combine the relative changes in the values of various degradation types into a single index number that could meaningfully be interpreted as a measure of the overall degree of degradation. Three procedures to aggregate measurements on different scales were investigated, namely standardised, target and three-point scale procedures.

3.3.1 Standardised Index

A standardised index was developed by transforming the measurement of each degradation type from a 0 to n class, to a 0-1 scale to indicate the proportion of the highest class recorded for a particular degradation type.

$$SI_{kg} = \frac{1}{m_k n_g} \sum_{p=1}^{n} c_{pg} f_g \qquad (1)$$

where,

SI	=	Standardised Index for degradation type k in LGA g
c	=	Degradation class recorded at survey point p in LGA g
m	=	Highest possible degradation class for degradation type k

f = Frequency of recorded class in LGA g
n = Number of degradation survey points in LGA g

For example, Gunnedah Shire (104 survey points) has sheet and rill erosion recorded in the following classes (1=negligible erosion, to 5=severe erosion):

Class	1	2	3	4	5
Frequency	52	45	6	0	1

The standardised index for sheet and rill erosion would be calculated in the following way:

$$SI = \frac{1}{520}(1*52+2*45+3*6+4*0+5*1)$$
$$= 0.317$$

A combined standardised index (CSI) can then be obtained by calculating the sum of the values derived from Equation 1 for all ten degradation types.

$$CSI_g = \sum_{k=1}^{10} SI_k \qquad (2)$$

The minimum value of zero describes a LGA with no or negligible degradation. The maximum value of ten describes a LGA with all ten types of degradation occurring at severe levels. An increase in one unit of the standardised scale implies a ten percent increase in the overall severity of degradation, although it is difficult to estimate which type of degradation may be having the largest influence on the standardised value.

3.3.2 Target Index

Another method used was the target index, where a target value was set at the lowest level of degradation, with this being scored at 1. The observed levels of degradation classes were converted to proportions of the target level.

$$TI_{kg} = \frac{1}{n_g} \sum_{p=1}^{n} c_{pg} f_g \qquad (3)$$

where,

TI	=	Target Index for degradation type k and in LGA g
c	=	Degradation class recorded for survey point p and in LGA g
f	=	Frequency of recorded class in LGA g
n	=	Number of degradation survey points within LGA g

Using the same Gunnedah Shire data, the Target Index for sheet and rill erosion may be calculated in the following way:

$$TI = \frac{1}{104}(1*52+2*45+3*6+4*0+5*1)$$
$$= 1.586$$

As with the standardised index, a Combined Target Index (CTI) can be determined for each LGA.

$$CTI_g = \sum_{k=1}^{10} TI_k \qquad (4)$$

The minimum value of ten indicates that the ten degradation types all occur at the minimum 'target' level of one, indicating negligible degradation. A maximum value of 37 (the sum of the highest class value for each degradation type) describes a LGA where the highest levels of each degradation type have been recorded.

3.3.3 A Three Point Scale

A third approach was to develop a degradation index that was determined by standardising the existing range of measurements into a three-point scale of Low, Medium and High (Appendix I). If the majority of degradation measurement class scores fell within the 'Low' scale, then the average levels of degradation in the LGA were negligible. Scores occurring within the 'Medium' and 'High' scales represent moderate and severe levels of degradation, respectively. Using a scale of 1-3 sacrifices some precision for the four degradation types measured on a scale with more than three points. For example, gully is reduced from a 1-7 range to a 1-3 range, but this method may still provide a useful means of standardisation between degradation types. Having converted the degradation types to this scale, the transformed data could then be applied to the indexes described in the previous two sections. A target index derived from standardised data in a three-point scale may provide a more useful interpretation than the original data.

3.3.4 Interpretation of Indexes

The variety of ways in which the presence and levels of degradation can be interpreted and presented raises questions as to which of these index measurements provides the most satisfactory means of representing degradation in a production function. The standardised index focuses attention on maximum degradation levels, and involves considerable variation between degradation types that have different maximum values. The three point scale decreases the precision of a number of degradation types. For the purposes of this study, the target index, which has a bounded lower value of one, was chosen as a means of index derivation because the target of negligible degradation if often seen as a management objective.

The problem of circularity or causality potentially arises in the combination of the degradation types sheet and rill erosion, wind erosion, acid and soil structure decline into an overall index. As described in Section 3.1, degradation in each of these types was evaluated using similar attributes, with some of these attributes also being included in the production function models describing the output of a particular land use enterprise. One solution to this problem would be to develop an index that excluded all four, or three of these four variables, in order to provide a satisfactory overall description of level of degradation. Another solution would be to develop interactive variables, produced by multiplying two or more of the individual variables together.

4 OTHER DATA CONSIDERATIONS

At present, the project is restricted to examining the land degradation types measured in the SCS survey. This section examines other potential issues relating to land degradation and agricultural output, and considers the possibility of their inclusion in further analysis.

4.1 Feral and Native Animals

In some parts of NSW, both feral and native animals have the potential to cause large amounts of land degradation and subsequent losses to agricultural production. Soil loss and vegetation degradation due to overgrazing may be caused by rabbits, goats or kangaroos, particularly during times when competition between domestic livestock and these animals is greatest. Feral pigs have the potential to directly cause soil erosion by rooting up the ground if they are concentrated in large numbers.

Because of the transient nature of wildlife and population fluctuations, it is difficult to assess agricultural loss as a result of land degradation caused either directly or indirectly by these animals. Perhaps the most comprehensive survey of feral animals in NSW was by Tisdell (1982), who looked at the economic cost to agricultural output caused by feral pigs. Estimations of feral pig densities and distributions were made, providing the possibility of the inclusion of a proxy variable relating to the presence or absence of feral pigs throughout the state and their possible contribution to land degradation.

4.2 Loss of Biodiversity

Biodiversity refers to the variety of all life forms, and at the ecosystem level this includes habitats, biotic communities and ecological processes. It also refers to the diversity within landscapes and ecosystems in terms of habitat differences and the variety of ecological processes. The loss of biodiversity and animal habitats are rarely considered in the agricultural interpretation of land degradation. The relationship between agricultural output and biodiversity is a poorly understood one, mainly due to the difficulty of defining a variable that is an appropriate measure of biodiversity in all its dimensions.

The data available for this study provide no real estimates of biodiversity, but some proxy variables may be included to give an indication of the biological diversity of the agricultural system and its influence on farm output. The Australian Bureau of Statistics 1989/90 Agricultural Census collected data on the area of trees on each landholders property, as well as the area of native pasture. The SCS survey recorded tree regrowth simply as presence/absence, and Wells et. al (1984) have made an estimation of the area of trees remaining since European settlement for each LGA.

5 AN APPLICATION: IDENTIFYING EXTREMES OF DEGRADATION

By aggregating the SCS degradation survey data to the LGA level, it was possible to identify areas where extremes of existing degradation occur and identify regions or LGA's that may be potentially at risk of becoming more severely degraded, given current land use practices.

Table 5 lists the ten LGA's recording the highest values for sheet and rill erosion and gully erosion in terms of the mean class value and percentage of 'high' class values. It can be seen that there is a high level of consistency between the LGA's for the two types of measurement of a particular degradation type, with six being common for sheet and rill erosion and eight being common for gully erosion for the highest degradation. This consistency was found to be the case for all ten degradation types.

Having selected the target index as the most satisfactory method of calculating an overall level of degradation, the LGA's with the highest and lowest overall levels of degradation on this index were identified. The results are shown in Table 6 and Figure 1 and 2. The Central Murrumbidgee region displays high overall levels of degradation, with Yallaroi on the Northern Slopes being the only LGA recording high degradation levels outside this region. The North Coast shows low levels of degradation, with the notable exceptions to this trend being Hay and Windouran in the Central Murray/Lower Murrumbidgee region, and Greater Lithgow in the Central West.

These observations are limited in that they are restricted to the types of degradation measured in the SCS survey. Some sources of potential degradation, such as development pressures on coastal environments, or the effects of feral animals in arid and semi-arid regions of the state, are not included in these index measurements, yet may have a large influence on overall levels of degradation. The predominance of North Coast LGA's as the least degraded according to the Target Index measurement may be attributed to the large amount of forested areas that remain in this region, where mainly low degradation levels were recorded. Agricultural areas in the same region are however, extremely vulnerable to various types of degradation.

Table 5

Ten LGA's with highest mean class value and percentage of high class values for sheet and rill erosion and gully erosion

SHEET AND RILL EROSION			
LGA	Mean values (5 classes)	LGA	% High[a]
Cowra	2.29	Harden	22.86
Wellington	2.09	Cowra	16.95
Junee	2.07	Weddin	14.29
Cabbone	1.87	Parry	10.71
Coolamon	1.86	Junee	9.52
Weddin	1.84	Cabbone	8.40
Coolah	1.83	Tweed	8.33
Harden	1.80	Wellington	7.89
Cootamundra	1.80	Yass	7.81
Temora	1.77	Coolah	7.45

GULLY EROSION			
LGA	Mean values (7 classes)	LGA	% High[a]
Barraba	4.47	Barraba	69.49
Yallaroi	4.02	Yallaroi	47.22
Gunning	3.79	Murrurundi	40.82
Murrurundi	3.57	Inverell	39.02
Guyra	3.41	Guyra	37.65
Bingara	3.39	Bingara	35.71
Inverell	3.39	Gunning	34.88
Merriwa	3.33	Yass	32.81
Yass	3.31	Merriwa	31.34
Harden	3.11	Weddin	27.14

[a]The percentage of class measurements in the 'High' scale, as defined in Section 3.3.3.

Table 6

Ten LGA's with highest and lowest target index values.

LGA (Highest)	Target Index	LGA (Lowest)	Target Index
Junee	16.88	Port Stephens	10.43
Lockhart	16.87	Hay	10.47
Culcairn	16.65	Windouran	10.47
Harden	16.42	Maclean	10.47
Coolamon	16.18	Bellingen	10.48
Gunning	15.72	Coff's Harbour	10.50
Temora	15.64	Greater Lithgow	10.59
Corowa	15.59	Ulmarra	10.63
Yallaroi	15.44	Kempsey	10.63
Cootamundra	15.33	Hastings	10.71

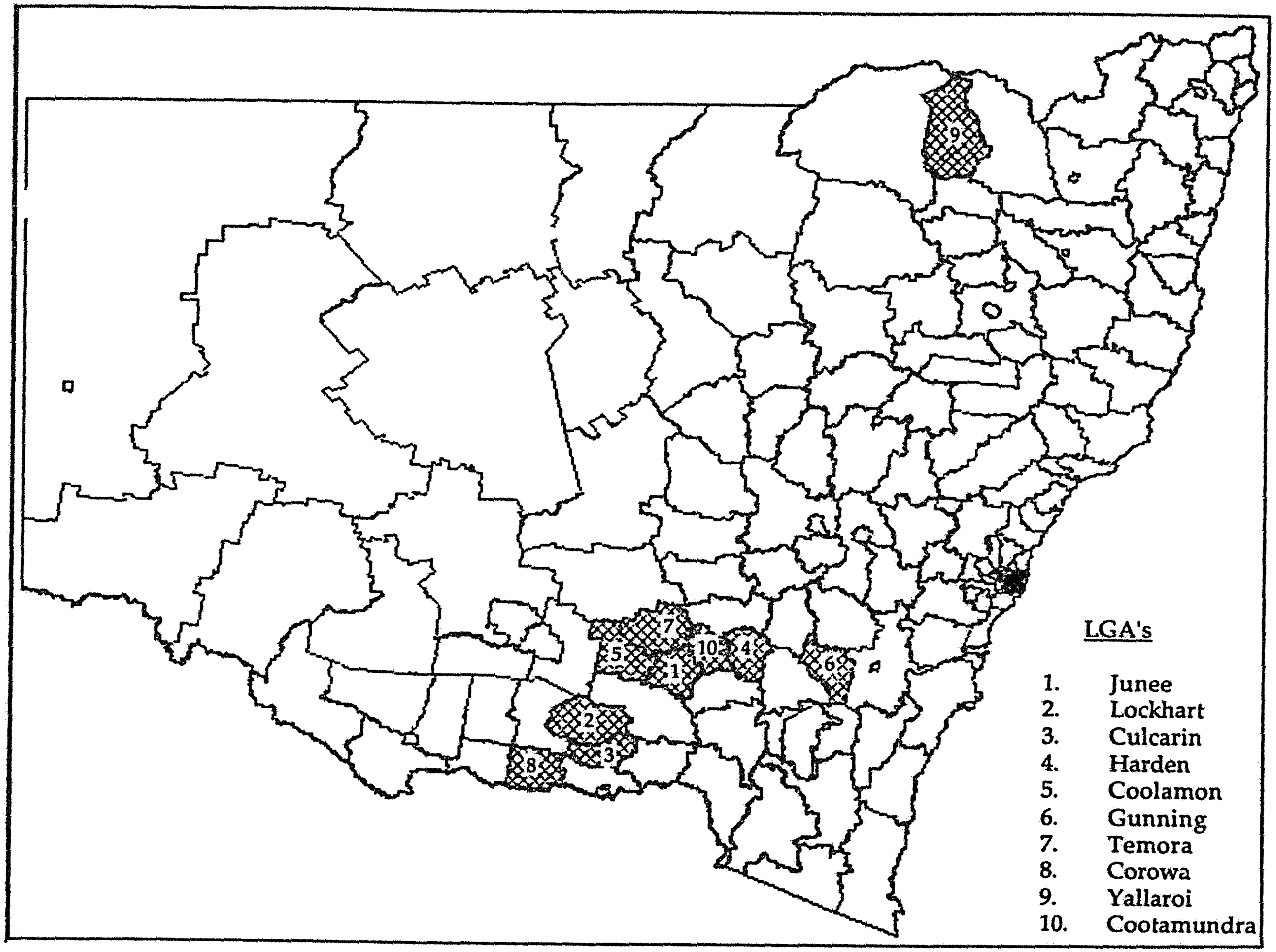

Figure 1 NSW Local Government Areas with the ten highest target index values.
Source: NSW Soil Conservation Service Research Station, Gunnedah.

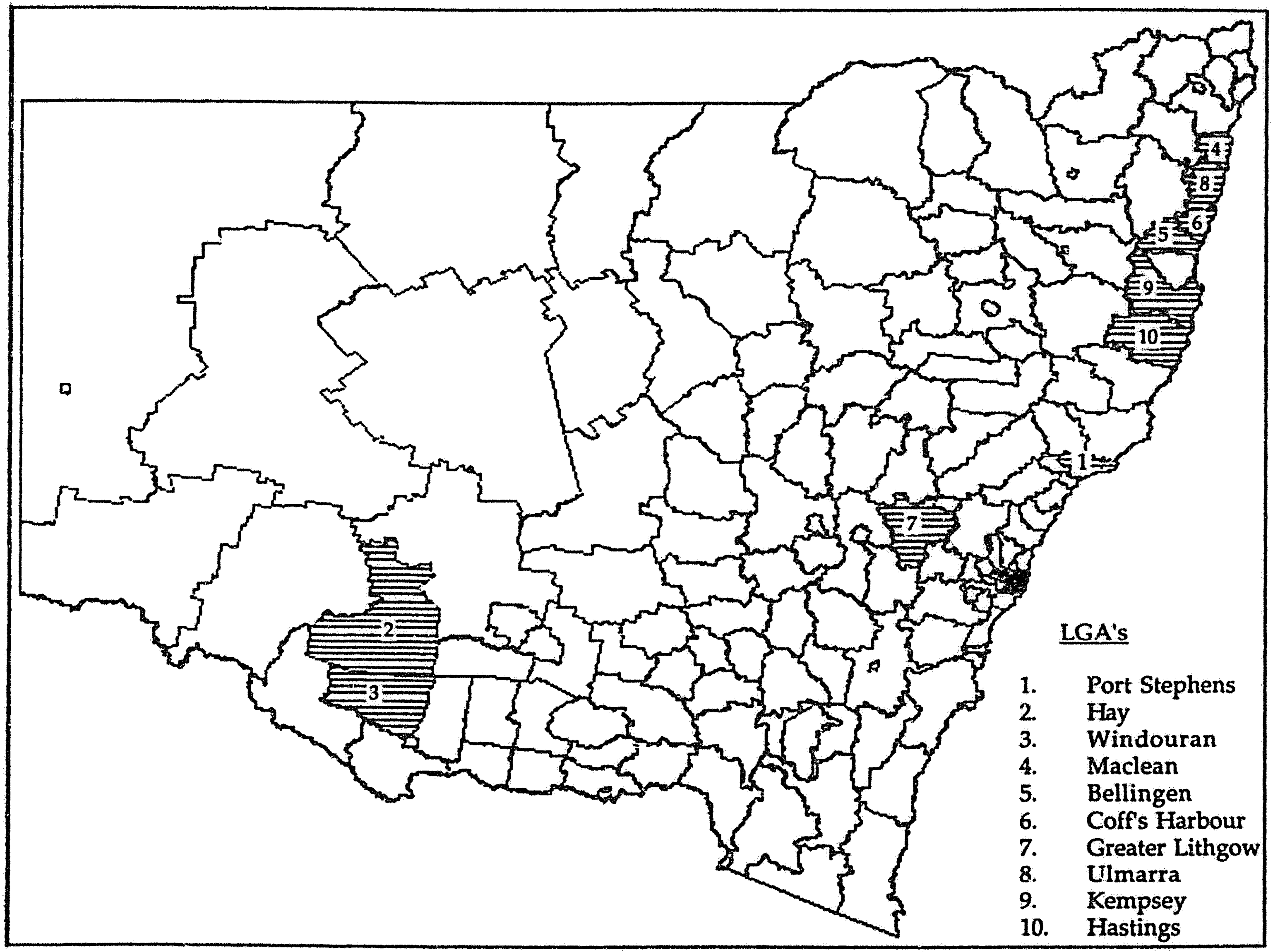

Figure 2 NSW Local Government Areas with the ten lowest target index value

Source: NSW Soil Conservation Service Research Station, Gunnedah.

6 DISCUSSION

There are many different types of land degradation, with the SCS (1989) providing the first set of consistent statewide measures. The basic question addressed in this paper is how best to use these data in the context of measuring the relationship between degradation and agricultural production. A number of possibilities have been reviewed as alternative means of expressing the data in a form suitable for inclusion in a production function:

(a) It is necessary to combine the data from each sample point into an observation descriptive of the distribution of data representing a complete LGA. The relative merits of the statistical measurements of minimum, maximum, median, mode, mean and standard deviation were discussed, and it was concluded that due to the presence of both actual degradation measurements such as tonnes of soil loss, and ordinal ranked measurements, the mean would be the most useful way to provide meaningful representations of the data.

(b) For some purposes it may be useful to have an overall estimate of the severity of degradation at a particular point or in a particular LGA. Various methods of constructing a degradation index were discussed and it was concluded that a target index, with its bounded lower value of one provides a useful standardised description of all the degradation types measured. The potential problems involved with combining degradation variables must be considered when using this index.

(c) By ranking LGA's in terms of highest recorded levels for a particular degradation type, it was found that there was a high level of consistency between different measurements of degradation when identifying these extreme levels. This suggests that measurement of individual degradation types by any acceptable method may be satisfactory.

The distribution and severity of land degradation throughout the state varies greatly between different degradation types. Subsequently, the level to which these types of degradation affect agricultural output may also vary considerably. The inclusion of a land degradation factor in an agricultural production function may be in the form of one or more individual land degradation types, or as an index that describes overall levels of degradation.

The choice of one or more individual degradation types for inclusion in a particular model may relate to the distribution of the degradation or the particular land use being examined.

Having examined the application of land degradation data, as measured by the SCS, this data has now been incorporated by Sinden and Yapp (1992) into production functions to express agricultural production as a function of the quality of the land, as well as the quantity of land, labour and capital. Individual and interactive degradation variables have been used, as well as an overall degradation index.

LITERATURE

Graham, O.P. (1989) Land Degradation Survey of New South Wales 1987-88: Methodology. Soil Conservation Service Technical Report No. 7.

Karmel, P.H. (1959) Applied Statistics for Economists. Sir Isaac Pitman & Sons, Ltd., Melbourne.

Sinden, J.A. and Yapp, T.P. (1992) Estimation of the Opportunity Costs to Agriculture of Land Degradation, Paper presented to the 36th Australian Agricultural Economics Society Conference, Canberra, February 1992.

Soil Conservation Service of New South Wales (1989) Land Degradation Survey N w South Wales 1987-88. Soil Conservation Service, Sydney.

Tisdell, C. (1982) Wild Pigs: Environmental Pest or Economic Resource? Pergamon Press, Sydney.

Wells, K.F., Wood, N.H. and Laut, P. (1984) Loss of Forests and Woodlands in Australia: A Summary by State, Based on Rural Local Government Areas. CSIRO Technical Memorandum 84/4, Canberra.

APPENDIX ONE

LOW, MEDIUM AND HIGH CLASS DIVISIONS

	Class Division		
Degradation type	Low (no appreciable levels of degradation)	Medium (moderate levels of degradation)	High (severe levels of degradation)
Sheet and rill	1	2,3	4,5
Gully	1	2,3,4	5,6,7
Mass movement	1	-	2
Wind erosion	1	2,3	4
Dryland salinity	1	2	3
Irrigation salinity	1	2	3
Scalding	1	2	3
Acidity	1	2	3
Structure decline	1	2	3
Woody shrubs	1	2,3	4
Tonnes of soil loss	< 1 t/ha	1-10 t/ha	> 10 t/ha
Length of gully	< 10 m/100ha	10-1000 m/100ha	>10000 m/100ha