LAND DEGRADATION AND THE AUSTRALIAN AGRICULTURAL INDUSTRY

Paul Gretton

Umme Salma

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Enquiries

Paul Gretton
Industry Commission
PO Box 80
BELCONNEN ACT 2616

Phone: (06) 240 3252
Email: paul_gretton@mail.indcom.gov.au

The views expressed in this paper do not necessarily reflect those of the Industry Commission.

Forming the Productivity Commission

The Federal Government, as part of its broader microeconomic reform agenda, is merging the Bureau of Industry Economics, the Economic Planning Advisory Commission and the Industry Commission to form the Productivity Commission. The three agencies are now co-located in the Treasury portfolio and amalgamation has begun on an administrative basis.

While appropriate arrangements are being finalised, the work program of each of the agencies will continue. The relevant legislation will be introduced soon. This report has been produced by the Industry Commission.

CONTENTS

Boxes

Tables

Figures

ABBREVIATIONS

na	not available
kg/ha	kilograms per hectare
..	nil or less than 0.5
0	small value rounded to zero in tables
AAGIS	Australian Agricultural and Grazing Industries Survey
ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
ANCA	Australian Nature Conservation Agency
APEC	Asia Pacific Economic Cooperation
BRS	Bureau of Resource Sciences
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ELZ	Extensive Landuse Zone
ESD	Ecologically Sustainable Development
FAO	Food and Agricultural Organisation
GIS	Geographic Information System(s)
IBRA	Interim Biogeographic Regionalisation of Australia
IC	Industry Commission
ILZ	Intensive Landuse Zone
IMF	International Monetary Fund
IUCN	International Union for Conservation of Natural Resources
NAFTA	North Atlantic Free Trade Agreement
NRIC	National Resource Information Centre
NRSCP	National Reserve System Conservation Plan
NSW	New South Wales
OECD	Organisation for Economic Cooperation and Development
R&D	Research and Development
RDC	Rural research and development corporation/council
SCS	Soil Conservation Service
SLA	Statistical Local Area
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
UNESCO	United nations Education, Science and Cultural Organisation
WWF	World Wildlife Fund

PREFACE

The Industry Commission has a statutory obligation to report on the performance of Australian industry. Management of land for agricultural and pastoral purposes on a sustainable basis is essential for the ongoing development of that sector.

For development and environmental issues to be adequately considered, a broad framework needs to be adopted and necessary information of both an ecological and economic nature needs to be gathered and analysed.

As part of its reporting process, this staff paper has drawn together certain information and has used a pilot study of New South Wales agriculture as a start to the very substantial task of understanding the relationship between agricultural production and land degradation.

The Commission intends this discussion paper to bring together information about agriculture and land degradation from a wide range of sources and in doing so it is intended that it contributes to the development of a broad policy framework for a sustainable agricultural sector. The Commission seeks comments on the content of the paper, errors and ommissions.

The authors would like to acknowledge the assistance received from colleagues in the preparation of the study. Outside the Commission, John Robertson of the Department of Statistics at the Australian National University provided a technical review on the New South Wales pilot study (see Appendix F) and Warren Musgrave of the New South Wales Premier's Department gave general support. Numerous other people provided information and studies. Any remaining errors are the responsibility of the authors.

OVERVIEW

The management of land degradation and its effects on environmental quality are important challenges. How the community responds to these challenges will affect the well being of all Australians both now and into the future. There are many causes of land degradation resulting from human activities, including the production of food and fibres by the agricultural sector.

This study explores the relationships between agricultural production, profitability and land degradation, and some of the broad issues that affect land management. In particular, it discusses the concept of ecologically sustainable development, the link between bio-physical and economic processes, information on the extent of land degradation, and the costs and benefits of degradation and repair. An experimental analysis of New South Wales agriculture is provided using a state-wide model developed in the Commission.

The agricultural industry and management of land

The agricultural sector is constrained in its capacity to increase supply and to influence demand. The supply of land suitable for agricultural activities is limited and its availability for agriculture comes under pressure from alternative uses. At the same time, the agricultural sector predominantly produces standard commodities (often traded on world markets) with individual producers having virtually no control over the prices that they receive for their output, nor the prices paid for their off-farm inputs to production.

The agricultural sector has experienced a systematic decline in its terms of trade over the last 40 years. To the extent that expectations about future prices have been based on the continuation of past trends alone, the incentives facing individual farmers would seem to have favoured early exploitation of the land resource in order to take advantage of relatively higher prices. However, past price trends are only part of the picture. Innovation to lower the unit cost of output, the expectation of a more favourable price outlook in the future, and the opportunity to vary farm outputs to take advantage of more profitable farming options, improve the economic incentives for land holders to preserve land resources for future agricultural use.

In practice, productivity growth has steadily improved with support from industry and government sponsored research and development, and with experience gained through farming Australian land. Over the last 20 years, agricultural sector growth has been sustained by more intensive use of existing farmland and by higher productivity. Opportunities for growth in agricultural output will continue. The positive links between rural research, development, farmer experience and productivity indicate the potential for further growth in output from supply-side changes.

On the demand side, there are population, income and policy induced changes that are likely to place upward pressure on the demand for Australian agricultural outputs in the longer term. These will come from increasing food needs in Australia and elsewhere (through exports) as populations increase and incomes rise. Australian agriculture is also likely to benefit as international trade liberalisation is extended. Commission estimates suggest that Australian agricultural output could expand by 5 per cent with the implementation of the Uruguay Round of trade negotiations and a further 12 per cent under the APEC free trade agenda.

Agricultural land use, along with other human activities, imposes pressures on the environment as land resources are increasingly used in production and consumption and as wastes are released. The management of those pressures involves both public and private spending and effort to conserve the environment for future use. Information is now becoming available concerning the level and purpose of environmental expenditure in Australia. ABS estimates of public and private environmental expenditures in 1991–92 suggest a nation-wide total for that year of at least $5.2 billion. Of this total, soil conservation and land management activities of the public sector amounted to $198 million. A substantial part of this spending is directed at agricultural resource management and support services. Measured private sector environmental spending by the agriculture sector amounted to $285 million, that is, about 2 per cent of the value of agricultural production. The management of land to conserve resources, however, does not imply that land degradation will not occur. Indeed some land degradation occurs naturally, that is, without human use or interferance.

Sustainability and land degradation

Available evidence suggests that land degradation in Australia is substantial. The forms of degradation vary widely and include: changing soil mineralisation, such as salinity and acidity; soil structure decline and erosion caused by water and wind; and biological changes such as plant and animal invasion, tree decline and the clearance of native vegetation.

Several of the most prominent forms of degradation such as soil structure decline and induced soil acidity are site specific and reversible. The initial effects of these forms of degradation occurs at the individual farm level with few spillovers to adjacent properties and areas. Other forms of degradation such as dryland and irrigation salinity relate to catchment or biogeographic regions and can be classed as reversible, too. In other cases such as loss of top soil, and loss of native habitats, flora and fauna, the natural repair periods are so long that for practical purposes, damage arising from human activities could be deemed as permanent.

An important question for sustainability is: will the generation of current income lead to a permanent reduction in national productivity and will essential life support systems be threatened? If degradation is irreversible — or if it can only be reversed at an uneconomic cost — those land uses dependent on the availability of non-degraded land are not sustainable without technological change.

Because the effects of degradation cannot always be confined to individual holdings, land degradation and its repair cannot be treated solely as a problem for individual farmers. They may not see the full social costs of degradation and may not be able to appropriate the full social benefits of conservation efforts.

Economic effects of land degradation

Land degradation involves reductions in the productivity of affected lands. The reduction in productivity — estimated as the decline from value of production obtainable with current land uses had there been no degradation — provides a measure of the *production equivalent* of degradation. A recent Prime Ministerial statement put the production equivalent of degradation at around 6 per cent of agricultural production or around $1.5 billion (in 1994–95 values) each year.

Production equivalent measures, so defined, are static and are compiled using restrictive assumptions that ignore accumulated net benefits to the community of past agricultural production and the productivity of farming activities operating in localities where degradation occurs. In addition, production equivalents do not take into account the fact that some degradation is likely to occur as farming systems become more specialised and land productivity is improved (eg irrigation farming and irrigation salinity) while other forms occur as unintended side effects of previous conservation efforts (eg improved pastures and induced acidity). For these reasons, the production equivalent measure is not a true reflection of the current cost of degradation. Nevertheless, it does clearly indicate that the usefulness of some elements of the landscape is substantially reduced by degradation.

Another approach to evaluating the impact of degradation on farming activity is to consider the costs of repairing or avoiding degradation and the benefits available from conservation programs. Available cost-benefit studies indicate that for irrigation and dryland salinity in some badly affected areas net benefits could be obtained by public- and farm-based programs to repair the degradation, given plausible discount rates and project planning horizons. Nevertheless, using the same assumptions, the studies do not always imply that eliminating the degradation is the most profitable course of action. Sometimes the highest returns can be obtained by slowing the rate of spread rather than halting or reversing the degradation and sometimes even by allowing degradation to increase. In addition, the costs of degradation can be substantially reduced by moving in favour of farming activities that minimise the adverse effects on farm profitability of the prevailing forms of degradation.

In other cases, the technology to repair degradation may be available, but only some agricultural activities generate the farm income to support conservation activities. For example, induced soil acidity can normally be lowered, and the productivity of the land increased, by the application of lime. This treatment is costly to the farmer and the feasibility of conservation expenditure depends on sufficiently increased returns per hectare to justify the liming expense.

Available cost-benefit studies are concerned with particular products or regions. They possibly exclude farming options that may be more profitable given prevailing discount rates and project planning horizons, but which are associated with even higher levels of degradation.

To make a start towards establishing a comprehensive empirical analysis of degradation, the Commission developed a state-wide model of New South Wales agriculture incorporating land degradation. The study focused on the effects of four forms of degradation: irrigation salinity, dryland salinity, soil structure decline, and induced soil acidity. The analysis represents a snapshot of New South Wales agriculture with the findings determined by prevailing levels of degradation and current farming systems. The model implicitly takes account of the opportunity costs to individual farmers of additional degradation. Within its framework, farmers are treated as choosing between activities that yield higher production and degradation in the current period with lower production in the future, and activities that yield lower production and degradation now to obtain higher production in the future.

The analysis tentatively indicates that there are incentives for individual farmers to move away from farming activities that induce higher levels of soil acidity or soil structure decline (indeed, available evidence suggests that new techniques are being adopted to ameliorate the effects of these forms of degradation). The apparent driving force behind this result is that these forms of degradation affect whole cultivated areas, reducing the productivity of the entire area. On the other hand, there appear to be positive incentives for farmers in New South

Wales to move towards activities associated with irrigation and dryland salinity. The driving force behind these results, is that these forms of degradation severely affect individual locations in otherwise productive farming areas. Farmers are willing to sacrifice those locations as part of a generally productive farming activity.

The constraining factor on the extension of farming systems subject to irrigation and dryland salinity may well be the availability of water for irrigation and of land typically subject to dryland salinity, rather than the adverse effects of these forms of degradation as such.

Because these results are based on a current snapshot of New South Wales, they do not take into account the dynamic effects of technological change and other sources of productivity improvement. Technological change and better land management may be able to improve farm productivity and profitability in all areas subject to degradation.

Summing up

The management of environmental expenditures and conservation effort is not a straightforward task. It is difficult even when measures of the usefulness of land resources and degradation can be expressed in financial terms or agricultural sector outcomes as in the above studies. It is made more difficult when some of the outcomes are non-market, such as, the effects of farming on the functioning of traditional ecological systems which are not easily factored into quantitative analyses. In assessments of the nature and role of government in agricultural land management as opposed to the role of individual farmers, there is a need to consider the property rights of farmers over land resources subject to degradation, and the trade-offs that occur between non-market land management objectives and agricultural sector productivity and profitability. There is also a need to consider impediments faced by individual farmers to ecologically sustainable agricultural land management imposed by government regulations, and other institutional arrangements.

With market-based outcomes, assessments of land degradation need to consider farm productivity, production and income with prevailing levels of degradation, the likely prospects of alternative farming activities given expected prices and technological developments, the effect these activities are likely to have on the future condition of the land, and the costs and benefits of reclaiming degraded land. To provide a community-wide perspective of the social benefits of higher farm productivity, it is also necessary to consider the external effects of the degradation on other farmers and the community generally, alternative land uses, and the time horizon over which the costs and benefits should be evaluated.

The Commission’s modelling effort has made tentative steps towards an appraisal of agricultural land degradation and farm profitability. There is a need for further research into the relationships between agricultural land degradation, farm productivity and profitability for the states and Australia. To support economy-wide assessments that are firmly based on the current activities and decisions of farmers in agricultural regions, there is also a need to improve the availability of information on land degradation and the environment, and develop links between that information and data about farm activities and decisions.

PART 1 REPORT

CHAPTER 1
INTRODUCTION

Land degradation can occur for many reasons associated with human activities. This study focuses on land degradation related to agricultural production and profitability. There are many causes of land degradation resulting from the use of land resources in agricultural production alone. Fundamental factors determining the nature and extent of degradation are the bio-physical characteristics of the land, economic imperatives and awareness of the full impact of farming practices.

Managing agriculture within the philosophy established by the National Strategy for Ecologically Sustainable Development, requires knowledge of the land degradation process, the current state of land resources and establishing a way to relate possible future degradation to management decisions.

This information paper draws together certain information and analyses as a tentative step towards understanding some of the issues faced by the agricultural sector in its management of land. It is structured as follows. Chapter 2 provides an overview of the agricultural sector and broad issues that affect land management. Chapter 3 discusses the concept of ecologically sustainable development, the definition of land degradation and the link between bio-physical and economic processes of land degradation. In Chapter 4, information about the extent of degradation, the costs and benefits of amelioration and an experimental state-wide model for New South Wales agriculture incorporating land degradation are provided and discussed.

The scope of the study has been limited. For example, it has not examined in detail levels of government support and assistance to the agricultural industry and how this has affected or could affect land use and degradation. The study also has not examined the many institutional arrangements that have been established for managing the land (such as catchment plans). Such matters and others will affect the level and incidence of degradation and the sustainability of agriculture in the Australian economy.

CHAPTER 2
AGRICULTURE AND THE MANAGEMENT OF LAND

2.1 Introduction

Land if left to degrade with agricultural use, would inevitably become unproductive for that use. The effect of declining productivity of existing agricultural land is pressure to change land management practices in order to reverse this trend where feasible, or to replace degraded land by clearing and bringing into production previously unfarmed land.

Each individual producer can have a significant effect on the use and condition of their land but each has little or no effect on the prices of their products. The agricultural sector predominantly produces standard commodities (often traded on world markets) with individual producers having virtually no control over the prices that they receive for their output nor the prices paid for their off-farm inputs to production.

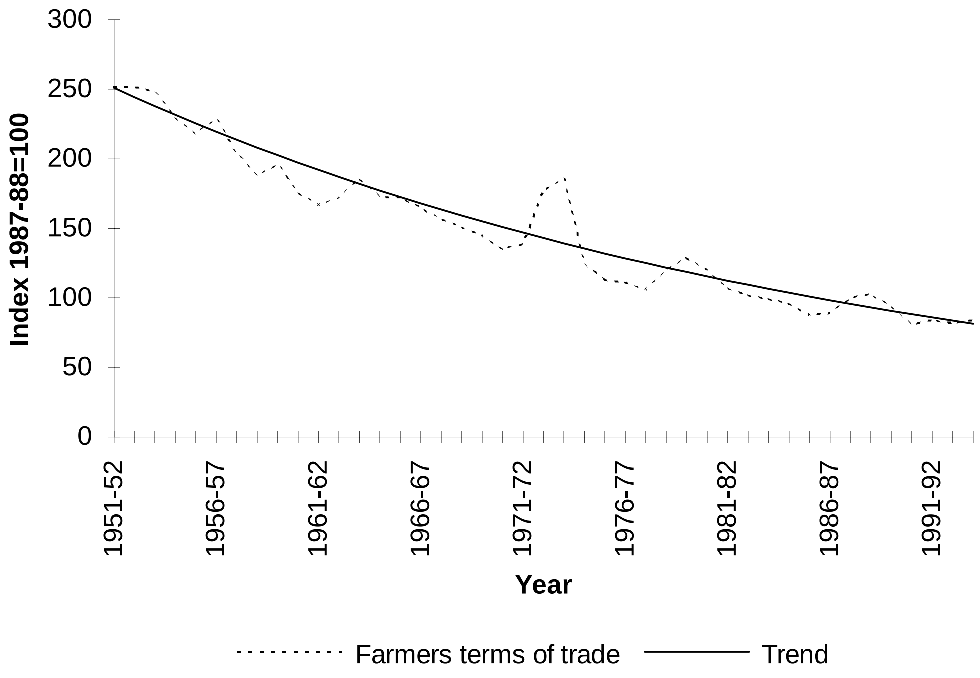
This chapter presents a general picture of the broad economic environment in which the agricultural sector operates. This provides a backdrop against which specific information about land degradation can be developed. The chapter looks at the terms of trade of the agricultural sector, contributions to growth in agriculture and the links between rural research and development (R&D) and industry growth, Commonwealth budgetary outlays to industry, and environmental spending by government and industry.

2.2 Farmers' terms of trade

One of the most fundamental factors governing the economic environment in which farmers operate is the prices that they receive for their outputs relative to the prices that they pay for their farm inputs — that is, the farmers' terms of trade. For the Australian rural industry, the terms of trade have declined over the past 40 years at an average annual rate of 2 per cent per annum around a series of erratic year to year changes (see Figure 2.1).

Without innovation to lower the unit cost of output or the expectation of increasing prices, other things being equal, the trend in relative prices would have provided a poor economic incentive for land holders to preserve the land for future agricultural use. Under these conditions, farmers would have an incentive to take whatever profits they could in the short-term, hoping to sell the property and invest in a business which is likely to be more profitable in the longer term. However, the market price of land should, all other things being equal, reflect its future earning capacity which in turn should reflect its future productivity (albeit not necessarily in agriculture). Consequently, a decision to ‘mine’ the land needs to be viewed as a trade-off between gaining current income and maintaining the longer-term value of land resources as productive assets. In the scenario of increasing land degradation, new sources of growth in agricultural output would need to come from the progressive employment and exhaustion of vacant land. Because the area of land suitable for the various forms of agriculture practiced in Australia is finite and there are other demands on the use of some of that land (eg mining, industry and metropolitan use), such a strategy would not provide for sustainable agriculture without changes in technology.

Figure 2.1: **Farmers’ terms of trade, 1951–52 to 1993–94**



Source: ABARE (1994).

2.3 Trends in farm sector growth

Over the period 1959–60 to 1989–90, the average annual growth in the value of farm product measured in constant dollars was around 2.3 per cent. A number of factors have contributed to the growth of the agricultural sector.

From the time of European settlement, there has been a progressive increase in the area committed to crops and sown pastureland, with the share of pastureland steadily increasing (see Figure 2.2a). Very little sown pastureland was available for agricultural use before 1900, indicating that the main source of food for grazing came from native pasture. From the turn of the century, the area of sown pasture progressively increased with some of the sharpest increases occurring during the 1950s and 1960s. In recent times, the rate of growth has declined.

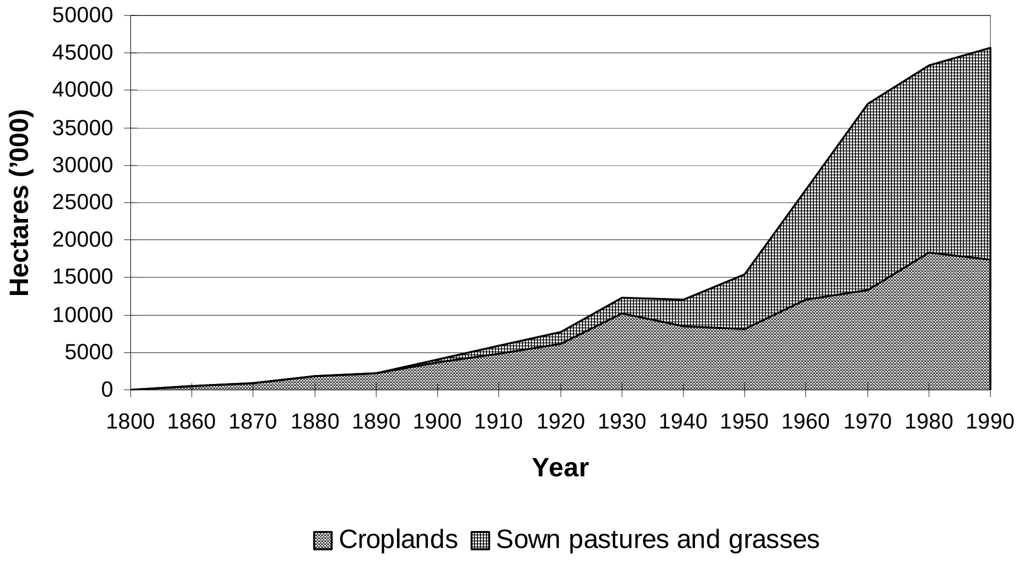
The trend towards increasing the intensity of land use is also evidenced by the fact that even though the total area of agricultural land actually declined during the 1970s and 1980s, the area committed to crops and sown pastures continued to increase (see Figure 2.2b).

Technology and land management practices contribute to the productive potential of agricultural land. For example, in a study of wheat yields in Australia since 1870, Hamblin and Kyneur (1993) have shown that, after an initial period of nutrient exhaustion, changes in land management practices have facilitated a progressive increase in average wheat yields since the turn of the century (see Figure 2.3). The study shows that productivity gains have come from the substitution of human technologies for naturally occurring low yielding processes. It illustrates in a practical way, that managing such substitution is a key element on the ongoing development of the agricultural sector.

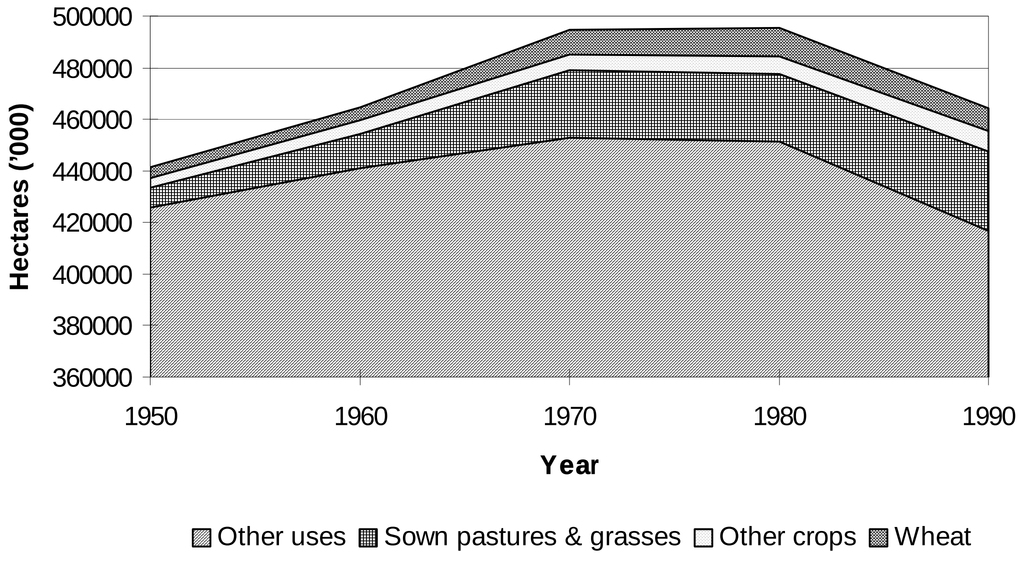
The analysis also illustrates that there are no standard relationships between the duration of productivity decline and subsequent productivity improvements. For example, the estimated wheat yield declined 370 kg/ha per annum over the 30 year period 1870 to 1900 and needed 50 to 60 years of productivity improvements to regain the initial yield levels (ie 860 kg/ha per annum). However, a further productivity gain of a similar magnitude was attained over the 1950s and 1960s (ie approximately two decades).

Figure 2.2: **Deployment of land for agricultural uses**
(thousand hectares)

(a) Historical time series of the area committed to crop and pastureland

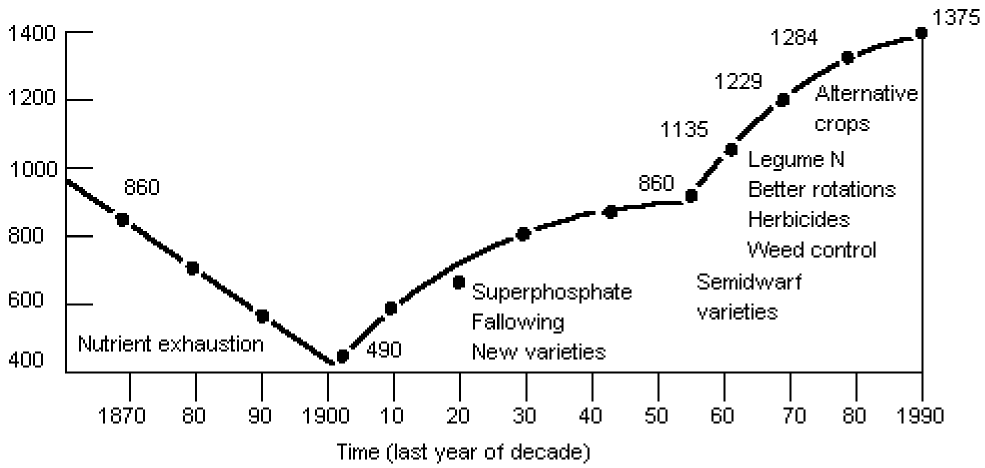


(b) Recent trends in the area of agricultural land and area committed to specified uses



Sources: ABARE (1994), Bullen (1995).

Figure 2.3: **Trends in average wheat yields since 1870**
(mean decennial yield: kilograms per hectare per year)[ab]



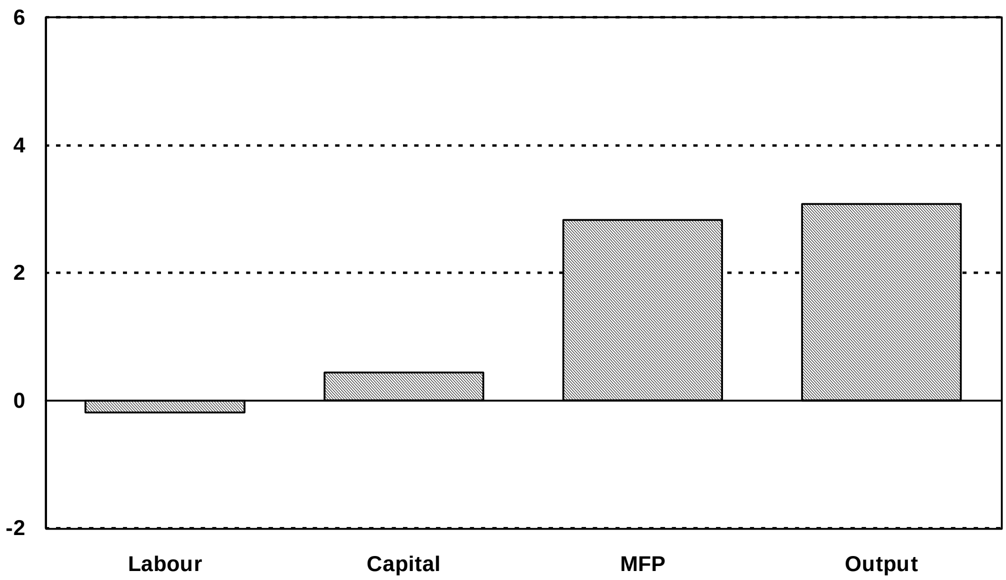
a The estimates shown relate to the average yield over the decade ending in the years shown.
b The analysis is based on average yields over the 140 year observation period. As wheat production commenced in some of the higher yielding areas and has progressively expanded into lower yielding areas, the estimates of productivity growth understate the productivity gains obtained in individual regions from changes in technology and improved land management.
Source: Hamblin and Kyneur (1993).

In interpreting the trends, it should be noted that the estimates are national averages and while they depict a pattern of national growth in yields, there is considerable underlying variation between regions. For example, the study found that yields have risen more slowly in the drier inland regions where pastures and crops are more difficult to establish and maintain. Even with technological improvements, yield declines were still experienced over the 1980s in areas such as the south-east mallee in south-western New South Wales, north-western Victoria and north-eastern South Australia, the Eyre Peninsula, and the Wimmera. The regions which showed yield growth acceleration over the 1980s adopted improved land management practices such as the incorporation of grain legumes into wheat rotations and the use of nitrogenous fertilisers. These same practices that provided a source of productivity growth, are now being recognised as sowing the seeds for future productivity declines through induced soil acidity (see Appendix A).

The large variation in wheat yields between regions indicates that an expansion of cropping areas would not necessarily provide a proportional increase in production. This is particularly so if new cropping areas are drawn from marginal lands that were unattractive to farming in earlier times.

The myriad of technological and land use changes that pertain to individual commodities and regions can be drawn together at the sector-wide level to show the contribution of productivity and other factors to growth. According to Commission growth accounting estimates for the period 1975–76 to 1993–94, improvements in agricultural sector productivity have been the main contributor to output growth (Figure 2.4). Also, as the sector has moved toward more capital intensive techniques, growth in capital inputs have also made a positive contribution to output, while labour inputs have declined.

Figure 2.4: **Contributions to average annual growth in real output by the agriculture, forestry, fishing and hunting sector,[a] 1974–75 to 1993–94** (percentage points)



MFP Multi-factor productivity.
a Labour is measured by total hours worked.
b Multi-factor productivity is estimated by subtracting from output growth the contributions due to labour and capital.
Source: Based on ABS Cat. No's. 5204.0 and 5221.0 and unpublished data.

To look behind productivity growth estimated as part of growth accounting exercises, the Commission undertook an examination of the relationship between productivity growth and possible causal factors in its recent inquiry into Research and Development (IC 1995). This analysis was undertaken for the broadacre agriculture component of the agricultural sector[1] and comparative analyses were undertaken for other sectors in the economy. The analysis covered the period 1974–75 to 1992–93.

The study found that such things as ‘learning by doing’ and farmer experience, public infrastructure, education attainment in the community generally, and expenditure on R&D produced a positive effect on productivity growth in the broadacre agriculture industry. With respect to R&D expenditures, the study found that the agricultural sector differs from other industry sectors (eg mining and manufacturing) in that there are very low levels of internally generated R&D.[2] Nevertheless, the rural R&D corporations and councils which sponsor R&D for the benefit of the agricultural sector are partly funded by industry contributions with the remaining funding coming from government contributions. To a substantial degree the R&D sponsored by these organisations is undertaken by public sector researchers, such as the CSIRO and state departments of agriculture. The estimates indicate, amongst other things, that the broadacre agriculture sector benefits from R&D undertaken by other business enterprises, public R&D (including rural R&D corporations) and foreign R&D. When converted to real rates of return to R&D, the estimates imply returns of 6.3 per cent, 7.1 per cent and 1.9 per cent, respectively (IC 1995, p. QB.33).

This analysis indicates that productivity growth, which has been the main source of output growth for the agricultural sector is, to a substantial degree, within the control of agricultural land managers and the community generally.

2.4 Sources of increased demand for agricultural outputs

Management of land degradation also needs to be viewed from the perspective that demand for Australian agricultural outputs will continue to grow. While it is not possible to give an exact forecast of future growth in output, there are identifiable changes (some policy induced) that are likely to place upward pressure on the demand for Australian agricultural products.

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1 Including the wheat and other crops, mixed livestock and crops, sheep, beef, and sheep-beef industries. All five industries are covered by ABARE’s Australian Agricultural and Grazing Industries Survey (AAGIS). ABARE has calculated total factor productivity for broadacre agriculture from data collected in AAGIS. One explanatory variable used in the analysis of this productivity variable is ABARE’s pasture growth index. This is based on the broadacre AAGIS regions and is a measure of productivity for these regions.

2 The ABS survey of business enterprise R&D excludes enterprises mainly engaged in agriculture, forestry, fishing and hunting partly because of collection difficulties and partly because the enterprises are believed to have very low R&D activity.

All things being equal, there are likely increases in demand due to the food needs of Australian and foreign residents (through exports) as the population of Australia and other countries increases and as incomes grow world-wide.

Australian agricultural producers are also likely to benefit as international trade liberalisation is extended to this sector. It is generally accepted that trade liberalisation would tend to raise the average world prices of agricultural and food products, as export and production subsidies afforded these products in many countries are scaled down or removed. Australia, with an export oriented and relatively lowly assisted agricultural and food processing sector, would expect to see an increase in demand from these international developments. For example:

- simulations of the effects on Australia's economy of implementation of the Uruguay Round suggest agricultural output could expand by 5.5 per cent and exports by 7.6 per cent (IC 1994). Subsequent annual growth in agricultural output and export would then continue from the post-Uruguay round output and production bases; and
- simulation of the impact of the implementation of Asia Pacific Economic Cooperation free trade commitments (under the principle of comprehensiveness confirmed at the Osaka 1995 meeting of APEC members) suggests that Australian agricultural output could expand 12.3 per cent against a benchmark established after the impact of the Uruguay Round and the North Atlantic Free Trade Agreement (Dee *et al.* 1996). The analysis showed that the liberalisation of agriculture would be the main force behind gains from the liberalisation of merchandise trade, contributing 60 per cent of total gains worldwide.

The Uruguay Round was completed in December 1993 and the agreed liberalisation processes are to be implemented by developed countries by 2001. Currently, liberalisation under the auspices of APEC agreements is to be implemented by 2010 for developed countries and 2020 for developing countries. The simulated changes in output are longer-run changes that would occur progressively from the time of policy implementation.

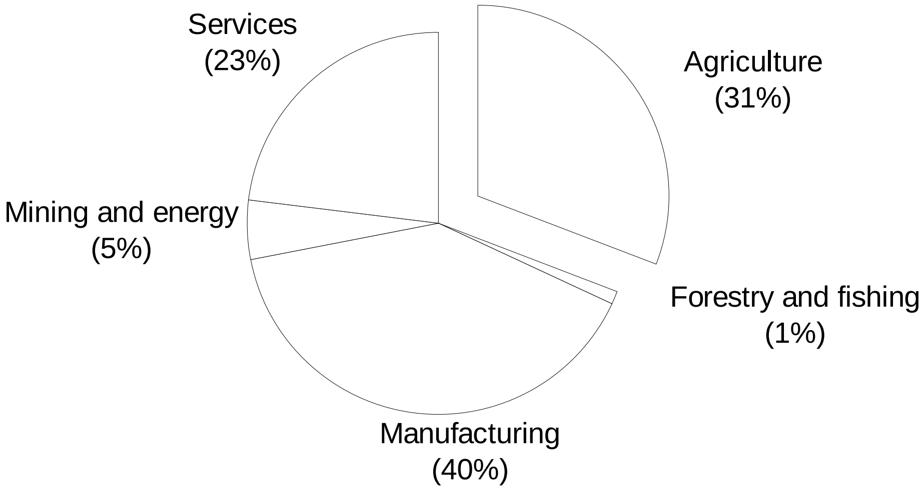
Thus, the management of agricultural land in Australia will be undertaken for the foreseeable future in an environment of increasing demands for agricultural outputs from the Australian industry.

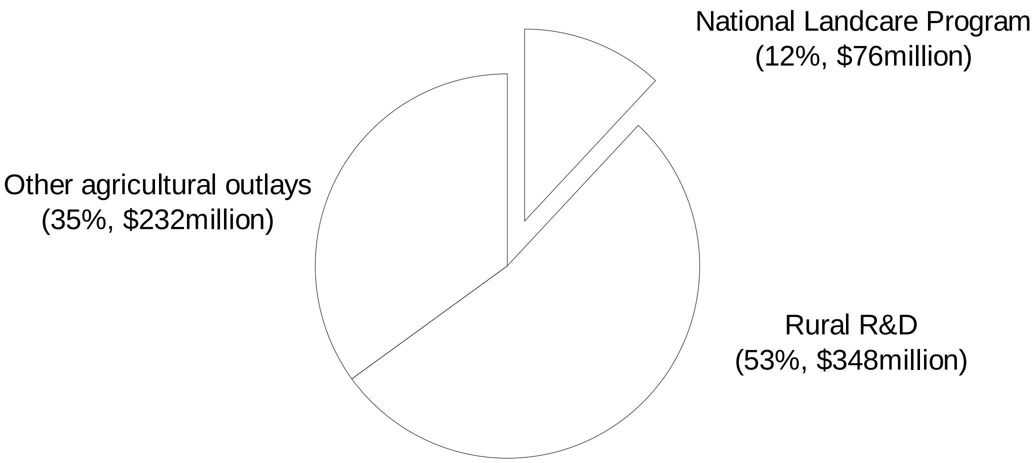
2.5 Government expenditures on agriculture and agricultural land management

The operation and growth of the agricultural industry is supported by a substantial level of government involvement. The agricultural sector received about 31 per cent of Commonwealth Government outlays to industry in 1994–95 (ie around $650 million) (see Figure 2.5). Of the total support for agriculture, 12 per cent ($76 million) was allocated directly to the National Land Care Program. More than half of the expenditure was allocated to rural R&D ($348 million) and is managed mainly through grants awarded through the rural R&D corporations and direct funding to the Commonwealth Scientific and Industrial Research Organisation.

A Commission survey has also estimated that state expenditure benefiting the rural sector would be at least $592 million (see 1990–91 estimate, Table 2.1). Around 16 per cent of these expenditures were committed to soil conservation services, with 30 per cent going to research and development and a further 13 per cent to disease and pest control. A comparison with an earlier 1981–82 survey shows that expenditures nominated as benefiting soil conservation increased from 5 per cent to 16 per cent of total expenditures (IC 1993). Over the same period, total expenditures increased from $355 million to $592 million. The share of disease and pest control remained relatively stable while the share of general research and extension services declined (from 36 per cent to 30 per cent, and 23 per cent to 14 per cent, respectively). Because the composition of the general research and extension service categories is not defined, the relative importance of soil conservation related work included in those categories in the earlier survey but not in the latter is not evident. The growth in relative importance of soil conservation services could therefore represent a combination of increased expenditures on those activities and a reclassification of some activities from general categories. In either case, the reported growth of soil conservation expenditures indicates a heightened policy emphasis on it.

Figure 2.5: **Commonwealth budgetary outlays to industry, 1994–95**





Total outlays: $2 092 million

Source: IC (1995).

Table 2.1: **State budgetary outlays benefiting agriculture by type of support,[a] 1990–91** ($ million)

	$million	*per cent*
Relating directly to outputs		
Inspection and market support	55.4	9.4
Lowering intermediate input costs		
Disease and pest control	75.6	12.8
Other assistance to inputs	10.9	1.8
Supporting employment of labour, fixed capital and land in agriculture		
Research and development	179.6	30.3
Soil conservation	92.6	15.6
Extension services	86.8	14.7
Natural disaster relief	17.0	2.9
Rural adjustment	9.1	1.5
Concessional credit	4.0	0.7
Rural support, relief etc	3.9	0.7
Other assistance to primary factors of production	57.3	9.7
Total	**592.1**	**100.0**

a Refers to current outlays only, that is, excluding capital expenditures on machinery and equipment and buildings.
Sources: IC survey, and IC (1993) and (1995b).

2.6 Expenditures on environmental protection

Agricultural land use, along with other human activities, imposes pressures on the environment as land resources are used in production and consumption and wastes are released. The management of those pressures involves both public and private spending to conserve the utility of the environment for future use.

Government expenditures for the rural sector overlap with environmental spending. These expenditures relate to a vast range of matters including market support, which both directly and indirectly feed back to land management. The proportion of those funds directed explicitly to environmental issues, including land degradation, and the share of these expenditures in national spending on the environment are not specified.

Nevertheless, some information on environmental expenditures by the public and private sectors is provided in a recently published nation-wide study of environmental expenditures (ABS 1995b). In addition, ABARE conducted a survey of farm land care expenditure for 1993–94. The ABS collection provides a nation-wide focus on environmental spending and the ABARE survey provides a farm focus.

The ABS has estimated that the national level of environmental expenditures in 1991–92 was around $5 153 million comprising $2 853 million in public spending and $2 300 million in private sector industry expenditures. Of the total, about 4 per cent ($198 million) was allocated to soil conservation and land management, while a further 5.5 per cent ($285 million) was environmental expenditures by farming enterprises. The industry expenditures are net of government grants and subsidies defined in the study to be concerned with environmental protection.

Net environmental protection expenditures by the agriculture sector comprise $321 million in industry spending less $36 million in grants and subsidies. The industry outlays of $321 million amount to nearly 2 per cent of the local value of agricultural production ($18 billion in 1991–92). The scope of environmental expenditures, as estimated, go well beyond measures that are easily recognisable as anti-degradation activities. The most important item of expenditure relates to water storage and reticulation expenditures with around 60 per cent of the total expenditure in this category coming from New South Wales and Queensland (see Table 2.2). The second most important category relates to the extermination of pests and insects. Only in Queensland is this ranking replaced by expenditures on earthworks to control, treat or prevent erosion.

The estimated grants and subsidies are nearly totally comprised of flood and drought relief (see Table 2.3). These expenditures are essentially short term in nature varying from year to year according to climatic conditions and the current requirements for industry relief, rather than the longer-term condition of agricultural land and sustainable agricultural enterprise. Only a small part of the grant support relates to soil conservation.

Table 2.2: **Estimated agricultural sector environmental protection expenditures by state,[abcd] 1991–92** ($ million)

Sector and environmental expenditure category	*NSW*	*Vic*	*Qld*	*WA*	*SA*	*Tas*	*NT /ACT*	*Total*
Preventing and controlling land degradation								
Eradication or extermination of animals or insects and the destruction of weed or plant growth detrimental to the land	40.0	15.3	12.4	3.8	6.0	2.7	5.3	85.5
Earthworks to control, treat or prevent erosion, salinity or water logging	23.3	11.5	18.9	4.0	2.1	0.4	0.9	61.1
Tree or shrub establishment/protection to control/prevent land degradation	5.2	3.4	1.9	2.0	0.9	0.4	0.4	14.2
Erection of fences to separate different land classes to prevent land degradation or exclude livestock or vermin from areas affected by degradation	4.9	3.3	4.2	3.7	1.7	0.5	0.9	19.2
Sub-total	**73.4**	**33.5**	**37.4**	**13.5**	**10.7**	**4.0**	**7.5**	**180.0**
Other environmental expenditures								
Water storage and reticulation systems	24.6	7.2	60.0	12.8	13.8	4.8	12.0	135.2
Costs of preparation of farm plan with the aim of better environmental management	1.9	0.6	0.6	1.1	0.1	0.1	0.1	4.5
Self education expenses on issues associated with land care	0.5	0.2	0.3	0.2	0.1	0.0	0.1	1.4
Sub-total	**27.0**	**8.0**	**60.9**	**14.1**	**14.0**	**4.9**	**12.2**	**141.1**
Total	**100.4**	**41.5**	**98.3**	**27.6**	**24.7**	**8.9**	**19.7**	**321.1**

.. Nil or less than $0.5 million.

na Not available.

a The statistics reported in this table were collected from a sample of farm businesses. The estimates are therefore subject to sampling variability. In many cases, the data reported have fairly high standard errors, and the estimates reported should be viewed with caution.

b The estimates do not include the cost of activities such as waste/effluent disposal of intensive enterprises (eg piggeries and cattle feedlots), improved drainage and infrastructure for the prevention and control of irrigation salinity, or the use of lime or other chemicals to repair/prevent degradation.

c The total environmental expenditures reported is $321 million. This estimate includes grants and subsidies received for environmental work. The above mentioned estimate for environmental expenditures of $285 million is equal to gross expenditures ($321 million) less the value of grants and subsidies ($36 million).

d Estimates for NT and ACT were not published by the ABS. The estimates provided were obtained by the Commission by deducting the reported total for Australia from the total across the six states.

Source: ABS (1995b).

Table 2.3: **Grants and subsidies received by farm businesses by state, 1991–92** ($ million)

Sector and environmental expenditure category	*NSW*	*Vic*	*Qld*	*WA*	*SA*	*Tas*	*NT/ACT(a)*	*Total*
Soil conservation	1.3	0.8	..	0.8	..	..	0.1	3.0
Flood and drought relief	12.7	0.4	18.7	0.5	..	..	..	32.7
Total	**14.0**	**1.2**	**18.7**	**1.3**	**..**	**..**	**0.1**	**35.7**

.. Nil or less than $0.5 million.
na Not available.
a Estimated by deducting the reported total for Australia from the total across each of the other regions.
Source: ABS (1995b).

In the ABARE survey of land care expenditures, respondents estimated the cost of eight types of works which were undertaken on their farm to treat or prevent land degradation. Around 40 per cent of broadacre and dairy farmers are estimated to have made some expenditure on land care in 1993–94 (see Table 2.4). For those farms with expenditure, the average expenditure was estimated to be $3 490 per farm. The most common type of land care expenditure reported was on weed control and the establishment of trees and shrubs. The most costly activities were earthworks to control salinity and water logging, estimated to average $4 460 per farm, and water storage and farm reticulation, averaging $4 540 per farm.

Of the broadacre and dairy farmers who made no expenditure on land care related works in 1993–94, an estimated 42 per cent stated that they had never had any land degradation problem while 19 per cent indicated that they had already dealt with any problem degradation (see Table 2.5). ABARE also reported that land care as a proportion of total farm costs was relatively similar across farm income groups and that no statistically significant difference could be found between farms with land care expenditure on higher income and lower income farms (ABARE 1995b).

Table 2.4: **Expenditure on land care by broadacre farms and the dairy industry, 1993–94** (average per farm)

Type of expenditure	*Farms with expenditure*	*Expenditure a*
	per cent	$
Control of animal pests	8	720
Control of weeds	11	1 500
Earthworks to control erosion	8	3 530
Earthworks to control salinity and waterlogging	5	4 460
Fencing to exclude stock from degraded areas	5	1 910
Fencing to separate different land classes	4	1 940
Tree and shrub establishment	15	1 130
Water storage and farm reticulation	7	4 540
Total land care works b	**39**	**3 490**

a For farms with expenditure in the respective categories.
b Land care works that fall into one of the above categories.
Source: ABARE (1995b).

Table 2.5: **Main reasons for broadacre and dairy industry farms not undertaking land care expenditure, 1993–94**

Reason for not undertaking expenditure	*Farms with no expenditure*
	per cent
Never had a problem	42
Already dealt with the problem	19
Low cash availability	19
Higher priority investments	3
Intend to make land care expenditures in coming years	7
No time, no labour	4
Made changes to farm management not requiring expenditure	1
Other	5
Total	**100**

Source: ABARE (1995b).

The inclusion of environmental protection expenditures in farm budgets shows that there are often good commercial reasons for farmers to undertake environmental expenditures. To a degree those inputs are substitutable with other inputs to production and land degradation. For example, it would appear from the ABARE analysis that many farmers are trading or have traded off current income against future conservation effort in reporting that they have either dealt with the problem (10 per cent of respondents) or plan to undertake land care works at some future time (7 per cent of respondents).

The analysis indicates that there are trade offs being made by farmers with respect to environmental expenditures in their total farm operation. Important questions for sustainable agriculture may concern the relationship between the expenditure trade offs being made by farmers, farm profitability and longer-term sustainability. Also of concern would be impediments to sustainable land management faced by individual farmers and imposed by government regulations and other institutional arrangements.

2.7 Conclusion

Improvements in productivity have provided one source of growth in the agricultural sector over the longer-term, with output of the farm sector increasing despite a longer term decline in the sector's terms of trade. Productivity growth has also entailed more intensive use of farmlands.

Government and private environmental expenditure is undertaken in order to support the capacity of land to meet future agricultural and environmental uses. Such expenditure is part of a much larger national spending on environmental activities.

Environmental expenditures are, explicitly or implicitly, intended to sustain some level of activity given the nature and capacity of the environment. To be economically and socially justified, those expenditures need to be accompanied by net benefits to the community. The next chapter considers sustainable agriculture and the links between the agricultural sector and the environment.

CHAPTER 3
SUSTAINABILITY AND LAND DEGRADATION

3.1 Introduction

This chapter discusses some of the major concepts that are necessary for an understanding of sustainability and land degradation. Sections 3.2 and 3.3 outline an environmental-economic framework, and concepts and definitions that underlie a consideration of land degradation. Section 3.4 examines land degradation in the context of ecologically sustainable development while Section 3.5 discusses some of the driving forces behind the incidence of land degradation. Section 3.6 considers whether land degradation is a private or social problem and Section 3.7 provides a conclusion to the chapter.

3.2 Environmental-economic framework

Introduction

Economic development involves, amongst other things, use of the natural environment. The development of the agricultural sector has progressively involved more intensive use of land resources for cropping and grazing, and with this, greater control and pressure on local habitats leading to environmental change. The development of the agricultural sector (along with other sectors of the economy), therefore, has involved adaptation to a changing environment.

The overall interaction between the production and consumption systems of humans and the environment can be conveniently summarised through a simplified presentation of the economy and the environment. This presentation can then be used to produce a more systematic framework for linking the economy and the environment.

Economic activity is normally associated with the production of goods and services using materials, labour and capital inputs and the consumption of those commodities. Production can be thought of as being undertaken by firms (or enterprises) and consumption by households who are also suppliers of labour. Government also enters the economic system as a producer of goods and services and employer of labour and capital. The value of economic activity is normally enumerated in monetary terms.

Economic problems that involve the dimension of time can be captured by discounting, which is a procedure for finding the present value of a future stream of benefits and costs. The rate at which benefits and costs are converted to present values is the discount rate.

Discounting

Discount rates are usually positive for two underlying reasons. First, people generally discount the future because they prefer benefits sooner rather than later; and, secondly, if resources are diverted for investment, rather than consumption, those resources will be able to yield a higher level of consumption in a future period.

Discount rates are used to capture both private and social time preferences. Private discount rates refer to the discount rate an individual would use when deciding whether an investment would be worthwhile. It is the rate of return the individual would have to receive to make that person willing to trade off consumption now against consumption in the future — resources not used today would be an investment in the future. They indicate the opportunity cost of capital for the individual. Private discount rates are applicable in financial analyses which are undertaken to assess whether an investment is profitable for the individual undertaking it.

The social discount rate should reflect society’s valuation of the future and the trade off society makes between consumption now and consumption in the future (ie social time preferences). It also represents the social opportunity cost of capital funds in the economy as a whole.[3] In a social discounting framework, public and private decisions would be appraised on a consistent basis that is concerned with social welfare. Social discount rates are relevant to economic analysis which is concerned with whether or not particular projects or policies will improve community welfare. Other things being equal, the higher the social discount rate the greater the emphasis on resource use and investments that provide income after short gestation periods. Benefits from resource use by

3 The social opportunity cost of capital and society’s valuation of the future, that is, the marginal rate of time preference, are two sides of the same thing. The opportunity cost of capital represents the demand side for capital funds while the marginal rate of time preference represents the supply side. In a perfectly competitive capital market, the equilibrium would occur in the capital market when the demand for capital funds exhausts supply. The equilibrium social discount rate would be the rate that applied when supply and demand are in equilibrium. However, capital markets are not always perfectly competitive and there are a number of possible approaches to estimating social discount rates. For further discussion of these issues in a cost benefit framework see Perkins (1994).

future generations (or projects with long gestation periods) would be heavily discounted.

Social discounting requires that the social costs and benefits of private projects, rather than the financial outlays and receipts, be considered in the social (or economic) appraisal of projects. Social analysis therefore differs from private analysis in that private analysis does not take into account the external effects which are conferred on society but not on the private enterprise making the decisions (such as down-stream pollution and spillover benefits to others of on-farm research and development). Even if those factors were included in the private appraisal of projects, the social discount rate would differ from the private discount rate for reasons such as imperfections in the capital market (which drive a wedge between borrowing and lending rates), the effects of taxes (which are costs to the individual, but transfers to society as a whole), and risk (which takes account of differences in riskiness of private and public sector projects).

The application of discounting depends on economic and environmental flows being valued in monetary terms. This is not the case when the benefits to future generations are not embodied in current prices or included in analyses through contingent valuation methods. Because discounting does not capture all factors relevant to sustainable development, formulation of sustainable development policies that balance the need for environmental resources of future generations against consumption of the current generation must look beyond the application of discounting.

Input-output linkages between the environment and economic activity

The environment consists of all *in situ* resources such as coal, oil and gas, ferrous and non-ferrous metals, other minerals, land and sea area, soil condition, and biomass comprising all manner of life forms including plants, insects, animals and fish. Environmental processes are most readily expressed in physical terms (eg litres of water used; hectares of land cleared, degraded or conserved; or tonnes of metal ore mined).

In relation to economic activity, the natural environment serves as a supplier of resource inputs. These may take the form of inputs to production (including agriculture) and environmental amenity flows (such as natural beauty, living and recreational space, and clean air and water). The natural environment also serves as a sink for wastes and discharges from industry and from households.

Where there are direct links between economic activity and the environment, a partial measure of the economic value of environmental resources would be embodied in the market values of goods and services. The value is partial in the sense that not all environmental processes are embodied in market processes. They are either not treated in markets or their market prices do not reflect external costs such as pollution. For these reasons, a full or even partial measure of the economic value of many environmental resources may not be easily determined or expressed in monetary terms.

The concepts of intra-system functions and inter-system dependencies are central to the following discussion of agricultural land management. To make the presentation of economic-environmental interactions clearer, the economic and environmental flows and the interaction between the two systems can be portrayed using a matrix presentation of inputs and outputs (see Figure 3.1). The matrix embodies both the monetary and physical aspects of the economic-environmental system.

The economic-environmental input-output matrix covers in its various components the inputs to industry (including agriculture, mining, manufacturing and services) and outputs from industry (such as wheat, wool, eggs and honey from agriculture). Household use and investment are included to close the system. (The presentation of the matrix abstracts from inter-country flows through imports and exports).

The model relates to economic and environmental flows and is divided into four quadrants, reading from left to right, top to bottom, to capture the economic and environmental functions just discussed. In the first quadrant economic activity as conventionally reported in national accounting systems is shown (eg see Australian national income and expenditure accounts (ABS catalogue no. 5204.0) and input-output tables (ABS catalogue no. 5209.0). This economic activity is expressed in monetary units of account and relates to the employment of labour and capital by industry for the production of goods and services for domestic use — by industry, households or capital accumulation — or export. When environmental flows have a recognised monetary value, those values are included in quadrant 1 as an input to production.[4]

4 Due to the interest and perceived importance of these flows for economic and environmental management, they are formally included in a system of satellite accounts to the internationally recognised System of National Accounts (Commission of the European Communities, IMF, OECD, UN, and the World Bank 1993).

Figure 3.1: **Economic-environmental input-output framework**

Quadrant 1 *Production and consumption of goods and services*	***Quadrant 2*** *Waste and discharges to the environment from industry and households*
Quadrant 3 *Inputs of environmental resources to industry and consumption by households*	***Quadrant 4*** *Environmental flows from natural systems and outflows being absorbed by those systems*

Note: Shaded areas would be measured in biophysical terms. Non-shaded area would be measured in monetary terms.

The agricultural sector is a producer of food and fibre products including meat, grain, fruit and vegetables. In order to produce those products, the agricultural sector (along with other industries) uses goods and services such as fuels, fertiliser, transport and business services. The sector also employs labour (including both wage and salary earners and farm managers), and fixed capital such as tractors, cultivation and irrigation equipment, and buildings. Through the monetised value of farm land which normally yields a return to the farmer, natural resource inputs to farming are given a monetised value. Broadly, the value of land to any one farmer would be equal to the present value of the expected income stream from that land. The monetised value of land resource inputs in any one year would therefore be equal to the marginal value of delaying the use of those resources to some future period — the rental price of that land. With higher discount rates, the rental price tends to be lower, while with lower discount rates, the rental price tends to be raised.

The second quadrant relates to wastes and discharges into the environment by industries (including agriculture) and households. The wastes and discharges cover a multitude of environmental flows. For agriculture, it covers the effects of agricultural chemical residues and salt run-offs into river systems, but it also includes other discharges that may be intended to have a positive effect on agriculture production in the future such as the effects of the treatment of soils through liming to prevent soils becoming acid. At a broader level, environmental discharges include sewage and other household waste from metropolitan areas and discharges into the environment by industry. Finally, Quadrant 2 includes transnational pollution (eg dust from Australia drifting across the Tasman Sea to New Zealand and greenhouse gases).

Quadrant 3 covers the use by industry and households of environmental services. The environment acts as a supplier of inputs to the agricultural sector (eg through water, minerals within the soil, fresh air, solar energy and light). Natural resource or environmental services used by this sector are conceptually covered within this part of the framework. The use of the environment by other sectors, such as mining and households is also covered by this quadrant. Quadrant 3 differs from quadrant 1 in that usage of environmental commodities is expressed in physical units of account. Therefore, to the extent that some resource flows are also monetised, Quadrant 3 overlaps with Quadrant 1. To the extent that resource and environmental amenity flows are not monetised, quadrant 3 complements quadrant 1.

Quadrants 1, 2 and 3, when taken together, represent a usage and distribution chain for the input of environmental resources into production and consumption, and the flow of residuals back to the environment. Industry sectors are linked both directly and indirectly to the environment. For example, for the farming sector, lime which might be used to improve soil fertility is, at an earlier point in the production and distribution chain, extracted from concentrations of that mineral by the mining sector. This is also the case for other fertilisers. Water used in irrigation is collected in high rainfall areas and transferred through water distribution networks to agricultural areas. Therefore, while the direct impact of environmental activities can be focused on individual localities or regions, in the presence of industrial specialisation and the capacity to transport goods and services over long distances, the indirect effects are much more widespread. The household sector similarly has direct and indirect links to the environment. The economic and environmental activities of the agricultural sector can be fully described within this economic-environmental framework.

Quadrant 4 is concerned with the natural functioning of environmental systems. It has no direct interaction with the economic production and distribution system. It includes an enormous range and diversity of bio-physical changes and functions from subtle changes in the earth's surface brought about, for example, by the movement of the tectonic plates to the natural functioning of localised forests and water courses. However, the ecological activity in Quadrant 4 is integrated with the rest of the extended economic-environmental framework because economic development involves the increasingly intensive use of natural resources, and greater control over and pressure on the natural environment (Quadrant 2). It is also integrated with the production and consumption system as wastes and discharges from industry and households flow into natural systems and must be accommodated/absorbed in competition with other, naturally occurring, flows (Quadrant 3). Through environmental flows conceptually covered in both quadrants 2 and 3, there can be a crowding out of natural occurring systems. The changes to the environment may be beneficial to industrial productivity (which historically has been the norm). Nevertheless, changes may also reduce the utility of the environment for some aspects of industrial or household use, and for the continued functioning of ecological systems.

Because many environment services are not formally valued in the economy and links between the economy and the environment span many generations, the full economic value of resources is not known. To overcome this information gap, it is tempting and, indeed appropriate, for the community to also determine the level and composition of ecological resources that the current generation wishes to bequeath to future generations.

3.3 Concepts and definitions

Concept of sustainable development

In 1980, the World Conservation Strategy was published by the International Union for Conservation of Natural Resources (IUCN) with advice and assistance from the United Nations Environment Programme (UNEP), World Wildlife Fund (WWF), and in collaboration with the Food and Agricultural Organisation (FAO), and the United Nations Education, Science and Cultural Organisation (UNESCO). This strategy was concerned with the maintenance of essential ecological processes, the preservation of genetic diversity and the sustainable utilisation of species and ecosystems.

In 1987, the concept of sustainable development was given further impetus worldwide through the report 'Our Common Future' issued by the World Commission on Environment and Development — the Brundtland Report, after the chairman of the Commission. The World Commission on Environment and Development was established as an independent body in 1983 by a resolution of the United Nations General Assembly. The Brundtland Report focused on the interactions between producers, consumers and the environment and concluded that economic development and environmental protection are aspects of a single overall social management problem. Within this system of interactions, the concept of sustainability does have limits imposed by technology, social organisation and the capacity of the environment to absorb the effects of human activity. The limits are not absolute in all cases, since there can be substitution between human capital and natural resources and the regeneration of some natural resources (eg soil fertility, forests). Thus, sustainability cannot be defined according to predetermined bio-physical criteria. To capture the broad concept of sustainability the Commission offered the following strategic definition:

> Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (World Commission on Environment and Development 1987, p. 43)

Finally, adoption of Agenda 21 (UNCED 1992) at the United Nations Conference on Environment and Development (UNCED) held in Brazil in June 1992 and the establishment of the United Nations Sustainable Development Commission signifies a high level of international commitment to the achievement of patterns of economic development which are sustainable.

Underlying international developments and interest in the links between the environment and economic development is the environmental input-output framework and a realisation that there are limits to the flow of environmental services to production and consumption and the use of the environment for the discharges of industry and households. However, economic-environment relationships are not static and a major influence on the potential for growth (including population growth and rising living standards) is technological change and limits on substitution of environmental factors and man-made technologies.

The international consensus on actions adopted at the UNCED does not impose legally binding commitments on governments or individual land managers to adopt sustainable land management practices. Although the UN Sustainable Development Commission will receive reports on environmental matters from member countries, ultimately, the sustainable development practices would be adopted for domestic land management reasons.

At the national policy level, the principles of ecological sustainable development have been enunciated in the National Strategy for Ecologically Sustainable Development (ESD) (Commonwealth of Australia 1992). For the purposes of that strategy, ESD is defined in the following way:

> ... using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased. (Commonwealth of Australia 1992, p. 6)

The essential message of this definition is the same as that provided by the World Commission. To provide an additional basis for the implementation of Australia's national strategy, it establishes three core objectives:

> - to enhance individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations;
> - to provide for equity within and between generations; and
> - to protect biological diversity and maintain essential ecological processes and life-support systems. (Commonwealth of Australia 1992, p. 8)

These are also very general guidelines which capture the concept of sustainable development and provide a basis for the development of an institutional framework for sustainable development.

The management of agricultural land degradation and the Australian agricultural industry are embraced within the broad concept of ecological sustainable development (Ecologically Sustainable Development Working Group-Agriculture 1991 and Commonwealth of Australia 1991).

Definition of land degradation

Land degradation has negative connotations that imply the loss of something of value. 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 the environment as a place for other human activities (eg mining, secondary industries and human habitation or as an assimilator of wastes). Agricultural land degradation is significant because it:

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

The existence of such degradation provides a threat to the achievement of national ecologically sustainable development objectives.

Johnson and Lewis (1995) have noted that discussions of land degradation have two critical aspects, namely that there must be a substantial decrease in the biological productivity of a land system and that the decrease is the result of human activities rather than natural events. On this basis,

> *land degradation* can be defined as the decline in the biological productivity or usefulness of land resources for their current predominant intended use caused through the use of the land by humans.

It encompasses soil degradation and changes in the traditional landscape and vegetation due to human interference. ‘Usefulness’ is a crucial attribute of land degradation (National Soil Conservation Council (undated), McTainsh and Boughton 1993, Johnson and Lewis 1995). Declining usefulness of land resources indicates that human uses are 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 effected. As land resources have many possible uses with changes to the landscape having both favourable and unfavourable effects depending on use, the qualification ‘current predominant intended use’ is necessary in order to make the definition of land degradation workable. Under this definition, desertification due to natural climate change would not be regarded as degradation while desert-like conditions due to overgrazing or inappropriate tillage practices would.

However, degradation does not necessarily imply an immediate loss in productivity. For example, biomass productivity could be maintained while degradation is present. This could occur during a period of overuse, so that the longer-term ability of the soil to maintain production is diminished for short-term gain. It could also occur when human technological solutions allow farming to co-exist with degradation (eg some areas of land may be sacrificed to salinity to allow an otherwise very productive farming area to continue operating).

While degradation has negative connotations, improving the condition of the land through land conservation has positive connotations. *Land conservation* can be defined as: the prevention, mitigation and control of soil erosion and other forms of land degradation. Conservation is concerned with maintaining the usefulness of the land and may be oriented to returning the land to some earlier natural condition or to maintaining its utility for farming, depending on the intended use of the land. It may be achieved through retiring the land from intensive use with a possible return to low input farming systems or conserving areas for native vegetation. The usefulness of the land can be maintained by substituting high yielding farming vegetation tolerant of the prevailing form of degradation (including tree crops), earthworks and land forming and other land measures, either singly or in combination, which enable the maintenance of land utility for future use.

Evaluation of the extent of land degradation also requires a benchmark representing the original condition of the land against which change can be evaluated. Conceptually, such a benchmark could be established with reference to the condition of the land (represented in Quadrant 4 of the environmental input-output framework) in the absence of human production and consumption activities. Such a theoretical benchmark would be impracticable to determine, and possibly not very relevant to current land management decisions. Therefore, some arbitrary benchmark against which to assess the level and change in land degradation must be chosen. In Australian studies, the arbitrary benchmark generally chosen is the land condition that existed around 1800, to coincide with the beginning of European settlement and the farming systems linked to the modern economy. In this context, the modern economy is characterised by the interdependence of urban centres and rural communities, with the rural communities producing a surplus to meet the industrial and consumer demands of urban populations in return for farm inputs and non-farm consumer goods.

Rising demand has been met by human ingenuity in the use of natural resources and the substitution between natural and human capital. It is self evident that the process enables the utility of the land to be maintained for the production of food and rural products although there may be a loss of usefulness of land for natural ecological systems. Notwithstanding increasing levels of output, there have been catastrophes and costly errors of judgement which occur as part of the development of more productive farming systems (eg excessive and inappropriate tillage of the Victorian Mallee earlier this century). Agricultural systems that do not take advantage of ingenuity and technical progress, but rather rely on natural regeneration, would not be expected to provide the highest level of income now or in the future. In general, such farming systems are likely to lack the potential to supply the broader community with sufficient food to achieve and maintain basic nutritional requirements (see Figure 2.1 and World Commission on Environment and Development, 1987).

Types of land degradation

A multitude of causes contribute to the loss of value of land for human and ecological purposes. Appendix A sets out in some detail a classification of land degradation and measures of the severity of each form of degradation, which have been used by the Soil Conservation Service (SCS) of New South Wales in its 1987–1988 state-wide survey of land degradation and land use. Such a comprehensive classification, to which the Commission has added other types of land degradation from other studies, provides a starting point for the linking of degradation to farm productivity and environmental issues.

Land degradation can involve the changing mineralisation of the soil, as occurs through irrigation and dryland salinity, induced soil acidity and heavy metal contamination of soils. Degradation can also involve changing soil structures and erosion that occurs with soil structure decline, surface scalding, water and wind erosion and mass movement of slopes. Finally degradation of land resources can involve changes in biological conditions due to such factors as woody shrub infestation, disappearance of perennial bush and the clearance of native vegetation, invasion by feral animals and other pest species, and pollution from organic residues and farm wastes.

3.4 Land degradation and ecologically sustainable development

Land degradation of some form is likely to occur as human use of land becomes more specialised and pressure on pre-existing natural environmental functions is increased. The usefulness of the landscape for some environmental functions is reduced. In addition, specialised and successful farming systems may co-exist with some forms of degradation, such as irrigated agriculture and irrigation salinity. An important question for the evaluation of sustainability is: will the generation of current income from agricultural land use and degradation today lead to a permanent reduction in national productivity, and will essential life support systems be threatened by the existence of degradation? If the degradation is irreversible — or if it can only be reversed at an uneconomic cost — those land uses dependent on the availability of non-degraded land resources are not sustainable given current technologies.

Sustainable development can be achieved by the introduction of new technologies and the substitution of human capital for environmental resources, or by the conservation and replenishment of available resources for future use. In determining the options available to land managers, it is necessary to determine whether individual land resources are renewable or depletable. Depletable natural resources are those whose replenishment is so slow that they can be considered to be available for direct human use only once, such as top soil in Australia, minerals and natural gas. For these resources, development can only continue if new supplies/deposits are found or society has available some backstop technologies that can substitute for resource intensive technologies.

By definition, renewable resources can be replenished over time; however, it should be recognised that they can also be driven to extinction if the stock reaches some critical minimum required for regeneration or replenishment. For example, the Dodo bird was a renewable resource while a minimum breeding stock remained. Once that breeding stock was depleted, the species became extinct. Many of the environmental impacts of agricultural activities can be classed as renewable resources on the basis that repair periods of less than 100 years are typical (Ecologically Sustainable Development Working Group-Agriculture 1991). In other cases, the natural repair period is so long that, for practical purposes, damage could be deemed as permanent (eg loss of native habitats, flora and fauna).

Degradation occurs at a regional level and may be a threat to naturally occurring ecological systems or to current farming systems. To evaluate environmental quality in an economic and ecologically meaningful way, an appreciation is needed of the biogeographic characteristics of each region, the land uses in those regions and the extent of prevailing land degradation. A nation-wide measure of environmental quality could then be obtained, taking into account the productivity of regions and regional ecologies.

In an effort to capture the biogeographic characteristic of regions at a national level, the Australian Nature Conservation Agency (ANCA) has coordinated a national project to prepare the Interim Biogeographic Regionalisation of Australia (IBRA) (Thackway and Cresswell 1995). This classification builds on the regional classifications developed by state land management authorities, in order to divide Australia into regions according to biogeographic characteristics (see Appendix B). It has been used in this study to combine information about regional land use from the ABS census of agricultural establishments and the New South Wales survey of land degradation (see Box 3.1).

While land degradation occurs at or is sourced to individual locations, there is substantial diversity between the spacial range of degradation problems (and benefits). A substantial number of degradation forms, such as soil structure decline, induced soil acidity, surface scalding and water and wind erosion, relate to land resources at the farm level. There could be off-site (or external) effects as soil run-off and nutrient loss induced by degradation enters the atmosphere and waterways. Nevertheless, other types of degradation have wider spacial ranges. For example, dryland and irrigation salinity relate to underground water tables and acquifer systems that are not necessarily confined within the boundaries of individual farms, and for which the point of water inception is normally remote from the point(s) of problem degradation. Off site, the effects could be negative as the utility of the soils and waterways is reduced due to salting and nutrient run-off, but could also be positive with the increased availability of underground water for some farms.

Box 3.1: **Pilot study using data on the biogeographic regionalisation of New South Wales**

In order to explore an approach that enables a comprehensive presentation of agricultural land use, land degradation and the environment, the Commission has used information from a number of sources. Data for New South Wales has been used in this exploratory study.

Information about agricultural production is available from the ABS agricultural census classified by Statistical Local Areas (SLAs) while land use and land degradation information is available from the New South Wales 1987–1988 land degradation survey which provides information for about 13 000 data points. To establish biogeographic regionalisation using these sources, information from the New South Wales survey was first aggregated from survey data to SLAs using Geographic Information System (GIS) techniques. This provided a comprehensive agricultural database at the SLA level of aggregation. Secondly, information at the SLA level was aggregated to IBRA biogeographic regions also using GIS techniques.

Using the New South Wales study data, the impact of agricultural management decisions on the overall management of regions with similar biogeographical characteristics differs substantially. Agricultural holdings cover about 75 per cent of the area of New South Wales. However, within the state the importance of agricultural land management decisions varies substantially. West of the tableland areas extending to the arid western areas of the state, agricultural holdings cover over 80 per cent of the land area. For these regions, farm land management decisions would have a major influence in determining the interaction of human activity with the environment. Degradation of native pastures is an issue in the arid rangeland areas.

In contrast, in the central and southern coastal areas, agricultural holdings cover less than one fifth of the biogeographical areas prospectively indicating a much lower level of influence over the environment. In these areas over three fifths of the area is taken up by parks, timber and shrub lands. For these regions, issues of greatest importance for agriculture might be the influence of non-agricultural land users on agricultural land management.

There is limited scope for progressively increasing the area committed to farms so that output growth would need to come, in the main, from the more intensive use of exiting holdings. Managing the land for more intensive use raises issues concerning the effect on land degradation of that use, flow-on effects to farm productivity and the effect on the regional environment as improved pastures and croplands encroach on remnant bushland and native pastures.

Appendix B provides a more detailed analysis of land use information by IBRA biogeographic region.

The incidence of degradation may also be much more widely spread and could encompass whole biogeographic regions and beyond. For example, degradation through biomass invasion evidenced by the harmful effects of feral and pest invasion, and vegetation decline may cover whole regions due to a common favourable habitat and general inability of land managers to control the biomass. In these cases, the origin or the point of inception of the biomass may be largely irrelevant for management and control.

The effects of land degradation also affect depletable resources (ie those that cannot be regenerated or replenished). The loss of topsoil or depletion/pollution of groundwater reserves is irreversible, for most practical purposes. In addition, the degradation of pre-existing environment through land clearance and contemporary farming systems effectively replaces those systems based on that pre-existing environment with new systems. Ultimately, ecological systems subject to progressive replacement by utilitarian activities like farming could be depleted. A similar picture applies to other land-using industries such as forestry, hunting and fishing. A different picture applies to the extractive industries within the mining sector, which by definition operates by progressively discovering and depleting mineral deposits. Where agriculture uses fertilisers and additives to maintain soil fertility and structure, it is drawing on the output of the minerals sector. Accordingly, the sustainability of those agricultural systems is dependent on the output of the mining sector, which in turn depends on the continued availability of certain non-renewable minerals.

3.5 Farmer incentives and agricultural land degradation

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.

Economic analysis would also suggest that in the absence of conservation effort, which is the case when a farmer simply mines land resources, farming would only continue while a normal return on fixed capital could be obtained. As the land resource was degraded potential future profits would also be reduced until ultimately, that land would be retired from its degrading use in preference for some other land use (Appendix D). As farmers must incur material, labour and capital costs to farm the land, it is unlikely that resources on which farming activities depend would be totally depleted — it would not be profitable for the farmer to do so. Totally depleted, is an extreme concept which in this context means environmental resources are depleted to the point where their regeneration and conservation is no longer possible (eg all topsoil is lost, soils become poisoned and useless for farming).

The economic choices faced by individual farmers may however be somewhat more subtle than indicated by these basic distinctions. While the sustainability of agricultural resource use may be bio-physically and economically achievable, the sustainable course of action may not be most profitable from the individual farmer's point of view. In evaluating expected returns, individual farmers may have several options yielding positive income streams once account is taken of the resale value of the property. Some of those options may in fact involve using (mining) the land resource until the resource levels fall below the minimum required for agriculture. Other options may involve conservation/sustainable farming systems that yield a positive net income from farming in perpetuity. In the normal course of events, it would be expected that the farmer would choose the option that provided the largest net benefit. If the sustainability options are always the most profitable, it may be said that agriculture is *strongly* sustainable (Pagiola 1993).

In other cases, the best alternative use may not be agriculture. For example, sustainable farming may be profitable in a region that is within an area being rezoned for metropolitan and industrial use. That alternative use would most probably attach a land premium to locality rather than soil fertility. The best option for the farmer may be to mine the soil up to the point of sale of the property for that alternative use. On the other hand, the farmer could persist with sustainable farming in the area and remain profitable as assessed against the cost of material, labour and fixed capital employed if, for his own reasons, he chose to do so. Competition from other alternative land uses such as, mineral development and retirement from agriculture on lease expiry (or termination) would afford the farmer similar non-conservation incentives.

The concept of sustainability is therefore most relevant where agriculture is the best use of the land and is likely to remain so for the foreseeable future. In general some level of conservation farming affording sustainability of agriculture would be justified in such regions.

The concept of sustainability is also not linked solely to the bio-physical requirements of agriculture and alternative land uses. Other factors could also influence farmer returns and decisions about land resource use. For example, expected declines in the agricultural terms of trade would lower the returns to agriculture relative to other activities given prevailing real discount rates. It would then pay farmers to bring forward output and sales effort and postpone conservation efforts. On the other hand, improvements in the terms of trade, would encourage current conservation efforts in order to take advantage of expected future real price increases, that is, the rate of growth of the resource value would at least equal the real discount rate. Secondly, conservation expenditure is one of a number of vehicles for raising the possible level of future farm outputs. Research and development and changing farm technologies and productivity, also raise output potential but may not necessarily reduce degradation. Some forms of new farming technologies such as feedlot farming may actually increase the levels of some forms of degradation such as soil structure decline. Other efforts may be directed at new farming systems that co-exist with prevailing levels of degradation (eg the development and use of salt or acid tolerant plants). The yields to the community from these alternatives may be greater than conservation farming, and therefore would be favoured by land managers.

From an individual farmers' perspective, those forms of degradation that affect productivity and profitability would be expected to be taken into account in the formation of farm plans and land management strategies. However, even if farmers had full information concerning the environmental impact of their operations, there would remain environmental concerns to the community at large that would not be taken into account in farm plans in the normal course of business. Through the destruction of habitats having little utility for contemporary agricultural systems, farming could reduce some natural resources dependent on those particular habitats below critical levels. For example, where land clearing leads to the loss of native habitat within a biogeographic region. Secondly, the on-farm use of chemicals and irrigation water may normally be considered from the point of view of the individual farming enterprise rather than from the point of view of the broader community which takes account of potential downstream pollution of rivers and aquifers.

The link between farm productivity and environmental amenity is not entirely decoupled as some polar interpretations of this distinction could suggest. Returning to the example of tree clearing, while clearing may not initially be an environmental issue for the farmer, over clearing can lead to reduced farm productivity due to, for example, dryland salinity.

Another source of agricultural land degradation can come from the introduction of new farm systems that are intended to improve farm productivity and profits through, amongst other things, reducing the adverse environmental effects of earlier systems. For example, it is now well documented that improved pastures and associated use of nitrogenous fertilisers were introduced to raise the productivity of the land while at the same time reduce the incidence of soil erosion through better ground cover. Those farming systems have been subsequently found to induce soil acidity, itself a cause of land degradation and lower farm productivity. In another example, chemical weedicides have enabled a reduction in tillage and degradation through soil structural decline; however, the chemical run-off is a source of environmental pollution.

3.6 A private or a social problem?

It is clear from the above discussion that land degradation cannot be treated solely as a problem for individual land-holders or for the current generation of land managers. The costs of degradation and the benefits of preventing, ameliorating or repairing it facing individual land-holders will, in many cases, differ from the costs and benefits to the community as a whole.

Because the availability of land resources and the effects of conservation and degradation cannot always be confined to individual holdings, conservation and degradation will exhibit, to varying degrees, the characteristics of a public good (or bad):

- non-excludability — a potential land resource user cannot be denied access to all of the land resources (including underground aquifer systems and water basins) of a locality or region; and
- non-rivalry — a number of users can use a land resource (including ‘goods’ such as rainfall but also ‘bads’ such as invasive plant and animal species) without changing its availability (or supply) to others in the locality or region.

These characteristics focus first on the ability of individual farmers to contain the effect of conservation and degradation to their own land (ie the externalities of conservation and degradation) and, secondly, on the ability of other land managers to isolate themselves from degradation occurring in or originating on other land management areas in the same locality or region.

Forms of erosion such as sheet and rill erosion (a form of water erosion) and wind erosion, might generally be confined to the affected properties. Nevertheless, where declining land conditions cannot be practicably contained within a single holding, the land conservation actions of adjacent holdings may not be fully effective in stopping the advance of the erosion. For irrigation salinity and pest invasion it may be difficult for an individual land-holder in an affected area to contain the effects within his property. Similarly, it may not be possible for other land mangers to isolate themselves from the effects of these forms of degradation or the conservation efforts of others.

It is clear that land resources and degradation cannot be treated as solely a problem for individual land-holders. Frequently land resources and degradation spread beyond individual holdings to catchments and broader regions, so that even on a group basis, land-holders do not necessarily perceive the full social costs of degradation.

The private and social division in the management of conservation and degradation extends beyond the occurrence of land resources and the interaction between farmers in the use of those resources. The recognition and assessment of land degradation, research towards a solution and implementation of conservation plans is not costless and trade offs exist between farmer and social effort to find and implement conservation programs. To some extent, farmer learning by doing may be sufficient to cope with a range of degradation problems. Farm revenues would then cover the cost of such conservation efforts. However, research into land degradation problems that ultimately benefit communities of farmers would not be commercially justified by any one individual. This is due to the fact that individual farmers are not normally in a position to appropriate the social benefits of their research to offset their private costs. Reliance on the research and development efforts of individual farmers, therefore, is likely to result in conservation efforts being less than the social optimum. This would be true even when the degradation problem is site specific, such as is the case with induced soil acidity. For this reason, research, development and land management information provided to the agricultural sector also has public good characteristics (Industry Commission 1995a).

Thus, there are public good aspects and management issues in both the incidence, prevention and treatment of land degradation.

3.7 Conclusion

Broad concepts and principles have been established at the international and national level for ecologically sustainable development. The agricultural sector as a user of environmental resources provides one interface for the community between its monetised system of production and consumption, and the environment. As the agricultural sector uses environmental resources some land degradation will inevitably occur. The nature of degradation will change with changes in technology associated with agricultural production and our understanding of the environment.

Environmental expenditures and technological change make it possible to prevent or ameliorate degradation. However, the extent of the commitment of resources to the prevention and amelioration of degradation is an empirical question. It requires an examination of the extent of degradation, the costs and benefits of repair from the community and farming points of view. It also requires an appreciation of the incentives facing farmers in their choice of farming systems.

CHAPTER 4
ECONOMIC EFFECTS OF LAND DEGRADATION IN AUSTRALIA

4.1 Introduction

The concept of land degradation implies some deterioration in land quality. The loss in productivity reflects the economic costs of degradation. However, positive economic costs do not necessarily lead to conservation activities to reduce degradation. There are links between levels of degradation, production and profit and therefore a trade-off exists between higher production and degradation.

This chapter considers the economic effects of land degradation in Australia and the costs and benefits of ameliorating activities. Section 4.2 focuses on the extent of land degradation in Australia. Section 4.3 reports selected estimates of the production foregone due to degradation and summary results from several cost-benefit analyses. Section 4.4 outlines the main findings of a Commission study of New South Wales agriculture undertaken to explore the links between production, profit and degradation.

4.2 The extent of land degradation in Australia

Introduction

The Commission investigated the extent of land degradation in Australia with two objectives in mind. The first objective was to investigate land degradation in New South Wales using information from the 1987–1988 SCS land degradation survey. The aim of this work was to assess whether the information could be successfully incorporated into a state-wide model of New South Wales agriculture in order to provide a broad view of degradation and the state agricultural industry.

The second objective was to undertake a preliminary collection of land degradation information from the New South Wales and other studies to broaden the view of land degradation in Australia.

Broad picture of degradation

State-wide studies

The Commission has found that there is a long-standing active interest in investigating the extent of land degradation. This interest is reflected in published results for states as a whole, detailed studies of localities and regions within states and individual forms of degradation (see Appendix C). However, while each exercise contains valuable land degradation information for the area/degradation type under study, integrated nation-wide information is lacking.

So far only one national degradation assessment study has been carried out (Woods 1983). This survey, conducted by the Commonwealth and States in a collaborative study of soil conservation over the period 1975 to 1977, focused on appraising the incidence of land requiring treatment rather than providing an inventory of land degradation. Such an inventory would have had the added advantage that it could have been used to assess the effects of degradation or as a benchmark against which future appraisals could be compared. Nevertheless, as it was, the study estimated that a total of about 80 million hectares, or 16 per cent of agricultural land required some form of treatment. Over two-thirds of the problems related to water erosion with New South Wales having the highest concentration of this problem (around 24 million hectares). Large areas of vegetation decline (eg woody shrub infestation) were also recorded as requiring treatment in Queensland, New South Wales and the Northern Territory.

Although a national study has not been repeated, more recent data on the extent of land degradation for individual states is available. This information paper has referred to data for New South Wales, Victoria, Western Australia and Tasmania. Each report shows that a number of types of degradation affect substantial portions of the states considered.

For New South Wales, the 1987–1988 survey considered the extent and severity of ten forms of land degradation. Over 10 per cent of the land area in that state was estimated to be affected by severe soil structure decline or gully erosion, while around 4 per cent suffered from severe induced soil acidity and woody shrub infestation. Severe vulnerability to wind erosion has affected around 11 per cent of the land whereas severe vulnerability to sheet and rill erosion (a form of water erosion) affected less than 1 per cent. Around 1 per cent of the state is also affected by severe salinity. Nevertheless, for each form of degradation considered, over three quarters of the state has nil or minor levels of land degradation.

The process of assessing the nature and severity of land degradation changes substantially over time. New forms of degradation emerge and previously recorded forms of degradation receive less attention. For example, the 1967 SCS survey of New South Wales land degradation examined only gully, sheet and wind erosion whereas the 1987–1988 survey included those forms of erosion with a much larger range of degradation types. By comparison, the later 1987–1988 survey included in its coverage less visible forms of degradation, such as soil structure decline and induced soil acidity.

Studies of land degradation in Victoria indicate a substantial reduction in water and wind erosion over the years, to the point where the area subject to these forms of erosion is small compared to the total area of agricultural land. However, other forms of degradation such as induced acidity and soil structure decline are now assessed to be very widespread. For example, 58 per cent of dryland pasture is extremely acidic and around 40 per cent of broadacre crop land and 90 per cent of irrigated pasture have severe soil structure decline. Irrigation salinity occurs in one fifth of the area of irrigated pasture and horticultural land, while dryland salinity occurs in about 1 per cent of agricultural holdings in Victoria. Based on the area affected, salinity appears to be less of a problem in Victoria than acidity and soil structure decline.

The most extensive forms of land degradation in Western Australia are vegetation decline and erosion in the rangelands which affects about 8 per cent and 3 per cent of the total area of this state, respectively. Of degradation associated with lands used for cropping and improved pasture, soil structure decline is the most widespread problem in Western Australia, affecting up to 7 per cent of the state. While the reported area of dryland salinity was only 0.2 per cent of the state, it is a potentially serious form of degradation because potential saline areas are concentrated in the more productive south-western coastal areas and the area of saline land could increase five-fold to around 1 per cent of the state.

For Tasmania, a survey of degradation on private freehold land was conducted over the years 1992 and 1993. Eight forms of degradation were examined. Taken together, the survey found that almost all private land suffers from some form of degradation. However, when each form of degradation, other than tree decline, is considered individually, it was found that over 80 per cent of private freehold land has nil or minor degradation of the type under consideration. For example, 85 per cent of freehold land was assessed as having nil to minor soil structure decline while only one per cent of the land was assessed as having severe soil structure decline. For tree decline (eg die-back of foliage), the survey found that 40 per cent of private land was affected by moderate to extreme degradation. The least common form of degradation on private land was tunnel erosion for which 5 per cent of land was affected by shallow to deep tunnels.

Overall, the state-wide results cannot be easily compared. Nevertheless, the coverage of each of the studies to include the less visible forms of degradation such as soil structure decline, induced soil acidity and dryland salinity indicates that these substantially on-farm forms of degradation are now considered important land management issues along with the more traditional forms of wind and water erosion. Obviously irrigation salinity is confined to irrigation areas and adjacent areas sharing common underground water systems.

Studies of particular regions or forms of degradation

While state or nation-wide studies can provide a broad picture of degradation, in order to fully understand degradation and its advance, it is necessary to look in more detail at individual locations or regions, and at individual forms of degradation.

There are a number of studies that have done this. The Commission has considered studies relating to irrigation salinity in the Murray-Darling Basin, dryland salinity across Australia and soil acidification (see Appendix C).

The studies indicate that under current land management practices these types of degradation will continue to advance. For example, irrigation salinity could increase over the next 30 to 50 years in the Riverine Plains Zone of the Darling Basin, spreading at rates of between 1 per cent and 3 per cent (per annum) during the 1990s. Estimates of the rates of increase for dryland salinity are not available, however across Australia the current level affected is estimated to be half of the potential level. Degradation from induced soil acidity could advance at between 0.2 per cent and 1 per cent (per annum) in New South Wales, depending on soil types.

Comparability of studies

One concern for the development of an overall view of degradation and its severity is the substantial differences between the estimated areas affected by degradation provided by the various detailed studies and the state-wide reports (see Appendix C). For example, the New South Wales SCS survey estimated that induced soil acidity (ranging from severe to highly acidic) affected around 2.8 million hectares whereas an AACM (1995) study found that there were around 13.5 million hectares of highly acid soils in New South Wales. However, for Victoria, the state study estimate of strong and extremely acid soil is 4.6 million hectares compared to the AACM estimate of 3 million hectares. In the case of dryland salinity a similar variable estimate is provided from a comparison of possible sources. In Victoria, the Land and Water Resources

R&D Corporation *et al.* (1992) analysis reported an estimated 135 thousand hectares of area affected, whereas the state report estimated 100 thousand hectares. In addition, data for New South Wales and Western Australia differed between sources.

In principle, it should be noted that the different estimates reflect the incidence of more intensive surveys, improvements in recognising the occurrence of degradation, different reference periods and different definitions. Thus, technical explanations could describe the somewhat different pictures of degradation provided by the different analyses. To take a forward looking land management perspective, an integrated and consistent view of the extent of degradation and its advance, would require comprehensive and consistent data sources assembled for common reference periods.

A closer look at land degradation survey information for New South Wales

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, the Commission analysed the New South Wales 1987–1988 survey data to obtain a regional disaggregation of land degradation. 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 149 SLAs with substantial agricultural activity (see Appendixes B and C). A composite index for all degradation types shows that the SLAs with the highest levels of degradation lie in an area extending from Goulburn in the South Eastern Highlands across SLAs in the South Western Slopes to the Riverina.

Of the ten types of degradation surveyed, four types — irrigation salinity, dryland salinity, induced soil acidity and soil structure decline — were selected for further analysis. For each of these types, separate indexes of degradation were estimated by SLA. The index results indicate substantial differences in the incidence of degradation across SLAs (see Figure 4.1). 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 across the South Eastern Highlands to the South Western Slopes. These regions tend to have higher rainfall, high levels of cleared land and sloping countryside, all of which make them more susceptible to dryland salinity than other SLAs in New South Wales. Irrigation salinity, as expected, is concentrated in the irrigation areas of the Riverina.

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. However, there is 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 focussed 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.

An important longer-term issue in understanding the processes of degradation, concerns the combination of farm management decisions and regional biogeographical characteristics that characterise the grouping of SLAs exhibiting potential induced soil acidity and moderate soil structure without also exhibiting severe cases of these forms of degradation. Are these SLAs in transition to more severe degradation , or is there biogeographic and land management reasons why severe degradation was not observed or has been avoided?

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

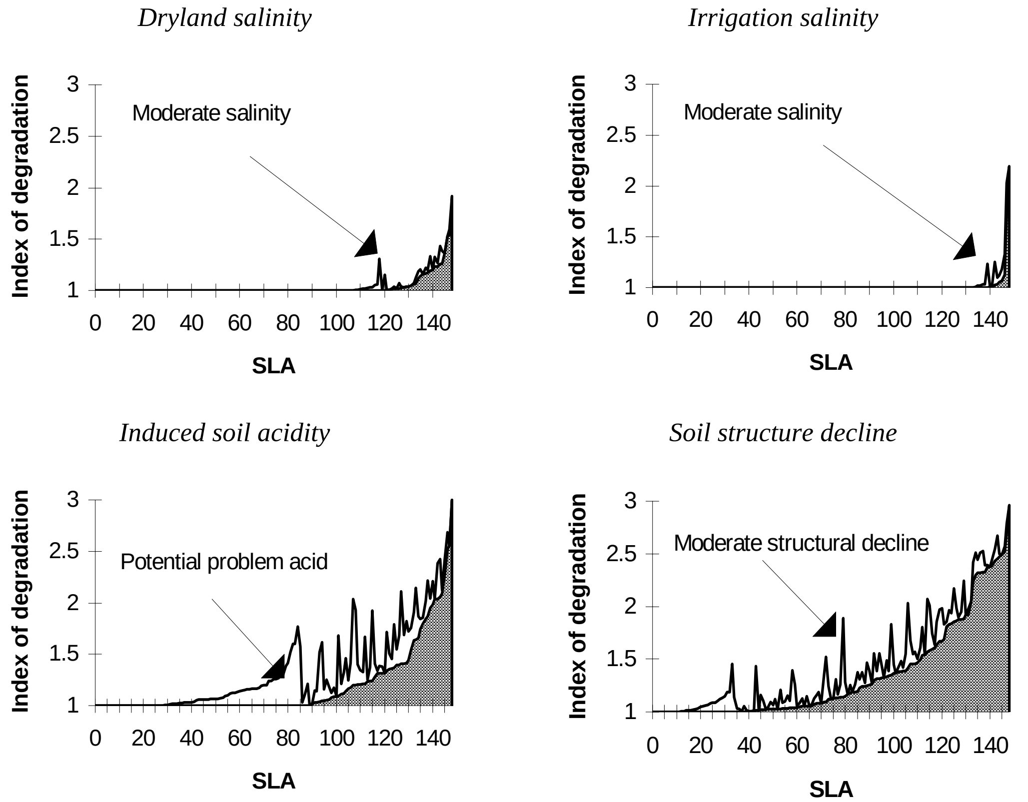
4.3 Production loss from land degradation and cost-benefit analysis of amelioration works

Implicit in the concept of land degradation is the notion that agricultural land use removes some useful ingredients from the land bringing about a deterioration in its quality and reducing its productivity. To assess the impact of land degradation, it is relevant to estimate the loss in economic value due to degradation. Two approaches have been traditionally followed. One approach is to estimate the potential productivity of the land, without degradation, in its current use. The concept of a ‘production equivalent of degradation’ is useful in translating a measure of the incidence of degradation into a standardised numeraire, that is, dollars of production or revenue. The other approach involves analyses of the cost of repair and conservation activities and future benefits expected from those activities.

A number of studies report estimates of the production equivalent of degradation. They range from a national average of 5 per cent of the value of agricultural production for all types of degradation to 6 per cent for sheet and rill erosion alone in the Lachlan catchment of New South Wales (see

Appendix E). The estimated reduction in the value of farm output of around $1.5 billion (Keating 1995) is consistent with these national averages.

Figure 4.1: **Index of land degradation by type of degradation and agricultural SLA in New South Wales,[abc] 1987–1988**



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 that 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.

In the interpretation of production equivalent measures, it should be noted that they are static measures compiled using restrictive assumptions that ignore benefits that have accrued to the community from agricultural production with higher levels of degradation, as well as the productivity of farming systems operating in localities where degradation occurs. The measure is also not a true reflection of the current cost of degradation because some types of degradation occur as a result of more productive farming systems. Thus, production equivalents do not take into account the fact that some degradation is likely to occur as farming systems become more specialised (such as irrigation farming and irrigation salinity) and other forms occur as unintended side effects of previous conservation efforts (eg improved pastures and induced acidity). Nevertheless, the production equivalent measures indicate clearly that the usefulness of some elements of the landscape is reduced by degradation.

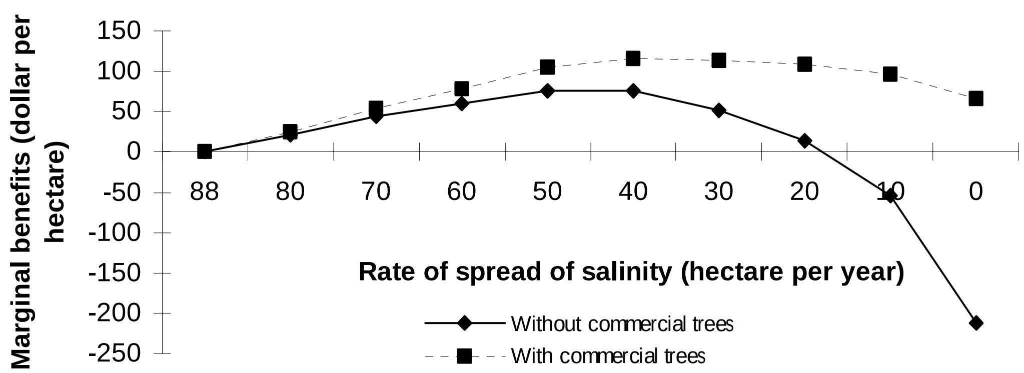
For the assessment of the economic value of repairing and avoiding degradation, a cost-benefit approach is required, which compares the present value of the costs of some action against the present value of improved land productivity (ie the benefits). A number of studies are available of the analysis of costs and benefits of degradation amelioration. Studies concerned with irrigation salinity in the Murray Darling Basin, dryland salinity in Victoria and Western Australia and induced soil acidity are considered in this discussion paper (Appendix E). The broad conclusion derived from these studies is that although conservation works may yield positive net benefits, the highest social returns can be obtained by slowing down the rate of degradation rather than halting or reversing it. Within the sample of studies examined, on and off-site benefits are reported for irrigation salinity repair and prevention activities. In those analyses, most benefits are reported as coming from on-site improvements in land productivity. For example, in an examination of irrigation salinity control measures, and land management schemes in the Murray Basin, the ratio of estimated off-site to total benefits ranged from 10 per cent to 25 per cent depending on assumptions that are made about the mix of schemes (Murray-Darling Basin Ministerial Council 1987).

The studies also indicate that conservation work targeted at maximising bio-physical objectives could lower potential economic returns. For example, in the study of salinity control measures in the Murray Basin, the selection of measures to maximise income showed the potential to reduce river salinity by 12 per cent (from prevailing levels) and provide additional income, including estimated off-site benefits, with a net present value of $290 million (1985–86 prices). On the other hand, the rearrangement of schemes to maximise the reduction in river salinity provided potential reductions in river salinity of 20 per cent from prevailing levels. In the latter case, greater off-site benefits were obtained at the expense of on-site benefits, so that the net present value of the potential income was estimated to be reduced to $124 million (assuming a discount rate of 5 per cent for public works and 10 per cent for private works).

Achieving some predetermined bio-physical objective may not be economically feasible once account is taken of the costs and benefits to agriculture. For example, a cost-benefit analysis concerned with the control of dryland salinity in the Neridup catchment, located north-east of Esperance 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 4.2). 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 study also considered the sensitivity of the results to the introduction of commercial forestry. 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 4.2)

There is a fair degree of variation in the cost-benefit methodologies adopted in the studies examined. One common feature is the adoption of a real social discount rate to estimate the present value of future streams of costs and benefits. Because of the adoption of different discount rates, over different time periods and for different regions, comparison between studies is not possible, or indeed appropriate.

Figure 4.2: **Marginal net benefits from controlling dryland salinity with and without commercial trees[ab]**



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).

Another common feature is the assumption that relative prices are unchanged. Under this assumption, the methodologies capture changes in the volume of inputs (costs) and outputs (benefits) arising from degradation repair and prevention activity. However, for any given discount rate, they do not capture the effects of relative price changes. A change in the terms of trade would alter the attractiveness of agricultural activities compared to other activities in the economy, and hence the attractiveness of investing in agriculture through for example, land degradation repair and prevention.

With no changes in the terms of trade, the money values of a unit of output would purchase the same bundle of materials, labour and capital inputs in the future as in the current period. With declining terms of trade, the money value of a unit of output would buy fewer inputs in the future. With an improvement in the terms of trade, additional inputs could be purchased with a unit of output or profits could be increased. Possible changes in the relative value of industry outputs, relative to the costs of inputs is not explicitly taken into account by discounting so that when no explicit adjustment is made for changes in relative prices, it is assumed that cost benefit analyses reflect constant relative prices.

In the presence of declining terms of trade, as has typified Australian agriculture, the methodologies adopted could overstate the possible net economic benefits to the community of environmental conservation projects. By the same token, were the agricultural terms of trade to improve in the future, the method would have the opposite bias and understate possible benefits.

Generally, it has not been possible to provide cost-benefit estimates revised to test the sensitivity of results to possible terms of trade changes. However, for the study into the reduction of induced soil acidity (AACM 1995 discussed in Appendix E), a re-estimation of the benefits of liming (ie a standard treatment for problem acid soils) has been possible. The original study suggests that over a 15 year period (with a real discount rate of 10 per cent), the net financial benefits of liming for wheat production in the Western Slopes of New South Wales has been estimated at $206.50 per hectare with constant terms of trade. Providing for the possible continued decline in agricultural terms of trade, this net benefit would be reduced to $114 per hectare. Industry outlook could therefore have a substantial impact on farmers assessment of land management strategies, given some standard commercial real discount rate.

The problem with off-farm effects of degradation is the inability of other resource users to exclude themselves from those effects (at least without additional costs to themselves). Some studies do take into account the off-site effects of degradation and conservation effort on the productivity of other economic activities. Where this is done, off-site benefits vary in importance. For example, a series of land management schemes to control irrigation salinity in the Murray-Darling Basin were ranked to maximise, on one hand, community income and on the other a reduction of river salinity. These provided net benefits of $626 million and $420 million (1986 prices) respectively (see Appendix E). The first group of projects obtained 90 per cent of the total estimated benefits from local farm based improvements in productivity whereas the second group of projects obtained only 75 per cent of benefits from farm-based projects with the remaining benefits, in both cases, coming from lower river salinity. In a broad economic context, an ecological target of lower river salinity could therefore be obtained by the community by forgoing agricultural income from the farming region.

Overall, the studies considered are oriented towards an economic analysis of the costs and benefits of conservation activities that may occur in an individual locality or region. Where appropriate, the external effects of those activities are incorporated in the analysis. The analyses indicate that most of the benefit from degradation repair and prevention activities would accrue to the community through on-farms returns, even for irrigation salinity projects. Due to the locality specific nature of land degradation, it would be useful to examine impediments to farmer involvement in conservation programs that benefit them.

4.4 An analysis of the state-wide effects of land degradation in New South Wales

Introduction

To make a start towards establishing a state-wide empirical framework for analysing degradation, the Commission has estimated a model of New South Wales agriculture incorporating land degradation. The model uses a snapshot, or a cross section, of the New South Wales agricultural economy in the early 1990s to study the effects of four forms of degradation: irrigation salinity, dryland salinity, soil structure decline, and induced soil acidity. The estimated effects of degradation on production and profits represent a medium to longer-run perspective. An overview of the model is provided in Box 4.1, while details of the model specification and results are provided in Appendix F. The biogeographic regionalisation used in the model estimation is discussed in Appendix B.

Box 4.1: The Commission’s econometric model of New South Wales agriculture

The effects of land degradation are examined using a model of agriculture in New South Wales developed by the Commission. This is an econometric model that is based on the profit-maximising behaviour of individual farmers.

It is assumed that farmers’ choose both their input and output mixes to maximise profits given a level of 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. Because the model is state-wide, it captures in aggregate, a snapshot of the production decisions of all farmers and provides an overview (or state-wide) assessment of agriculture and the effects of degradation.

The model evaluates the responses of farmers to changing conditions on the basis of a cross-section of New South Wales agricultural industry data disaggregated into 149 SLAs. Analytical results therefore are based on a comparison of the variability in farmer responses to relative price changes, given land, labour and degradation constraints. 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: dryland salinity; irrigation salinity; soil structure decline; and induced soil acidity.

In order to account for regional differences in production and income due to interregional biogeographical features, the following seven New South Wales regional dummy variables were included in the model: North Coast; Central and South coast; Tablelands; Central areas; Central-west areas; Western areas; and Irrigation areas.

The model implicitly takes into account the opportunity cost of land degradation to individual farmers. Within its framework, farmers are treated as choosing between either production in the current period at the expense of additional degradation, or lower levels of production at some future, indeterminate, time and less degradation in the current period. Because data are drawn from a cross-section of state agriculture, the estimated effects of degradation on production and profits have a medium to longer-run perspective, even though only data for two years are used.

Production, input and price data are drawn from a combination of ABS and ABARE data sources. The reference years for the analysis are 1991–92 and 1992–93. Land degradation data used in the model were taken from the 1987–1988 Survey of Land Degradation conducted by the SCS of New South Wales. Because of the slow advance of degradation, using data for this earlier year is deemed to provide a useful proxy of the regional intensities of degradation.

The specification of the model, model results and data sources are discussed in detail in Appendix F. The biogeographic regionalisation of New South Wales is discussed in Appendix B.

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 discussion paper should be regarded as tentative. They are presented here to encourage discussion and further analysis.[5]

Econometric model results are determined by an analysis of the variability of farmer responses to land degradation and other factors taken into account in the model. 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 (Table 4.1). 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 their profits (see also Marshall *et al.* 1994). The results are discussed below.

Table 4.1: **Estimated responsiveness of current production and profit due to changing land degradation[ab]**

	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

a Responsiveness in this analysis is estimated in terms of estimated elasticities of production and profit to changes in degradation. An elasticity represents the change in production or profit for a one percent 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 allows the agricultural economy scope to adjust to changes in degradation.

Dryland and irrigation salinity

Dryland and irrigation salinity tend to be isolated to individual points in otherwise productive farming areas although the underlying causes may come

5 For those interested in re-estimating the model or undertaking further reviews of the data and methodologies, the estimation data base and input files to the SHAZAM econometric package are available from the Commission on request.

from underground water tables, aquifer systems and regional farming practices.[6] This confinement of problem salinity would lend support to the notion that farmers could be drawn into high levels of land clearance in areas susceptible to dryland salinity and to irrigation farming even at the expense of some additional salinity problems. This may be particularly so when the farms undertaking clearing or irrigating highly productive lands will not necessarily be the same farms that experience the problem salinity.

Consistent with this perspective, the econometric estimates indicate that higher levels of production could be achieved by a shift toward farming activities that are characterised by higher levels of dryland or irrigation salinity. A shift entailing a 1 per cent increase in the index of degradation due to dryland salinity is projected to raise crop and animal production by around 0.09 per cent with crops increasing fractionally more than animal products. 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 2.3 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. The econometric results tentatively suggest that livestock products would be favoured over crop products. Many factors could be at work in determining this. In the case of dryland salinity, which tends to occur in hillier areas, water accessions may be reduced and water tables controlled by the introduction of deep-rooted perennial plants, such as lucerne. When these pastures are grazed directly, higher livestock output could occur. On the other hand, where plantings are cut for hay, crop production (inclusive of lucerne and grass hay) would be favoured. The estimates suggest that cropping may have a slight advantage over grazing activities. 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 increases. 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.

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. The estimation of land degradation indexes and a further discussion of this problem is provided in Appendices C and F.

Overall, the projected increases in production and profits from higher levels of dryland and irrigation salinity indicate that, at the current level of development of the agricultural industry in New South Wales, there are incentives for farmers who are operating with evident salinity not to move away from those farming activities. The regional groupings identified with these farming incentives would have moderate to severe degradation as identified in Figure 4.1. Similarly, there are incentives for other farmers to move towards those farming activities that co-exist with higher levels of degradation. The regional groups identified with these farming incentives would have nil or minor degradation (ie an index value of one) in Figure 4.1. In practice, the constraining factors to the extension of farming systems subject to irrigation and dryland salinity are likely to be the availability of water for irrigation or land for agricultural use in the higher rainfall areas typically subject to dryland salinity, rather than the adverse effects of these forms of degradation as such.

Induced soil acidity and soil structure decline

Soil structure decline and induced soil acidity tend 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.

Consistent with this perspective, the econometrically 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, albiet possibly to only a minor extent.

For induced soil acidity and soil structure decline, the strategies would necessarily be directed at minimising farm productivity and profit losses from more widespread or more severe degradation. In the case of increases in induced acidity, the estimated substitution of animal products for crops is consistent with the productivity of pastures being, in general, less acid sensitive than crop and plant farming systems. Whereas the estimated, but less pronounced, substitution of livestock for crop production with increased soil structure decline, is consistent with amelioration strategies involving reduced tillage and the establishment of pasture leys within cropping rotations as a means of restoring soil fertility.

The negative effects on output and profit due to these forms of degradation provides some rationale for the large groupings of SLAs with potential soil structural decline and potential induced acidity presented in Figure 4.1. In the case of these forms of degradation, the incentives appear to be against higher levels of land degradation.

Other considerations

When individual localities and regions are severely affected by several forms of degradation, productivity and profit would be jointly affected by each form. The actual outcome for a farming region from increases in land degradation would therefore be dependent on the balance between forms of degradation and the product substitution possibilities for individual farms and localities.

While the Commission’s snapshot analysis of New South Wales data suggests that further degradation of land may increase profit in the medium term, it does not necessarily imply that degrading more land is a sustainable activity in perpetuity given current technologies. On the other hand, because these results are taken from a current snapshot of New South Wales agriculture, they do not take into account the dynamic effects of technological change and other sources of productivity improvement. Technological change and better land management may be able to improve farm productivity and profitability in areas subject to many forms of degradation.

4.5 Conclusion

There are various forms of land degradation with various degrees of intensity. These can have diverse effects on farm output and profitability.

The site-specific nature of land degradation problems means that there are few short-cuts to understanding its incidence and severity. 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 various forms of degradation. There is limited nation-wide data to match this requirement.

Nevertheless, available analyses of costs and benefits of amelioration options for farmers and the community indicate that zero degradation, even if it were deemed desirable from some bio-physical or general ecological point of view, does not necessarily lead to maximum income, as conventionally measured, for the community. Net benefits to society are possible with some positive levels of degradation and even growth in some types of degradation. This result is so, even when off-site (external) effects are considered in the analysis.

The Commission's own empirical study of land degradation also suggests that there are incentives for farmers to co-exist with certain forms of degradation, while there are also positive incentives to avoid some other forms.

PART 2 APPENDICES

APPENDIX A
CLASSIFICATION OF AGRICULTURAL LAND DEGRADATION IN AUSTRALIA

A.1 Introduction

The analysis of land degradation requires a standardised classification of the types of degradation that may be encountered. Such a classification would provide a reference against which benchmark levels might be developed, the prevailing condition of the land resources measured, degradation hazard and potential changes analysed, and costs and benefits of amelioration considered.

Currently, there is no single standardised classification of land degradation although there has been a long history of degradation assessments in Australia. Nevertheless, there are many reports which provide lists of degradation types and their severity, either according to region or for individual types of degradation. While there are common elements between the reports, there are also differences in degradation descriptions and categories of severity. Also there is no standard measurement methodology, measurement unit or time period for reporting adopted by the various monitoring authorities and researchers. Land degradation has also been the subject of broad assessments and evaluations such as McTainsh and Boughton (1993), Land and Water Rural Research and Development Corporation (1995) and in state of the environment reporting by state and Commonwealth governments.

The only Australia-wide study of degradation is provided in Woods (1983). This study, which is for the reference year 1975, assessed degradation in terms of the need for treatment, to focus attention on the integration of prevention and reclamation to improve productivity and maintain environmental amenity. This approach was adopted in preference to a land degradation inventory approach. At the time of the survey, the inventory approach was judged to be of limited use due to the potential subjectivity of such a classification (with terms such as severe and minor often being subjectively assigned), and the absence of a direct link between damage and repair costs. The successful application of the less demanding treatments approach depended mainly on the systematic gathering of experiences gained in applying land degradation control treatments.

On the other hand, the New South Wales Soil Conservation Service survey of land degradation in New South Wales (Graham 1989) adopted an inventory approach in order to catalogue the severity of each form of land degradation, as defined for the survey. A similar approach has since been adopted for the assessment of soil and land degradation on freehold land in Tasmania (Grice 1995). The inventory approach adopted in these studies used a combination of criteria based on the degree of vulnerability of the land to soil erosion, possible future soil loss potential, changes in the physical appearance/characteristics of the land, and the lost service potential due to degradation. The New South Wales survey generally uses as its benchmark the land condition at the time of European settlement 200 years ago (as understood at the time of the survey). The New South Wales methodology, therefore, considers land that has only become degraded as a result of clearing and farming techniques introduced in the last 200 years. It does not consider as degradation land that is inherently poor, such as naturally acidic soils or naturally occurring salt pans or deterioration due to human intervention that occurred before the benchmark period.

In other studies, the concern is with a particular land resource characteristic whether it is naturally occurring or due to human use For example, the Land and Water Resources RDC-commissioned study of the Economic Feasibility of Ameliorating Soil Acidification (AACM 1995) reports total areas having designated acidity levels whether naturally occurring or anthropogenic. Some caution therefore needs to be exercised in making comparisons between studies and attributing land resource characteristics to the effects of human use or natural causes.

Unless otherwise stated, the following definitions of the major types of land degradation, and benchmarks adopted are taken from the Soil Conservation Service (SCS) New South Wales, Land Degradation Survey 1987–1988 (Graham 1989, SCS-New South Wales 1989, and EPA-New South Wales 1993). An initial listing of agricultural land degradation categories by broad physical property is provided in Table A.1. Where New South Wales criteria are not provided, descriptions from other sources are used.

Where source material permits, typical land uses of degraded areas and land vulnerability to further degradation, degrees of severity and management and amelioration possibilities are discussed.

Table A.1: **Types of agricultural land degradation identified by physical property group[a]**

Type of degradation		*Source of definition*
Non-energy mineralisation		
1	Dryland salinity	SCS-NSW survey 1987-1988
2	Irrigation salinity	SCS-NSW survey 1987-1988
3	Induced soil acidity	SCS-NSW survey 1987-1988
4	Heavy metal contamination	Other reports on the environment
Soil structure and erosion		
5	Soil structure decline b	SCS-NSW survey 1987-1988
6	Surface scalding	SCS-NSW survey 1987-1988
7	Sheet and rill erosion hazard	SCS-NSW survey 1987-1988
8	Gully erosion	SCS-NSW survey 1987-1988
9	Tunnel erosion	Dept of Primary Industry and Fisheries, Tasmania (Grice 1995)
10	Mass movement of slopes	SCS-NSW survey 1987-1988
11	Wind erosion hazard	SCS-NSW survey 1987-1988
Biological condition		
12	Woody shrub infestation	SCS-NSW survey 1987-1988
13	Occurence of perennial bush	SCS-NSW survey 1987-1988
14	Tree decline	Dept of Primary Industry and Fisheries, Tasmania (Grice 1995)
15	Clearance of native vegetation	NSW-SCS survey 1987-88 & CSIRO land disturbance survey (Graetz *et al*. 1995)
16	Feral animal and pest invasion	CSIRO land disturbance survey (Graetz *et al*. 1995)
17	Dispersed organic chemical residues and farm waste residues	Other reports on the environment

a A similar grouping of degradation types is provided in McTainsh and Boughton (1993, p.4). The current classification is based on the sources cited in the table with the groupings based on a classification of natural resources in Sweeny (1993).

b The Tasmanian survey includes the item 'Soil structure decline hazard' which is the risk of structural decline due to land use.

Sources: As listed.

The classification of land degradation according to the three groupings identified in Table A.1, are discussed in Sections A.2, A.3 and A.4, respectively. The focus is on land degradation and its effect on the land resource, as it relates to land management in agriculture. Other forms of land degradation also arise (eg due to mining, secondary industry and suburban development) but these forms of environmental degradation are not considered within the scope of this study.

A.2 Induced changes to non-energy mineralisation

Dryland salinity (saline seepage)

Description

> Dryland salinity is the build-up of salt in surface soil on non-irrigated areas usually as a result of rising water tables and subsequent groundwater seepage. (EPA-New South Wales 1993, p. 71)

Dryland salinity occurs on lands which are outflow zones for saline water tables. It differs from saline scalds which result from the removal of surface soil to expose subsoil high in salts. Once saline seepage is established, there is an increased possibility of other types of erosion (eg sheet and rill erosion and gully erosion).

Associated land use and land vulnerability

Dryland salinity can occur naturally. Anthropogenic causes come mainly from the clearance of native forest for agricultural and pastoral production with the final manifestation being dependent on local/regional geology (eg rock formations guiding underground water flows), climate (eg rainfall in recharge areas), soil type (eg regulating the flow of water between the surface and groundwater zones) and farm management. Clearing hillslopes of native vegetation results in more water entering the soil due to reduced transpiration levels of shallow rooted pastures and farm crops in comparison with the native vegetation. Subsequently, the additional water load moves through the soil, dissolving salts which occur naturally in the soil and rock, and flowing laterally underground to emerge on the surface lower down the slope as salty water. The salt becomes concentrated in these outflow patches, as evaporation occurs, resulting in the death of all but salt-tolerant vegetation.

The bare areas so formed become subject to other types of erosion. For example, on grazing land, stock congregate on the sites to lick the salt. The accompanying trampling damages any remaining vegetation and disturbs the surface thus aggravating the erosion problem.

Degree of severity and New South Wales base classification

The severity assessment in the New South Wales survey was based on 100 hectare circles centred on sample points. If there was evidence of more than one severity class anywhere in the area, then the whole circle was assigned to the highest severity value observed. The severity classes and criteria are provided in Table A.2.

Table A.2: **Categories of land degradation due to dryland salinity**

Category	*Description*	*Dryland seepage salinity criteria*[a,b,c]
1	Nil to minor	No obvious signs of salinity.
2	Moderate	Salt-tolerant species present in pasture, crop or watercourse with species varying with climate and season. Pasture and/or crop production and health obviously depressed. Tree vigour reduced. Bare spaces in pastures, but rarely larger than 1 square metre. Brackish or saline water in water courses.
3	Severe	Extensive areas of bare ground larger than 1 square metre. Trees dying or dead. Salt-tolerant species are the only species present. Salt crusts possibly occurring in bare areas.

a Salt tolerant plants include those used for revegetation (eg saltbush).

b Tidal zones of coastal streams are not classified as a form of degradation even though they are brackish.

c Naturally occurring salt lakes are not treated as degradation.

Source: Graham (1989, p. 25).

The gradation from nil to severe degradation in the inventory of dryland salinity is associated with declining land productivity. The inventory of land degradation due to dryland salinity provides a measure of degradation against a benchmark of natural growing conditions 200 years ago (as understood at the time of the survey).

Off-site effects

The borders of recharge, run-off and drainage depressions within a hydrological zone do not necessarily coincide with the boundaries of individual farms and other properties (eg residential areas). Because the land resource is not exclusive to an individual farm, the clearance of deep rooted native vegetation and its replacement with shallow rooted pastures and crops on one farm, to increase its own productivity, may lower the productivity of other farms in run-off areas and drainage basins.

Further, because individual land users are not given exclusive control (through surface area entitlements) of the land resource (including subsurface aquifers), the property rights over all aspects of the land resources within an entitlement may not be very well established. The productivity of individual farms, and its capital value, would therefore depend partly on the management of the farm, and partly on its proximity to common resources and the use made of those resources by others.

The off-site effects of dryland salinity can extend beyond the farm and local area as the increased level of free salts on the surface may be washed into streams and rivers. In addition, soil run-off due to secondary erosion could enter streams and rivers. Secondary erosion could occur once dryland salinity has reduced plant growth and increased the hazard of the soils to wind and water erosion.

On-farm management and amelioration possibilities

Despite the fact that individual farms may not have exclusive use of the full land resource because of the incidence of saline seepage, a number of possible treatments come from on-farm managements practices designed to limit degradation. For example, on-farm treatments include:

- reducing stocking rates or totally excluding stock from the effected area;
- using salt tolerant grasses, herbs, shrubs and trees on saline areas;
- surface mulching using old meadow hay or straw to facilitate moisture penetration;
- surface tillage or deep ripping of the site to assist plant germination;
- subsurface drainage to lower the water table;
- strategic soil conservation works (eg installation of interceptor banks to divert water away from a drainage basin) to isolate affected sites from runoff and the risk of secondary soil erosion; and
- changes to the management of the subcatchment (as it is located on an individual property) to incorporate high water using pastures (eg deep rooted perennial species) and regeneration of timber on groundwater intake zones.

In a broader context, changes in management practices over a subcatchment resource may reduce the incidence of saline seepage in individual parts of the catchment. While a range of catchment wide and individual farm management strategies are available, it is important to determine which strategies or combination of strategies, provides the greatest farm and community income gains at least cost.

Irrigation salinity

Description

> This is salting associated with irrigation land. Soils become saline when soluble salts are concentrated in the surface horizon as a result of rising water tables. (SCS-New South Wales 1989, p. 26)

The rising water levels are caused by the application of water additional to the requirements of crops and pasture. Excess water percolates to the water table, causing ground water levels to rise, thus bringing the salts into contact with vegetation. The soluble salts may come from a number of sources including: dissolved salts in the irrigation water; salt in the soil profile that is redistributed in regional groundwater systems through downward water movement; and lateral flow from an impounded source (eg channels or rice paddies) or pumped from sub-artesian sources.

Associated land use and land vulnerability

Irrigation salinity occurs in areas in which irrigation farming is widespread. Areas most susceptible to salinity problems are those with underlying aquifer systems where the natural water table is relatively close to the surface and the soil is mainly imperviable clay (eg as in the Riverina Plains of southern New South Wales and north central Victoria). For areas under flood irrigation that incorporate constructed surface bays, the risk of salinity is increased by the absence of subsurface drainage.

Degree of severity and New South Wales base classification

As for saline seepage, the severity assessment in the New South Wales survey was made for an 100 hectare circle centred on survey sample points. If there was evidence of more than one severity class anywhere in the area then the whole circle was assigned to the highest severity value observed. The severity classes and criteria are provided in Table A.3.

Each of the categories identified in the inventory of irrigation salinity relates in some way to declining land productivity. The inventory of land degradation due to irrigation salinity provides a measure of degradation against a benchmark of no irrigation.

Off-site effects

Within an irrigation area, access to water tables and underground aquifer systems may not be defined by land surface entitlements. The property rights of individual farmers over surface areas, therefore, will not define access or otherwise to subsoil resources relevant to irrigation farming. Therefore individual farms may not be able to fully protect themselves from the actions of other farms working on the same or related hydrological systems.

Further, off-site effects extend outside of the local area affected by irrigation salinity. The run-off from areas affected by irrigation salinity contain higher than average levels of salts and other ground minerals, farm fertilisers and chemicals. The run-off lowers water quality in rivers, streams and underground water reserves. The utility of the affected water is reduced for downstream agricultural use, other industries and household consumption.

Table A.3: **Categories of land degradation due to irrigation salinity**

Category	*Description*	*Irrigation salinity criteria*[a]
1	Nil to minor	No obvious signs of salinity. The saline water table is greater than 5 metres from the surface.
2	Moderate	Salt-tolerant species present in pasture, crop or watercourse with species varying with climate and season. Pasture and/or crop production and health obviously depressed. Tree vigour reduced. Bare spaces in pastures, but rarely larger than 1 square metre. Brackish or saline water in water courses (including revegetated areas).
3	Severe	Extensive areas of bare ground larger than 1 square metre. Trees dying or dead. Salt-tolerant species are the only species present. Salt crusts possibly occurring in bare areas. Includes saline lakes that may have encrusted salt on the shore. Watertable above the surface or fluctuates and is within the root zone of plants (ie less than 2 metres).

a Salt tolerant plants include those used for revegetation (eg saltbush).
Source: Graham (1989, p. 27).

On-farm management and amelioration possibilities

The basic treatment for irrigation salinity is through the lowering of water tables below the root zones of pastures and crops. This may be achieved in a number of ways including: changes in irrigation practice so that only enough water for the needs of crops and pasture is applied; substitution in favour of crops and pastures needing less irrigation water; and surface management (eg deep drainage channels). The later method may not be very effective in containing and controlling water tables in the most affected districts as water in saturated areas will tend to seep to unsaturated areas.

Where water tables are already high and are restricting production, mechanical systems can be installed/used to divert saline waters and lower water levels. This process could have negative off-site effects if the drained water is allowed to enter unfiltered into the stream and river system. To counter such adverse off-site effects, saline water may be diverted to evaporative basins (eg through salt interception schemes). These systems might be implemented at the farm or regional level.

Induced soil acidity

Description

> Soil acidity is a process or set of processes whereby the level of hydrogen ions or certain toxic elements increases when compared to the pristine land condition. (SCS-New South Wales 1989, p. 29)

This definition is concerned with induced (or additional) acidity, rather than the absolute level of acidity. The New South Wales land degradation survey adopted the induced acidity approach, while some soil studies look at the total level of soil acidity whether naturally occurring or induced (eg Land and Water Resources RDC 1995). From the point of view of this study, it is acidity induced by human use that is relevant.

Associated land use and land vulnerability

Many soils are naturally acidic. Other soils may become acidic by the use of acidifying nitrogen fertilisers; the use of legume dominated pastures which fix high levels of nitrogen in excess of pasture requirements; the nitrification of soil organic compounds and their subsequent leaching from the root zone; the removal of alkaline products and waste (eg manure); and increased soil organic matter.

Induced soil acidity affects the chemistry of the soil which in turn affects land productivity as the relative level of soil nutrients and their availability to plants varies with soil pH levels. Problem acid soils are often characterised by a pH of less than five (measured in a calcium chloride solution). The effects of acid soils include the release of elements that are detrimental to pasture and crop growth. For example, levels of aluminium or manganese increase when the pH level falls below five. The resulting decreased ground cover increases the susceptibility of the land to other forms of soil erosion.

Degree of severity and New South Wales base classification

In order to estimate induced soil acidity in the New South Wales survey, a four hectare quadrant around each sample point was assessed. If more than one severity class occurred within the quadrant, then the most severe class was recorded. The assessment was a function of local specialist knowledge of soil pH in farm paddocks compared with undisturbed areas, soil buffer capacity (high buffer capacity soils being more resistant to pH decline than lower buffer capacity soils) and the presence of toxic elements (particularly exchangeable aluminium).

The severity of induced soil acidity in New South Wales was divided into three classes (see Table A.4).

The categories identified in the inventory of soil acidity relate either to a potential induced acidity problem (Categories 1 and 2) or to severe acidity (Category 3). The inventory of land degradation due to induced acidity provides a measure of degradation against a benchmark of natural conditions in the locality of the survey point. The overall assessment is productivity based since problem acid conditions are defined in terms of their potential to restrict plant growth and farm output potential.

Off-site effects

The off-farm effects that could occur as an indirect consequence of induced acidification potentially include:

- dissolved organic carbon from soil acids moving into streams and reducing water quality;
- potential risk of heavy metal contamination or low product quality; and
- reduced plant growth and water use in upper parts of the landscape where acidification is often severe, increasing the flow of water to the water table thus increasing dryland salinity in run-off areas and drainage basins. (Hamblin and Williams 1995).

Incidental run-off from individual farms could not be easily excluded from surrounding environmental amenities such as streams and rivers.

Table A.4: **Categories of land degradation due to induced soil acidity**

Category	*Description*	*Induced soil acidity criteria*
1	None	**No soil acidity problem** Well or highly buffered soils. Includes highly alkaline soils. Problem unlikely to develop. Can tolerate moderate acid condition.
2	Potential to become acid	**Soils which are not problem acid, but which are likely to proceed to severe acidity with inadequate management** Soils with a low to medium buffer capacity which cannot tolerate repeated acid addition. Soils which do not have problem acid properties although similar soils may be classified as problem acid. Soils at hazard of becoming problem acid with current land use.
3	Severe	**Soils which are classified as problem acid or affected by chemical toxicities.** Soils are included if: They have a topsoil (0-10 cms) pH <=5.0 ($CaCL_2$) pH 5.5 (water solution);[a] or the agricultural soils have an average pH of more than half a pH unit *less* than adjacent non-agricultural (virgin) soils;[b] or the soils have a significant level of chemical toxicity that has developed with recent land use with a corresponding decline in vegetation.[c]

a Soils that have these pH levels under undisturbed conditions are included in category 1.

b Such lower pH value soils are often associated with a history of pasture improvement generally extending over 30 years of intensive farming where ammonia based fertilisers have been regularly used.

c Toxicities can include exchangeable manganese and aluminium. Such soils may not necessarily have as large a pH decline as some other acid soils included in category 3. The soils may have naturally low pH levels.

Source: Graham (1989, p. 31).

On-farm management and amelioration possibilities

Acidification can be treated by changes to farm management practices, such as:

- liming with an appropriate rate and method of application (including a suitable quality lime, applied at the correct time and with effective incorporation into the soil);
- use of acid tolerant species; and
- changes in the management of farming systems to reduce the rate of acidification (including modifying fallow practices, using deep rooted,

non-legumous perennial pasture species and ammonia based fertilisers, and increasing grass levels in legume pastures).

Heavy metal contamination

Description

Abandoned cattle tick and sheep dips can carry high levels of arsenic. These sites are particularly common in the eastern and southern grazing lands of Australia (Hamblin and Williams 1995). These sites are amongst a broader group of contaminated sites arising from agricultural, mining, industrial, commercial and household land uses (eg acid/alkali plant and formulation, asbestos production and disposal, chemical manufacture and disposal, service stations, tanning and associated trades (EPA-New South Wales 1993)).

In addition, Hamblin and Williams suggest that cadmium is a potential concern in products from phosphate-fertilised land. However, they point out that there has been a recent voluntary regulation of the cadmium content of imported rock phosphates and the practical damaging extent of the problem is not known.

Off-site effects

The environmental impact of contaminated sites generally depends on the contamination involved, the characteristics of the site, its ecosystem, land use and range of potential recipients of the contamination. As with organic farm chemicals, contamination can be carried in media such as farm produce, dust particles and water. Initially contamination is site specific. The off-site effects would come from secondary pollution and ingestion.

A.3 Induced changes to soil structure and erosion

Soil structure decline

Description

> Soil structure is produced by the arrangement of soil particles and the air spaces between them. ... Soil structure decline refers to undesirable changes in this structure as a result of various land use practices. (SCS-New South Wales 1989, p. 20)

A stable soil is important for optimal water infiltration and aeration, and to allow seedlings to emerge and plant roots to grow. Soil structure decline inhibits these processes through plough pan at the base of the cultivation layer and compression. A stable soil structure also reduces susceptibility of soil to other types of degradation.

Associated land use and land vulnerability

The most substantial changes can be attributed to cropping practices. Tillage machinery can pulverise the soil aggregates and generally compact the soil. Eventually, a very dense layer (referred to as 'plough pan') forms at the base of the cultivation layer. The amount of soil organic matter, part of soil structure and fertility, is also reduced by tillage.

Trampling by stock also causes a decline in soil structure, but this effect is generally less severe than effects arising from the use of cultivation machinery.

Different soil groups differ in susceptibility to structural decline. Fine sands, silts and medium sands have little structure to begin with and therefore their structure would change little with farming. Coarse sands, loams and sandy/loamy soils (eg light textured brown soils, skeletal soils and red brown earths), and clays and clay loams are more structured and therefore can be degraded structurally in the short term. With appropriate management, structure can be re-established in the longer term.

Degree of severity and New South Wales base classification

In order to estimate the severity of soil structure decline in the New South Wales survey, a four hectare quadrant around each sample point was assessed. If more than one severity class occurred within the quadrant, then the most severe class was recorded. The severity of structural decline at each sample point was determined by considering the land use, cultivation history and intensity (with an initial assumption that the longer an area had been cropped, the greater the cultivation cycles and the greater the degree of degradation), evidence of hardpans, surface crusts, vulnerability of local soil types to structural decline, land use rotations and local knowledge. Assessments were made in comparison to benchmark undisturbed sites in the vicinity of each survey point. The degree of soil structure decline was recorded according to the following regime (see Table A.5).

Table A.5: **Categories of land degradation due to soil structural decline**

Category	*Description*	*Structural decline criteria*
1	Nil to minor	Soils are essentially undisturbed or exhibit the same structural conditions as undisturbed soils.
2	Moderate	Soils show minor structural decline problems which may include a slight hardpan which does not significantly impede root growth or some surface disaggregation from stock trampling.
3	Severe	Soils exhibit several indicators of structural decline including a hardpan which restricts root growth, surface crusting, surface disaggregation (powdering) and lack of macro pores.

Source: Graham (1989, p. 33).

The ranking of the categories identified in the inventory of soil structure decline relates to declining land productivity. The inventory of land degradation due to soil structure decline provides a measure of degradation against a benchmark of naturally occurring soil conditions.

Off-site effects

To the extent that soil structure decline on an individual land holding increases soil erodability on that holding, structural decline can contribute indirectly to off-site degradation through the off-site effects of secondary erosion (eg water and wind erosion).

On-farm management and amelioration possibilities

The treatment for soil structure decline is essentially an on-farm management issue. Soil structure decline may be reversed by the establishment of vigorous pasture that includes fibrous rooted grasses. On cropping lands, the on-farm amelioration possibilities include:

- integrating pasture leys within the cropping rotation;
- using reduced tillage, no-till or direct drill practices which are most effective in moderately textured red-brown earths;
- using green manure crops to increase the organic matter content of moderate to light textured soils; and
- breaking up plough pans or compacted soils by deep ripping, although the benefits of this practice may rapidly disappear in soils with high silt and fine sand content.

Surface scalding

Description

> Scalds are bare unproductive areas, varying in size from a few square metres to hundreds of hectares. They form when the surface soil is removed by wind and water erosion, exposing a more clayey subsoil which is relatively impermeable to water. (SCS-New South Wales 1989, p. 16)

Associated land use and land vulnerability

Scalds are a typical erosion form on duplex, or texture-contrast, soils in arid and semi arid regions and are often associated with the floodplains of major rivers and streams. Duplex soils have highly erodable topsoils built up by sand and loam deposited by wind and water, and once these materials are eroded scalds form.

Scalds are most common in arid and semi-arid grazing country which characterise the rangeland areas. They reduce the land productivity by restricting vegetation growth on the bare compact surface. Scalds can be used for dam or tank catchments, although overall this provides limited compensation for the degradation. Scalds are difficult to regenerate because of lack of topsoil and poor moisture availability. The surface has few cracks for seeds to lodge and is often saline.

Scalding caused in the above ways is treated separately from scalds caused by dryland and irrigation salinity.

Degree of severity and New South Wales base classification

Scalding was assessed in the New South Wales survey for an area within 100 hectares of survey sample points. Three classes of severity were recorded based on the proportion of scalded land within the circle (Table A.6).

Table A.6: **Categories of land degradation due to scalding**

Category	*Description*	*Scalding criteria*
1	Nil to minor	Less than 5% of the 100 hectares scalded.
2	Moderate	5 and less than 50% of the 100 hectares scalded.
3	Severe	More than 50% of the 100 hectares scalded.

Source: Graham (1989, p. 28).

Each of the categories identified in the inventory of scalding is determined by the physical appearance of the land. The inventory of land degradation due to scalding provides a measure of degradation against a benchmark of no scalding.

Off-site effects

The direct effects of scalding are localised with the possibility of some erosion creep across farm boundaries. Nevertheless, once the ground is subject to scalding there is vegetation loss and it becomes vulnerable to other forms of erosion such as wind, sheet and rill erosion. To the extent that these erosion types combine with scalding, the off-site effects would be similar to those for the other erosion groups.

On-farm management and amelioration possibilities

Scalding is a localised form of land degradation and the amelioration possibilities are therefore also localised. Rehabilitation techniques aim at improving the infiltration of runoff water into the scald surface, trapping windblown seeds and providing an improved environment for seedling growth. For example, water ponds are used to reclaim scalds as they improve the moisture regime by holding runoff water on the scald surface where it can be slowly absorbed. The addition of water also reduces surface salinity and forms an uneven surface which is conducive to revegetation.

Revegetation also depends on an abundant supply of fertile seed. While annual plants establish themselves quickly, to achieve durable regeneration, it may be necessary to reintroduce perennial species such as saltbush by hand sowing or seeding.

Sheet and rill erosion

Description

Sheet and rill erosion are two of several forms of land degradation resulting from flowing water. They mainly occur on sloping land where there is insufficient ground cover to prevent soil loss.

> Sheet erosion involves the removal of a fairly uniform layer of soil from the land surface by raindrop splash and/or runoff. No perceptible channels are formed. Rill erosion is the removal of soil by runoff, with numerous small channels, generally up to 30 cm deep being formed. (SCS-New South Wales 1989, p. 4)

Associated land use and land vulnerability

Sheet and rill erosion are most severe on cultivated lands. Rill erosion typically occurs on recently cultivated or disturbed soils. It also occurs on grasslands where pasture cover is minimal or when pastures are cultivated for resowing or establishment of fodder crops. Similar problems exist in tree plantations during stages of site preparation and planting.

Sheet and rill erosion can be most significant at the end of a drought when vegetation cover is negligible and significant amounts of topsoil carrying organic matter, phosphate fertiliser and reactive clay that make up the majority of the soil's fertility can be lost (Hamblin and Williams 1995).

The New South Wales survey considered these two erosion forms together because farm management techniques for controlling them are usually the same.

Degree of severity and New South Wales base classification

The visible effects of sheet and rill erosion can disappear soon after they occur. Therefore, the New South Wales survey assessed land degradation due to sheet and rill erosion by estimating the vulnerability of land to sheet and rill erosion. The estimated degree of vulnerability is referred to as the erosion 'hazard' prevailing under current land use, land condition, soil type, and climate. However, the estimate of hazard does not measure the erosion that has occurred in the past, nor does it predict the erosion that could occur with a shift to highly exploitative land management practices or climatic extremes.

Hazard is indicated using a modified form of the Universal Soil Loss Equation (USLE). The USLE adopted by SCS-New South Wales uses five factors: rainfall erosivity (R); soil erodibility (K); slope length and gradient (LS); ground cover (C); and management practices (P). Hazard was evaluated in the model:

$$A = R * K * LS * C * P .$$

The estimated rate of soil loss (A) is measured in tonnes per hectare per annum (see Table A.7).

Table A.7: **Estimated soil loss hazard from sheet and rill erosion, sample land uses and topographical situations for soil loss categories**

Class	*Calculated potential soil loss (t/ha/yr)*	*Sample land use and topography*
1	< 1	Most pasture and timbered lands.
2	1 to 5	Flat to gently sloping cropping land with banks, and poor and/or very poor pastures
3	5 to 10	Banked cropping land and some gently sloping cropping land without banks.
4	10 to 25	Steeper cropping land.
5	> 25	Cropping on steep slopes or in areas subject to high run-on rates.

Source: Graham (1989, p. 17).

Each of the land degradation categories identified relates to the vulnerability of the land to sheet and rill erosion. Lands having the best vegetation cover are the least vulnerable. Due to the periodic exposure of soil, cropping lands are ranked as having a higher soil erosion hazard than pasture lands. The inventory of sheet and rill erosion hazard is measured against an implicit benchmark of no sheet or rill erosion hazard.

Off-site effects

When sheet and rill erosion occurs, there is a transfer of soil from the degraded site to other sites. This process can lead to silting of rivers and water ways and secondary degradation through pollution of the environment. The organic matter, fertilisers and chemicals when carried into the water ways can reduce water quality. The reduction in water quality caused by erosion and other factors can have serious side effects such as the growth of blue-green algae and destruction of coral in the Great Barrier Reef.

However, on-farm sheet and rill erosion is not the only source of reduced water quality from the erosion of bare lands. Clay moving from earthworks and unsealed roads into waterways could contribute a greater silt load in watercourses than clay coming from exposed farms (Hamblin and Williams 1995).

On-farm management and amelioration possibilities

Sheet and rill erosion is largely an on-farm problem, although having occurred, run-offs of soil would affect other farms and increase sediments in river systems.

Management and treatment involve maintaining a good ground cover of grasses, herbs or leaf litter. On cultivated lands soil conservation and structural works such as contour banks can be used to reduce the velocity of surface run-off, divert run-off to safe disposal sites, and contain sediment within channel banks. Tillage on natural contours can also prevent sheet and rill erosion.

Crop and soil management practices that reduce on-farm sheet and rill erosion on cultivated land include: changes to rotations to reduce the number of cultivations; stubble retention to protect the ground surface; green manuring to improve organic matter levels; and reduced or non-tillage systems which involve the use of non-residual herbicides to control weed growth and reduce the level of soil disturbance (although the use of additional chemicals may have its own adverse effects).

On grazing lands, ground cover can be improved by adjusting stocking rates and removing stock when ground cover falls below critical limits, evenly distributing grazing points and applying fertilisers, including trace elements for known deficiencies. If erosion levels are severe, constructing works to control surface runoff across bare areas and assist revegetation can be used for soil conservation.

Gully erosion

Description

> A gully is an open incised erosion channel down which water flows during or immediately after rain.
>
> Gullies are generally deeper than 30 cms. Any erosion channel less than this depth is classified as rill as it can usually be removed by tillage. Areas of stream bank erosion are included in the assessment of gully erosion. (SCS-New South Wales 1989, p. 6)

The major effects of gully erosion are the removal of fertile topsoil layers, sedimentation of creeks, rivers and water supplies, and the formation of pathways for the removal of sediments from adjacent areas.

Associated land use and land vulnerability

Gully erosion occurs when small rill streams unite to create a stronger flow. It is evident in cropping and grazing country under similar conditions to sheet and rill erosion. To graduate from sheet and rill erosion to gully erosion, there needs to be added soil loss potential either due to higher rainfall, additional soil erodibility (which occur with sandy or light textures soils), steeper slopes and/or longer gradients, greater ground cover depletion or deficiencies in management.

Degree of severity and New South Wales base classification

The New South Wales assessment included only active gullies and stream bank erosion because the processes which produce it are similar to those occurring in gully walls. Gully erosion was classified into seven categories of active erosion with the level of severity reflecting the current physical appearance of the land (Table A.8).

Table A.8: **Categories and description of gully erosion by density of gully**

Category	*Description*	*Gully density (metres/100 ha)*
1	Not appreciable	less than 10
2	Minor	10 to less than 100
3	Moderate	100 to less than 500
4	Moderate to severe	500 to less than 1000
5	Severe	1000 to less than 2500
6	Very severe	2500 to less than 5000
7	Extreme	more than 5000

Source: Graham (1989, p. 19).

Each of the categories identified in the inventory of gully erosion is determined by the physical appearance of the land at the time of measurement. The inventory of land degradation in this case provides an absolute measure of gully erosion with the implicit benchmark being no gully erosion.[1]

Off-site effects

These effects are similar to those of sheet and rill erosion and include transportation of topsoil to new locations, sedimentation of rivers and creeks, discolouration and contamination of water caused by clay materials carried in the suspension formation of pathways for the removal of sediments from adjacent areas, and the destruction of public facilities such as roads.

1 This benchmark however would not necessarily imply that there was no gully erosion 200 years ago.

On-farm management and amelioration possibilities

On-farm effects include: the removal of the more fertile top layers of soil; lowering of the water table which can adversely affect plants in adjacent areas (in contrast to salinity where the presence of a rising water table is the problem); reduction of the area of arable land; the division of land into smaller parcels increasing the costs of farming operations; and damage to farm improvements (such as fences traversing erosion gullies).

Gully erosion is linearly concentrated in comparison to sheet and rill erosion and while gully erosion is restricted to areas with a concentration of water flows, such areas would not necessarily be confined to individual holdings. Therefore, without containment strategies on a degraded holding or an adjoining holding sharing the same drainage channels, the erosion would spread between properties.

A number of on-farm management practices are available for treating gully erosion. These treatments may include soil conservation earthworks and the adoption of management practices that better match the capability of the land. Changing management practices can involve changes in land use. For example, eroded cropping land can be rested by converting it to fallow land, grazing land or possibly allowing the return of native forest. Grazing land may be used less intensively or withdrawn from production to allow reafforestation to take place.

Tunnel erosion

Description

Tunnel erosion is:

> ... the transportation of sub-surface soil by water while the surface remains relatively intact. It relies on the seepage of water into dry soil causing dispersion of soil particles into suspension. The dispersed soil is then removed by seepage until the seepage path gradually enlarges to a tunnel. (Grice 1995, p. 32)

The transported material emerges through a gully wall, an embankment, or is forced to the surface through hydrostatic pressure. Tunnels enlarge during wet periods and eventually collapse in the normal course of events to form gullies or potholes.

Associated land use and land vulnerability

In Tasmania, tunnel erosion is largely confined to the south of the state in areas dominated by Permian mudstone and Triassic sandstone. The tunnels form in complex parent rocks with interbedded sequences or with rapid internal drainage, depending on the nature of local subsurface systems.

The major problem identified with tunnel erosion is the hazard to livestock and traffic plus the tendency for tunnels to form gullies.

Degree of severity in Tasmanian base classification

Tunnel erosion was assessed by inspection of the extent of erosion in a typical 100 hectare zone of a land system or its component. Tunnel erosion was classified into three categories of severity reflecting the incidence of this form of degradation (Table A.9)

Table A.9: **Categories and description of tunnel erosion by density of tunnel**

Category	*Description*	*Tunnel density*
1	None	No evident tunnel erosion.
2	Minor	Tunnels present were less than one metre in depth from ground surface to tunnel floor.
3	Severe	Tunnel depth exceeds one metre.

Source: Grice (1995, p. 32).

Off-site effects

These would be similar to gully erosion involving transportation of soil to new locations, sedimentation of rivers and creeks, discolouration and contamination of water, and the destruction of facilities undermined by tunnels.

Mass movement

Description

> Mass movement is a process that involves the downward movement of soil and rock materials under the influence of gravity. (SCS-New South Wales 1989, p. 8)

The process is complex and the movement of material may be continual, episodic or catastrophic. There are many forms of mass movement including soil creep, earthflow, slumps, land slips, landslides and rock avalanches.

Mass movement can destroy houses, roads, agricultural land, flora and fauna and (in the extreme) human life.

Associated land use and land vulnerability

Commonly, slope failure occurs on steeper terrain with increasing water levels in the soil. Mass movement can occur naturally. It is also caused by anthropogenic activities. For example, the clearance of forest cover from steeper slopes for agriculture, as part of a forestry operation or to build a road, can increase the vulnerability of the land to mass movement as rainwater is able to better penetrate the soil reducing its strength which, in turn, may then begin to slide.

The areas that are worst affected tend to be near the coast; however, there are isolated occurrences in hilly country, elsewhere.

Degree of severity and New South Wales reference classification

The SCS-New South Wales classification includes only those types of mass movement that were considered to be due to land clearing and land use practices. Thus, natural rock slides and individual rock falls were excluded whereas soil creep (including terracing) earthflow and debris slides and slumps were included.

Mass movement was classified into two classes (see Table A.10).

Table A.10: **Categories of land degradation due to mass movement**

Category	*Description*	*Mass movement criteria*
1	Not present	No evidence of mass movement in 100 hectare sample circle
2	Present	Evidence of mass movement

Source: Graham (1989, p. 20).

As with gully erosion, mass movement is determined by the physical appearance of the land at the time of the survey assessment. The inventory of mass movement therefore provides an absolute measure of mass movement with the implicit benchmark being no mass movement.

Off-site effects

Quite clearly most of the effects relating to mass movement would be concentrated at the movement site. Off-site effects would be similar to sheet rill and gully erosion including siltation of water ways.

On-farm management and amelioration possibilities

Land damage by mass movement could be expensive to repair and may remove damaged land from agricultural production. In highly unstable lands, the appropriate farm management strategy may be to limit the use of unstable lands, reduce clearing of slopes or adopt engineering approaches such as decreasing slope angles and reducing water levels in the soil.[2]

Wind erosion

Description

> Wind erosion is the detachment and transportation of soil by wind. (SCS-New South Wales 1989, p. 10)

Extreme examples of wind erosion are the Mallee dust storms of the 1930s, and more recently, those associated with the droughts of 1982–83 and 1994–95. Unlike water erosion, wind can erode upslope with the angle of air flow changing quickly. Eroded soil can be transported a great distance.

Associated land use and land vulnerability

Sandy soils in drier areas can be blown away if they are not protected by plant cover and are therefore the most vulnerable. Soil vulnerability is increased by repeated disturbance of a surface by tillage or grazing stock. The disturbance has the effect of pulverising soil aggregates (eg into dust) making the soil even more susceptible to wind erosion. Vulnerability is further increased by the loss of the finer soil particles which cause a reduction in the soil’s nutrient levels and its ability to retain moisture for plant growth.

Degree of severity and New South Wales base classification

As with sheet and rill erosion, the degree of degradation from wind erosion is assessed by a wind erosion hazard rating. This rating describes the relative

[2] Engineering solutions to contain potential mass movement in unstable areas, in general may be more evident along roadways or in areas subject to residential or other development, than in rural areas because of the greater cost/inconvenience of mass movement in those areas.

susceptibility of the surface soil to erosion when the soil is in its most vulnerable condition over an annual cycle (Table A.11). For a cultivated paddock, the most vulnerable condition is after cultivation and before significant growth. For pasture, the most vulnerable condition is when there is least cover.

Table A.11: **Estimated soil loss hazard from wind erosion, sample land uses and topographical situations for soil loss categories**

Category	*Description of hazard*	*Sample land use and topography*
1	Nil to minor	Most timbered and shrub land, irrigated pasture, orchards and vineyards.
2	Moderate	Shrub, native pasture and improved pasture on coarse and clay soils with poor vegetation cover.
3	Severe	Native and improved pasture, and orchards, vineyards and nurseries on light/sandy soils.
4	Very severe	Cropping on sandy soils and cropping with poor cover on coarse sand and loamy soils. Quarrying and mining on all soil types.

Source: Graham (1989, p. 22).

Overall, lands that have permanent vegetation cover are ranked as having the lowest wind erosion hazard. The inventory of wind erosion hazard is measured against an implicit benchmark of no wind erosion hazard.

Off-site effects

In extreme cases, dust clouds can extend over whole regions. Less dramatic and generally localised effects include the burying of cropping land, roads and fences. While the loss of soil has negative effects, the addition of top soil through dumping also has its positive effects.

On-farm management and amelioration possibilities

Under current technologies, the least cost approach to the management of lands such as sandy/loamy soils in dry areas which are subject to very severe wind erosion hazard, may be to leave them in their natural state. As the erosion hazard becomes progressively less severe with heavier soils or higher soil moisture levels, grazing can be supported on cultivated pasture providing good vegetation cover can be maintained. The progression to lands suitable for cropping is more gradual, with some drier, sandy/loamy areas suitable for cultivation for grazing but not suited to cultivation for annual crops.

Land characterised by heavier soils or soils with higher moisture content have lower wind erosion hazard when cropped. On cropping lands, the wind erosion hazard can be reduced through: the retention of crop stubble for as long as possible after harvest; avoidance of stubble burning; sowing seeds into stubble residues; and reduced tillage. In addition, increasing lengths of pasture rotation between crops can be used to improve soil structure and reduce wind erosion hazard.

As with sheet and rill erosion, wind erosion is an extensive form of surface degradation which could spread between holdings within a locality at risk. Without containment strategies by holdings, the incidence of wind erosion could spread.

A.4 Induced changes to biological conditions

There are a number of degradation types which were not included in the New South Wales survey of land degradation but which appear to reduce farm productivity and the utility of the environment as a natural asset. With the exception of woody shrub infestation and perennial bush decline which were included in the New South Wales survey, these forms of agricultural land degradation include clearance of native vegetation, tree decline, feral and other animal invasion, and dispersed organic chemical residues and farm waste residues.

Woody shrub infestation

Description

> Woody shrubs (woody weeds) are inedible native plants that are rapidly infesting large areas of semi arid to arid regions. (SCS-New South Wales 1989, p. 8)

Growing up to 3 metres in height, woody shrubs commonly occur as dense stands, although they may appear as individual bushes or small clumps. Species of native inedible woody shrub in New South Wales include:

- turpentine (*Eremophila sturtii*);
- budda (*Eremophila mitchelli*);
- narrowleaf hopbush (*Dodonea viscosa ssp. angustissima*);
- broadleaf hopbush (*Dodonea viscosa ssp. angustifolia*);

- punty bush (*Cassia eremophila*); and
- silver cassia (*Cassia artemisioides*).

The species of relevant invasive plants varies between regions and is therefore not confined to the list of problem plants defined for the purpose of the New South Wales survey. For example, exotic weeds such as prickly acacia (*Acacia nilotica*), mimosa (*Mimosa pigra*), rubber vine (*Cryptostegia grandiflora*), and Chinese apple (*Zizyphus*) are spreading rapidly in Queensland and the Northern Territory and displacing native vegetation and grass lands (CSIRO 1995). A general discussion of plant invasions of Australian ecosystems can be found in Humphries *et. al* (1991).

Associated land use and land vulnerability

The infestation of woody shrub is particularly endemic in inland New South Wales and southern Queensland areas. The shrubs are native species which proliferate owing to favourable growing conditions and the lower incidence of fire in outback areas. Woody shrub severely restricts the growth of surrounding pastures due to competition for scarce moisture and light. This results in poor pasture cover on bare ground. In addition, because the shrubs are unpalatable, livestock concentrate on adjoining areas not affected by woody shrub invasion where the grazing potential is better. These adjoining areas then risk overgrazing, further improving the growth prospects of woody shrub. Shrub invasion increases the susceptibility of land to sheet and rill, gully and wind erosion.

Degree of severity and New South Wales base classification

Shrub infestation in New South Wales was assessed according to the reduction in grazing capacity caused by shrub presence. Four categories of severity are delineated (Table A.12).

Table A.12: **Categories of land degradation due to woody shrub infestation**

Category	*Description*	*Woody shrub infestation criteria*
1	Nil	Woody shrubs are not present. Land may be susceptible to shrub infestation.
2	Minor	Isolated juvenile or mature plants or stands of woody shrubs present. This class has suffered from a 0–5% reduction in ground cover vegetation.
3	Moderate	Light to moderate establishment of woody shrubs. This class has suffered from a 5–40% reduction in ground cover vegetation.
4	Severe	Dense, widespread establishment of woody shrubs. This class has suffered from a >40% reduction in ground cover vegetation.

Source: Graham (1989, p. 36).

Each of the categories identified in the inventory of woody shrub invasion is determined by estimated changes in the vegetation cover, and indirectly to the productivity of land for grazing. The inventory of land degradation due to woody shrub infestation provides a measure of degradation against a benchmark of land vegetation conditions 200 years ago (as understood at the time of the survey).

Off-site effects

As noted above, woody shrub invasion can increase the susceptibility of land to soil erosion. Woody shrub can also spread between rural holdings through seeding so that woody shrub infestation is not naturally confined within the boundaries of a single holding.

On-farm management and amelioration possibilities

The localised nature of woody shrub infestation is essentially determined by the invasiveness of the weed plant. The relevant solutions begin at the farm level, but could extend beyond individual farms where the weed invasion has gone beyond the control of individual farmers or it has invaded non-farm land, such as road sides, reserves and residential areas. Treatments for woody weed include:

- prescribed burning which is effective against young and scattered woody shrubs;
- mechanical control including pushing, chaining, and root ploughing or the use of land imprinting rollers (or 'sheep foot' rollers);
- chemical control by point application for selective treatment; and
- cropping, which is limited to areas of reliable rainfall.

Perennial bush decline

Description

> The death of edible perennial bush is a significant form of land degradation in the semi-arid and arid regions of New South Wales. Good perennial bush cover provides protection of the soil surface from wind erosion, creates more favourable ground surface conditions for pasture plants and provides an important source of stock fodder during droughts. (SCS-New South Wales 1989, p. 28)

Associated land use and land vulnerability

Overgrazing of perennial bush can reduce its occurrence or eliminate it. For example, in adjoining grazing areas, perennial bush might be seen on one side of a boundary fence and not on the other as a result of different grazing management practices on either side of the fence.

Historically, perennial bush has not been evenly distributed throughout the semi arid and arid regions. The actual distribution depends on climate, soils and landforms. As there is no benchmark against which to assess the degree of degradation, the New South Wales survey mapped the presence and relative density of perennial bush in the State. The species for which incidence was surveyed included:

- bladder saltbush (*Atriplex vesicaria*);
- black blue bush (*Maireana pyramidata*); and
- pearl blue bush (*Maireana sedifolia*).

These species were chosen for their typically wide distribution, ease of identification and importance in the stability of arid and semi arid rangelands.

Intensity of coverage and New South Wales base classification

The intensity of coverage was assessed according to a sample of field points. Perennial bush occurrence was classified into four categories (Table A.13).

Table A.13: **Density of perennial bush occurrence**[a]

Category	*Description*	*Density of coverage criteria*
1	Dense	Dense bush. Bush increasing grazing capacity by more than 15%.
2	Frequent	Moderate bush. Bush increasing grazing capacity by between 5 and 15%.
3	Scattered	Sparse bush. Bush increasing grazing capacity by up to 5%.
4	Absent	Absence of bush where it would otherwise be expected·

a The New South Wales survey report lists the incidence of density in reverse order to that shown here (ie in the survey report Category 1 has no bush). The order adopted here is consistent with the ordering of the forms of land degradation with the highest numbered category relating to the less productive or more degraded condition.
Source: Graham (1989, p. 40).

Each category identified in the inventory of perennial bush occurrence is determined by observed vegetation coverage. The inventory of perennial bush occurrence provides a measure of intensity against a benchmark of dense bush cover. However, because perennial bush naturally occurs sporadically, any deviation from the benchmark does not necessarily imply degrees of degradation.

Off-site effects

As with other forms of degradation affecting land cover (eg woody shrubs), the decline of perennial bush increases the possibility of soil erosion with its attendant off-site effects.

On-farm management and amelioration possibilities

Perennial bush decline is essentially a local problem with the possible treatments including:

- reseeding of overgrazed areas;
- grazing management strategies to reduce stock concentrations at critical times during the flowering, seeding and seedling establishment phases of the plant cycle; and
- excluding stock when bushes are being overgrazed.

Tree decline

Description

Tree decline:

> ... is the sudden or gradual death of trees (Grice 1995, p. 33).

Associated land use and land vulnerability

In Tasmania (the state which provides the reference for this category), tree decline particularly effects eucalypts on drier areas of agricultural land. The Tasmania study points out that the *Phytophthora cinnamomi* root rot fungus which causes dieback of Jarrah in Western Australia is not implicated in the tree decline of agricultural land in Tasmania.

In Tasmania, factors implicated in tree decline include: drought; repeated defoliation by possums or insects; damage to root systems by cultivation or compaction by livestock; and changes in the micro climate as surrounding trees are removed. In addition, grazing of seedlings or coppice results in lack of regeneration and the eventual death of mature stands due to old age. Overall, tree decline was found in Tasmania to be more typical of the lower rainfall areas.

Degree of severity and Tasmanian base classification

The Tasmanian methodology assessed degradation using land systems as ‘sample points’. This was deemed appropriate because of the small size of the state and the complexity of land forms. The vigour of the majority of trees in a land system was assessed by survey field officers and classified according to the following classes of severity (Table A.14). The implicit benchmark for the survey is healthy trees.

Table A.14: **Categories of land degradation due to tree decline**

Category	*Description*	*Percentage of dead branches in canopy*
1	Nil to minor	Trees healthy: less than 10 per cent.
2	Moderate	Visible die back in canopy: 10 to less than 40 per cent
3	Severe	Trees in serious decline: 40 to less than 80 per cent
4	Extreme	Trees dead or dying: 80 or more per cent
5	No remnant vegetation	No assessment possible

Source: Grice (1995 p. 33).

On-farm management and amelioration possibilities

Improvement of growing conditions for the trees and replanting.

Clearance of native vegetation

Description

Clearance of native vegetation involves:

> ... the effective replacement of the canopy with a herbaceous layer of crop or pasture plants. (Graetz *et. al* 1995, p. 19)

In principle, the replacement of old growth forests with plantation forests, such as pine plantations, should be treated as native vegetation cleared. In the study examined, however, this distinction was not made.

Associated land use and land vulnerability

Clearly, some fairly extensive clearing is necessary for the establishment of agriculture. However, excessive clearing increases the vulnerability of the land to other forms of degradation (eg water and wind erosion, and dryland salinity) and reduces the habitat of naturally occurring species. By changing habitat conditions, land clearing may contribute to a change in the biological makeup of an area.

For the study of landcover disturbance over the Australian continent (Graetz *et.al* 1995), satellite data in digital format were used in conjunction with map information and visual reconnaissance to classify the status of land coverage of native vegetation in Australia. The continent was divided into two land use zones: the intensive land use zone (ILZ); and the extensive land use zone. The ILZ was defined by inspection to cover areas that have been cleared for agriculture or which could be cleared. It covers approximately one third of the continent extending inland from the coast on eastern, southern, south-west and northern Australia. The remaining two thirds of the continent is covered by the extensive land use zone (ELZ). The most common form of agriculture in the ELZ is extensive pastoral activity that is characterised by the grazing on native (or naturalised[3]) pasture. The ELZ also covers land made over to community groups, unallocated crown land and outback communities. The areas covered by the ILZ and the ELZ is provided in Table A.15.

Table A.15: **Australia-wide coverage of land use zone categories**

	square kms	*per cent*
Intensive landuse zone	2 983 908	39
Extensive landuse zone	4 708 092	61
Total	**7 692 000**	**100**

Source: Graetz, Wilson and Cambell (1995, p. 20).

Intensity of coverage and base classification

The coverage of native vegetation in the ILZ was divided into one of four categories (see Table A.16).

Each category identified in the inventory of native vegetation occurrence in the ILZ is determined by an analysis of vegetation coverage as it might occur naturally. Nevertheless, as mentioned, the methodology adopted does not distinguish between native and re-afforested areas, with both being classified as uncleared.

The study classified the ELZ into three disturbance classes — slight, substantial and significant. The allocation of the land to one of these three classes was intended to reflect the contemporary level of disturbance imposed by the two principal agents of land use: grazing of domestic stock; and to a lesser extent repeated burning (Graetz *et. al* 1995, p 21).

Off-farm effects

Naturally occurring vegetation is site specific. However, off-site effects that can occur from clearing include induced salinity in the forest catchment as water tables rise, reduced biological diversity that may have an anthropocentric relevance (eg insect eating bats, native flowers for honey bee populations), and pollution arising from soil erosion that follows from land clearing. A property

[3] Naturalised pasture refers to introduced pastures that are largely self maintaining under natural growing conditions.

would have limited scope for containing the effects of clearance within the boundaries of a single land holding and those off-site may also have limited scope for ameliorating the effects of land clearance elsewhere.

Table A.16: **Categories of clearance of native vegetation in the intensive land use zone**

Category	*Description*	*Coverage criteria*
1	Uncleared	Having an intact canopy relative to all the remnants of any landcover type. For landcover types with open and sparse canopy types (< 30 per cent of projected foliage cover) it is difficult to separate clearing, the loss of overstory, from the effects of overgrazing.
2	Thinned	An intermediate class of tree cover between uncleared and cleared.
3	Cleared	The effective replacement of the canopy with a herbaceous layer of crop or pasture. The overstory was assessed to be reduced to < 5 per cent of assessed naturally intact canopy. That is, scattered or no trees.
4	Naturally occurring grasslands and indeterminate	Assigned to accommodate two cases: (i) where an allocation relating to canopy change was not meaningfull eg naturally occurring grassland; and (ii) where technical difficulties prevented full identification (the less important of the two cases).

Source: Graetz, Wilson and Cambell (1995, p.19–20).

On-farm management and amelioration possibilities

Vegetation clearance lowers one element of the biological resource available to an individual holding. Where that clearance negatively affects farm productivity land managers have available the prospect of re-establishing some native vegetation. However, from the point of view of farm productivity, the appropriate action might be to establish substitute farming systems (eg perennials, salt interception and drainage systems). For this reason, the improvement of productivity would not necessarily involve the re-establish of native land cover.

Feral and other animal invasion[4]

Description

Feral animals include: the rabbit; fox; cat; and pig which are the most important in terms of biotic impoverishment on a continental scale (Graetz *et al.* 1995, p. 22). Other species such as the goat, horse, buffalo and camel are not as widespread or as influential (although they may cause serious degradation problems in localities where they do congregate). Graetz *et. al* have assessed the relative densities of the main feral species across the continent and were able to establish a relative coding of none, low, moderate and high densities. In addition to feral animal invasion, the populations of native animals (eg the red kangaroo — supposedly the most abundant large mammal in the world) may become invasive as habitat changes favour certain species. The invasion of those native species could also lead to competition for resources and secondary degradation, such as wind and water erosion following overgrazing, in a comparable way to feral species.

Each invading species damages the environment in different ways with the severity of the damage being largely based on the ease with which the species have been able to establish themselves, crowd out native species (successfully competing for food and space), or prey on native and other species with little natural protection.

Off-farm effects

The problem of species invasion is not easily confined by the boundaries of individual land holdings. As such, the negative effects to agriculture of feral animals (eg overgrazing of pastures due to rabbit infestation leading to increased susceptibility of the land to sheet rill and wind erosion, increased susceptibility to gully erosion from rabbit burrows, and loss of young stock and small native animals to foxes) cannot be practicably contained or excluded by the actions of individual land managers. The establishment and infestation of certain regions by the feral species provides statistical evidence of this. The increase in the kangaroo population supported by permanent watering sources in arid areas and improved pasture has similar effects.

4 In additional to feral animal invasion, feral plant, insect and reptile invasion can also be of concern as a form of environmental degradation.

Dispersed organic chemical residues and farm waste residues

Description

The residues from farm chemicals such as pesticides and weedicides accumulate in the soil. In addition, farms carry organic matter, such as animal wastes, and nutrients, such as phosphorous, and act as a store of these materials (Cullen and Bowmer 1995). It has been suggested (Hamblin and Williams 1995) that there has been a steady accumulation of organic chemical residues since the 1970s when pesticides came into general use.

The build up of toxins is a form of land degradation in the sense that their presence can lower the marketability of farm produce (eg meat containing chemical residues), and reduce the health of waterways (eg through increasing frequency of algal blooms, loss of native fish populations and the destruction of floodplain and native vegetation).

Chemical residues can come from broadacre farming (eg cotton growing) and intensive rural industries (eg cattle feedlots, piggeries, dairying and wineries (EPA-New South Wales 1993)). At this stage there does not appear to be an identifiable classification of degradation severity although readings of standardised chemical characteristics are made (eg EPA-New South Wales 1993).

Off-farm effects — pollution of waterways and other aquifers

An off-farm problem arises more generally when chemicals applied to farm land and animal and plant wastes enter the waterways. The residues change the water quality potentially reducing its downstream value for use by agriculture, other industries and households. The contamination arises directly as water becomes unfit for drinking and indirectly as chemical residues enter the food chain through animal and plant products. The progressive increase in resistance of weeds, diseases, and pests that chemicals are intended to control, and the existence of soil erosion and other land degradation in catchment areas contribute to the severity of the problem.

Individual land managers may have little control over the disbursement of chemicals and farm residues once they are applied on the holding, although farm or region based interception schemes (as adopted for irrigation salinity) may provide one means of restricting environmental flows. Once farm run-off enters the water ways it mixes with all other water and material entering the system and is dispersed widely. Users of the system may not be able to easily exclude themselves from the effects of the secondary pollution.

APPENDIX B
CLASSIFICATION OF AGRICULTURAL REGIONS IN NEW SOUTH WALES

B.1 Introduction

Chapter 3 discusses the need for information about the biogeographic characteristics of each region in order to evaluate environmental quality in an economic and ecologically meaningful way. In that chapter, reference was made to the use of the Interim Biogeographical Regionalisation (IBRA) of Australia (Thackway and Cresswell 1995) to combine regional land use information from the ABS census of agricultural establishments and the New South Wales survey of land degradation. This appendix provides details of the classifications adopted and how they are linked as well as information about land use drawn from the respective data sources.

Information about agricultural production is available from the ABS agricultural census classified by Statistical Local Areas (SLAs) which are the spatial units in the Australian Standard Geographical Classification (ABS Cat. No. 1216.0). Land use and land degradation information is available from the New South Wales 1987–1988 land degradation survey for about 13 000 data points. To establish biogeographic regionalisation using these sources, information from the New South Wales survey was first aggregated by the National Resource Information Centre (NRIC) from survey data to SLA using Geographic Information System (GIS) techniques. This provided a comprehensive agricultural data base at the SLA level of aggregation. The SLA spatial units thus provided the central building blocks for the analysis. Secondly, information at the SLA level was aggregated to IBRA biogeographic regions using a concordance between SLAs and IBRA regions provided by the Australian Nature Conservation Agency (ANCA).

The land use picture for the SLAs has been drawn from ABS Agricultural Census information for 1991–92 and the Soil Conservation Service (SCS)-New South Wales Land Degradation Survey information for 1987–1988. The overall structure of land use changes sufficiently slowly to enable the information from both sources to be combined for analysis. However, the joint use of the two data sources and the linking of SLA information to biogeographic regions has necessitated some classification approximations that are not evident in the broad regional discussion above but which become more evident once data are disaggregated to the SLA level.

Section B.2 outlines the IBRA and defines IBRA regions for New South Wales and provides information about land use for these broad regions. Section B.3 uses the framework of the SLA classification to discuss the issues relating to the combination of data sources and land use information. The section also provides a disaggregated analysis of agricultural land coverage of SLAs and land use in New South Wales.

B.2 Interim Biogeographic Regionalisation of Australia

The IBRA was developed for the National Reserve System Conservation Plan (NRSCP) by ANCA in consultation with each state and mainland territory. The IBRA is based on the biogeographic classifications defined by nature conservation agencies across their respective jurisdictions. The current IBRA (Version 4) contains 80 regions throughout Australia derived on the basis of expert knowledge about:

- climate;
- lithology;
- landform;
- vegetation;
- flora and fauna;
- land use; and
- other attributes if needed.

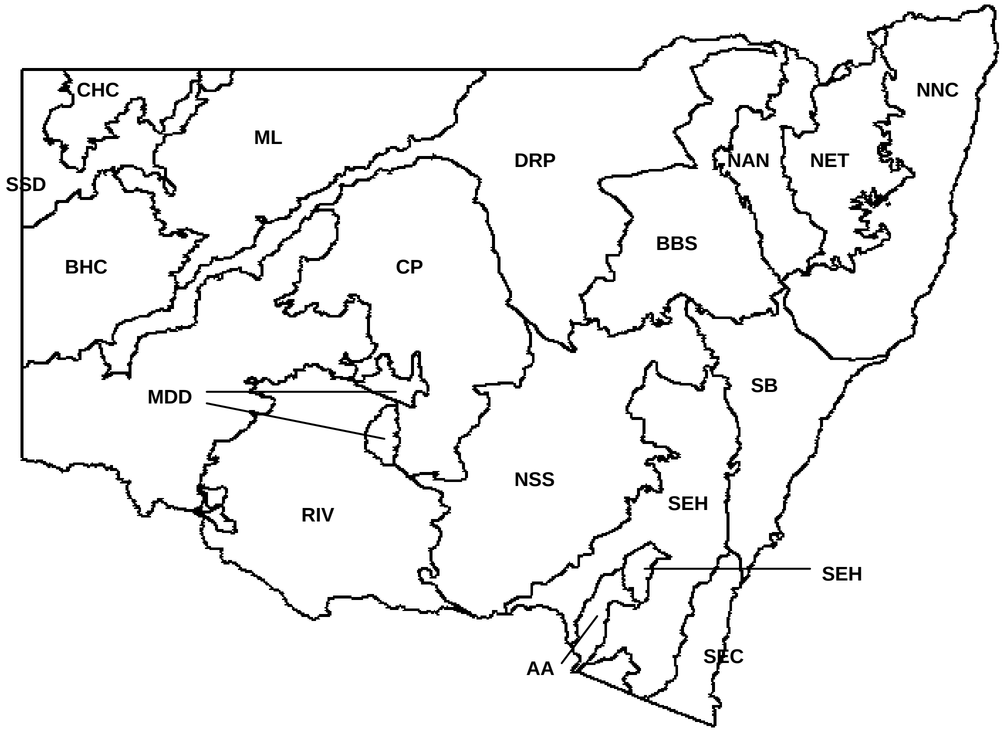
The biogeographic regionalisation of New South Wales is set out in Figure B.1. The name of each region identified in the map is shown in Table B.1 while Annex B1 provides standard definitions for each region.

Only three of the 17 regions listed are located entirely in New South Wales (see Table B.1). This gives a strong indication that regional land management issues are unlikely to take on an entirely state specific character. With the widespread overlapping of regions with state administrative boundaries, the total area covered by relevant biogeographic regions is about two and a half times the area of around 801 400 square kilometres falling within New South Wales State boundaries. The largest biogeographic regions cover the arid inland areas with the smaller regions being concentrated around the eastern mountain ranges and coast.

The coverage of regions by agricultural holdings and the average size of agricultural holding varies substantially (see Table B.2). On the one hand, the biogeographical regions on the North Coast, and the Central and south coast have a large number of small agricultural holdings which collectively cover less than half of the respective biogeographic regions — well below the average agricultural holding coverage of 75 per cent for the state as a whole. The coastal areas also have a larger than average proportion of area devoted to non-agricultural uses (see Annex B2 for a definition of land uses). For example, in the South East corner around 79 per cent of the land area is covered by parks, timber and shrub lands which compares to the state average of around 22 per cent. The direct influence of farm land management decisions on regional land management is limited in these areas by the low proportion of area covered by holdings. At the other extreme, regions in the Western areas are characterised by a small number of very large holdings covering nearly 90 per cent of the land area. Reflecting the arid nature of these regions nearly all of the land is characterised as native and voluntary pasture (including naturalised exotic grasses and legumes used for grazing). Land management decisions on agricultural holdings would accordingly be the dominant overall influence in regional land management in these areas.

There is substantial variation across the regional groupings between these two extremes. For example, in the Tablelands group, agricultural holdings in New England and Nandewar occupy over two thirds of the total area whereas in the Southern highlands around 50 per cent of the area is covered by agricultural holdings. There are also a larger number of smaller land holdings in the Southern highlands when compared to the northern tableland regions. Because over half of the land in these regions is occupied by agricultural holdings, land management decisions on those holdings would have a major influence on regional land management.

Figure B.1: **Biogeographic regions included in New South Wales or having a New South Wales component**



Background

The Interim Biogeographic Regionalisation for Australia (IBRA) was developed cooperatively by the Commonwealth and the State and Territory nature conservation agencies to assist in the process of identifying deficiencies in the National Reserves System (NRS).

In order to provide a framework for establishing priorities for NRS, it was necessary to have general agreement on the broadest level break-up of the Australian environment into biogeographic regions. The regions also provide a basis for establishing common criteria for identifying deficiencies in the existing protected areas system.

The IBRA comprises 80 discrete ecologically meaningful regions which are derived by integrating combinations of terrain, climate, geology, soil, vegetation and where information on the flora and fauna are available, these have been included as well.

The IBRA was derived by compiling the best available data and information about each State and Territory including specialist field knowledge, published resource and environmental reports, and biogeographic regionalisations for each State and Territory, as well as continental data sets.

Source: Thackway and Cresswell (1995).

Table B.1: **Biogeographic regions covering New South Wales**[ab] (square kilometres)

Code	*Region name*	*States covered*	*Area of IBRA region*	*Coverage of area of Australia*	*NSW component of IBRA region*
				percent	
AA	Australian Alps	NSW, Vic.	11 718	0.2	4 285
BBS	Brigalow Belt South	Qld, NSW	279 496	3.6	52 458
BHC	Broken Hill Complex	NSW, SA	57 055	0.7	38 222
CHC	Channel Country	Qld, NSW, SA	305 543	4.0	14 289
CP	Cobar Peneplain	NSW	73 501	1.0	73 501
DRP	Darling Riverine Plain	NSW, Qld	105 511	1.4	92 578
ML	Mulga Lands	QLD, NSW	257 850	3.4	65 814
MDD	Murray-Darling Depression	NSW, Vic., SA	197 480	2.6	84 396
NAN	Nandewar	NSW, Qld	27 322	0.4	21 030
NET	New England Tablelands	NSW, Qld	29 347	0.4	27 931
NNC	NSW North Coast	NSW, Qld	60 794	0.8	58 189
NSS	NSW South West Slopes	NSW, Vic.	84 278	1.1	80 874
RIV	Riverina	NSW, Vic.	90 534	1.2	69 068
SB	Sydney Basin	NSW	36 655	0.5	36 655
SEC	South East Corner	Vic., NSW	27 477	0.4	13 459
SEH	South Eastern Highlands	NSW, Vic., ACT	82 576	1.1	48 771
SSD	Simpson-Strzelecki Dunefields	SA, NT, NSW, Qld	277 876	3.6	20 953
	Sub total		**2 005 013**	**26.1**	**802 473**
	Australia		**7 684 968**	**100.0**	

a A biogeographic region may cover more than one state. The states covered by a single region are listed in descending order of the area contributed to a biogeographic region.

b The total area for Australia and New South Wales shown in the table differ fractionally from the total areas of 7 682 300 and 801 600 reported in the Year Book, Australia. The reason for the difference is due to different projections used by different spacial data bases.

Sources: ABS (1995a), and Thackway and Cresswell (1995).

Table B.2: **Land area and land use by New South Wales biogeographic region**

	IBRA region	*Holdings*	*Average size of holding*	*Area of agricultural holdings*	*Percent of total area*	*Total area*	*Parks, timber & shrub lands*		*Native and voluntary pastures*		*Improved pastures, croplands etc*		*Irrigated lands*		*Other, & unspecified*	
		no.	ha	ha	per cent	ha	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent
Agricultural regions																
NNC	**North Coast**	**5 366**	**354**	**1 901 797**	**39**	**4 838 195**	**2 621 921**	**54.2**	**1 538 692**	**31.8**	**510 838**	**10.6**	**18 633**	**0.4**	**148 109**	**3.1**
	Central and south coast															
SB	Sydney Basin	2 867	232	666 200	20	3 353 669	2 189 781	65.3	548 157	16.3	424 076	12.6	10 878	0.3	180 777	5.4
SEC	South East Corner	344	316	108 728	11	972 633	766 045	78.8	56 209	5.8	126 326	13.0	..	..	24 054	2.5
	Sub-total	**3 211**	**241**	**774 928**	**18**	**4 326 302**	**2 955 826**	**68.3**	**604 365**	**14.0**	**550 402**	**12.7**	**10 878**	**0.3**	**204 831**	**4.7**
	Tablelands															
NET	New England Tableland	2 183	975	2 128 761	67	3 193 265	1 232 954	38.6	957 822	30.0	965 176	30.2	..	..	37 313	1.2
NAN	Nandewar	1 534	953	1 462 398	71	2 072 315	494 685	23.9	994 577	48.0	548 145	26.5	..	..	34 908	1.7
SEH	South Eastern Highlands	4 383	642	2 813 104	49	5 784 805	2 425 944	41.9	1 289 264	22.3	1 941 055	33.6	4 916	0.1	123 625	2.1
	Sub-total	**8 100**	**791**	**6 404 263**	**58**	**11 050 384**	**4 153 582**	**37.6**	**3 241 664**	**29.3**	**3 454 376**	**31.3**	**4 916**	**0.0**	**195 846**	**1.8**
	Central areas															
BBS	Bigalow Belt South	3 322	1 098	3 648 911	70	5 193 817	1 217 493	23.4	1 691 096	32.6	2 158 425	41.6	115 439	2.2	11 364	0.2
NSS	South Western Slopes	7 698	817	6 292 293	83	7 540 264	790 042	10.5	1 554 462	20.6	5 050 003	67.0	68 718	0.9	77 040	1.0
	Sub-total	**11 020**	**902**	**9 941 204**	**78**	**12 734 080**	**2 007 535**	15.8	**3 245 558**	25.5	**7 208 428**	56.6	**184 156**	1.4	**88 403**	0.7
	Central-west areas															
DRP	Darling Riverine Plains	2 026	3 710	7 517 371	90	8 352 068	676 175	8.1	5 510 566	66.0	1 835 336	22.0	194 932	2.3	135 060	1.6
CP	Cobar Peneplain	958	6 374	6 106 224	83	7 385 463	1 949 547	26.4	4 469 160	60.5	941 793	12.8	10 162	0.1	14 801	0.2
RIV	Riverina	3 736	1 619	6 046 836	89	6 777 353	446 259	6.6	3 963 368	58.5	1 423 284	21.0	848 123	12.5	96 318	1.4
MDD	Murray Darling Depression	743	13 439	9 985 383	100	9 997 317	1 101 491	11.0	8 601 323	86.0	185 794	1.9	1 264	0.0	107 444	1.1
	Sub-total	**7 463**	**3 974**	**29 655 813**	**91**	**32 512 201**	**4 173 473**	12.8	**22 544 418**	69.3	**4 386 207**	13.5	**1 054 482**	3.2	**353 622**	1.1
CHC, ML, BHC, SSD	**Western areas (b)**	**310**	**37 703**	**11 687 927**	**88**	**13 207 385**	**838 239**	6.3	**12 249 845**	92.7	**19 035**	0.1	**11 383**	0.1	**88 882**	0.7
Total agricultural regions		**35 470**	**1 702**	**60 365 931**	**77**	**78 668 547**	**16 750 576**	21.3	**43 424 542**	55.2	**16 129 287**	20.5	**1 284 449**	1.6	**1 079 693**	1.4
Remaining area (c)		**78**	**9**	**702**	**..**	**1 472 556**	**470 424**	31.9	**860 458**	58.4	**301 713**	20.5	**19 551**	1.3	**- 179 693**	-12.2
Total New South Wales		**35 548**	**1 698**	**60 366 633**	**75**	**80 141 103**	**17 221 000**	21.5	**44 285 000**	55.3	**16 431 000**	20.5	**1 304 000**	1.6	**900 000**	1.1

For footnotes, see next page.

Footnotes to Table B.2

NOTE: The total area for each SLA and biogeographic region was derived from New South Wales CaLM data provided on disk classified by Land Degradation Survey point using GIS mapping techniques. The total area for New South Wales was 78.8 million hectares which differs fractionally from the total of 80.2 million hectares reported in the Year Book, Australia. The difference between totals is included in the table category 'Remaining area'. Detailed analysis of the data differences by SLA shows that the difference is spread fairly evenly across SLAs within the state with no one difference exceeding 3% of the total obtained from the ABS (1995). Because all detailed data classified by land use has not matched all aggregate data, it has been necessary to enter a (negative) adjustment entry in the "other and unspecified" column against the 'remaining area' row.

.. Nil or less than 0.5 (or 0.05).

a Includes SLAs with more than 100 hectares of land occupied by agricultural holdings in 1991–92.

b Includes the biogeographic areas of: Channel Country (CHC), Simpson-Strezlecki Dunefields, Mulga Lands and Broken Hill Complex. SLAs within this region are large in area and overlap biogeographic areas. Data by biogeographic region cannot therefore be derived from the aggregation of SLA information.

c Includes SLAs with less than 100 hectares of land covered by agricultural holdings in 1991–92 and other areas within NSW not included in the analysis of CaLMs data, and data differences, see NOTE, above.

Sources: ABS (1995), Conservation and Land Management (1995), and Bureau of Resource Sciences (1995).

B.3 Statistical Local Area spatial units

Relationship between data sources

The ABS data relates to activities of rural holdings. These holdings can overlap SLA boundaries but where farm sizes are small relative to the total area of an SLA, such overlapping does not cause a problem for aggregation. However, for areas where the holdings are large, the effects of overlapping can become apparent at the aggregate level. On the other hand, the SCS land use data has been aggregated from land use survey grid point information to the SLA level using GIS area sampling techniques, which again can present aggregation problems when sample areas cross SLA boundaries. The most obvious effect of these two problems is that agricultural land holding information (taken from ABS sources) does not always appear consistent with overall land area/land use information (taken from SCS information). For example, in Conargo and Broken Hill, the reported area of agricultural land holdings is large and some holdings overlap the SLA boundaries. Because of this overlapping, the reported farm area exceeds the area for the SLA (see Table B.3). A similar situation also occurs for a small number of other SLAs; these are evident in Table B.3 (eg Blayney and Cabonne in the South Eastern Highlands).

In addition, the boundaries of biogeographic regions do not correspond to SLA boundaries, and not all SLAs fall within a single biogeographic region. To indicate the biogeographic specialisation of SLAs, the percentage of each SLA falling within each biogeographic region is reported (see Table B.3). For the majority of SLAs, the specialisation is over 80 per cent, however, for others, the level of specialisation is somewhat lower. For example, for Carrathool only half of the SLA area falls within the Riverina and only 36 per cent of the Unincorporated Far West falls within the Broken Hill Complex. For many biogeographic regions, gaps and overlaps between region and SLA level generally compensate for one another. Nevertheless, even after taking into account the net effect of all gaps and overlaps, there are still deficiencies. In particular agricultural and land use data are not separately available for the Australian Alps (included in the South east highlands), the Channel Country and the Simpson-Strzelecki Dunefields (included in the Mulga Lands and the Broken Hill Complex).

Land use

Keeping in mind these methodological issues, the information on land use presented by biogeographic region in Table B.2 is disaggregated to component SLAs in this section (see Table B.3). The disparities in farm size, agricultural holding coverage and land use evident between biogeographic region are also evident between SLAs within some biogeographic regions. For example, there are substantial differences between SLAs within the North Coast biogeographic region. In this region, while the average coverage of agricultural holdings is 39 per cent, agricultural holdings cover less than 20 per cent of areas for SLAs such as Port Stephens, Coffs Harbour and Nambucca. For this group of SLAs, agricultural land management decisions are likely to have a relatively small influence on overall land management for the area. On the other hand, there is another group of SLAs in the region in which agricultural holdings cover more than 50 per cent of area — for Scone the coverage is 80 per cent — and agricultural land management decisions are likely to have a commensurately large effect on regional land management practices.

The major land use in the North Coast biogeographic region is in ‘Parks, timber and shrub lands’, and ‘Native and voluntary pastures’. Together these account for around 80 per cent of the region with the relative mix varying between SLAs. Some overlap between these areas and farm holdings is likely, particularly as the overall share of farm land rises. However, the extent of this overlap is not available.

Moving to other regions, the Sydney Basin, South East Corner and South Eastern Highlands also exhibit substantial variation with respect to the coverage of the area and potential farm influence on overall regional land management. The importance of parks and native pasture in these regions is influenced by the incidence of national parks (eg the Kosciusko National Park would enter into the South Eastern Highlands which as mentioned above, subsumes the Australian Alps).

From the tablelands of northern New South Wales, extending inland to the central and western areas, the coverage of agricultural land holdings in the total area of each SLA is generally high, although some variation between SLAs and between regions is evident. For these areas, farm management decisions would be the dominant influence on land management.

Irrigation farming of New South Wales in concentrated in the Riverina biogeographic region, although there are areas of irrigation farming appearing across all biogeographic regions (see Table B.3). In the Riverina, farms cover nearly 90 per cent of total area with some variation between SLAs. It can be seen that farm size differs substantially between SLAs in this region depending on the incidence of irrigation farming. For those SLAs in which irrigation farming is concentrated, the average farm size is well below the regional average, reflecting the intensive nature of irrigation farming as it is currently practiced relative to dryland farming.

Table B.3: Land area and land use by New South Wales biogeographic region and agricultural SLA[a]

Code	*IBRA region and SLA*	*Holdings*	*Average size of holding*	*Area of holdings*	*Percent of total area*	*Total area*	*Percent of SLA in IBRA region*	*Parks, timber & shrub lands*		*Native and voluntary pastures*		*Improved pastures, croplands etc*		*Irrigated lands*		*Other, & unspecified*	
		no.	ha	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent
NNC	**North Coast**																
110055050	Maitland (C)	111	123	13 641	35	38 549	58	11 486	29.8	16 662	43.2	1 787	4.6	3 685	9.6	4 928	12.8
110056400	Port Stephens (S)	106	111	11 724	14	84 224	56	43 411	51.5	13 319	15.8	5 845	6.9	1 242	1.5	20 407	24.2
110102700	Dungog (S)	265	378	100 163	45	222 336	100	97 249	43.7	103 024	46.3	22 063	9.9	..	..	..	..
110103050	Gloucester (S)	224	703	157 506	54	289 581	99	152 672	52.7	101 797	35.2	35 112	12.1	..	..	..	..
110103400	Great Lakes (S)	131	510	66 798	19	346 202	99	250 052	72.2	52 168	15.1	42 131	12.2	..	..	1 850	0.5
110106800	Scone (S)	277	1 144	316 833	80	394 870	67	136 927	34.7	200 215	50.7	44 021	11.1	13 706	3.5	..	..
120057551	Tweed (S) - Pt A	87	62	5 402	44	12 329	98	1 595	12.9	2 894	23.5	1 584	12.8	..	..	6 256	50.7
120100250	Ballina (S)	265	68	17 910	38	46 722	100	1 253	2.7	16 037	34.3	26 386	56.5	..	..	3 047	6.5
120101350	Byron (S)	194	78	15 074	27	55 345	100	6 266	11.3	30 506	55.1	12 214	22.1	..	..	6 358	11.5
120101650	Casino (M)	22	226	4 962	55	8 958	100	..	..	546	6.1	4 511	50.4	..	..	3 901	43.5
120104550	Kyogle (S)	447	354	158 112	45	350 286	100	127 579	36.4	186 527	53.2	30 802	8.8	..	..	5 379	1.5
120104850	Lismore (C)	398	123	48 825	39	125 942	100	19 125	15.2	65 600	52.1	37 093	29.5	..	..	4 125	3.3
120106600	Richmond River (S)	268	335	89 687	36	245 745	100	112 344	45.7	90 547	36.8	37 971	15.5	..	..	4 883	2.0
120107552	Tweed (S) - Pt B	371	92	34 161	30	114 563	100	46 135	40.3	40 027	34.9	22 433	19.6	..	..	5 967	5.2
125050600	Bellingen (S)	155	188	29 084	19	156 506	97	104 369	66.7	16 128	10.3	34 597	22.1	..	..	1 412	0.9
125051800	Coffs Harbour (C)	310	44	13 681	15	94 027	100	62 084	66.0	10 819	11.5	14 600	15.5	..	..	6 524	6.9
125052250	Copmanhurst (S)	150	1 137	170 534	55	308 860	100	176 009	57.0	131 178	42.5	121	0.0	..	..	1 553	0.5
125053200	Grafton (C)	15	286	4 293	53	8 036	100	..	..	7 843	97.6	..	..	..	..	193	2.4
125055000	Maclean (S)	207	211	43 687	43	102 171	100	51 791	50.7	27 145	26.6	14 811	14.5	..	..	8 425	8.2
125055700	Nambucca (S)	205	122	24 924	17	146 097	100	103 198	70.6	28 359	19.4	9 804	6.7	..	..	4 735	3.2
125056050	Nymboida (S)	138	1 570	216 720	43	500 041	94	369 295	73.9	99 900	20.0	27 700	5.5	..	..	3 146	0.6
125057600	Ulmarra (S)	101	444	44 808	27	164 058	100	101 525	61.9	42 670	26.0	18 021	11.0	..	..	1 843	1.1
125103350	Greater Taree (C)	380	327	124 241	37	331 449	100	190 433	57.5	72 340	21.8	33 518	10.1	..	..	35 158	10.6
125103750	Hastings (M)	284	280	79 558	22	361 626	99	271 889	75.2	56 393	15.6	19 000	5.3	..	..	14 345	4.0
125104350	Kempsey (S)	255	429	109 469	33	329 673	100	185 236	56.2	126 050	38.2	14 713	4.5	..	..	3 675	1.1
	Total	**5 366**	**354**	**1 901 797**	**39**	**4 838 195**	**95**	**2 621 921**	**54.2**	**1 538 692**	**31.8**	**510 838**	**10.6**	**18 633**	**0.4**	**148 109**	**3.1**

For footnotes, see end of table.

Table B.3: **Land area and land use by New South Wales biogeographic region and agricultural SLA[a] (continued)**

Code	*IBRA region and SLA*	*Holdings*	*Average size of holding*	*Area of holdings*	*Percent of total area*	*Total area*	*Percent of SLA in IBRA region*	*Parks, timber & shrub lands*		*Native and voluntary pastures*		*Improved pastures, croplands etc*		*Irrigated lands*		*Other, & unspecified*	
		no.	ha	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent
SB	**Sydney Basin**																
105252850	Fairfield (C)	40	11	437	4	10 035	100	194	1.9	2	0.0	2 645	26.4	..	..	7 194	71.7
105254900	Liverpool (C)	91	47	4 250	14	30 196	100	9 879	32.7	8 101	26.8	9 582	31.7	..	..	2 635	8.7
105301450	Camden (M)	76	102	7 725	39	19 913	100	361	1.8	201	1.0	19 351	97.2	..	..	..	..
105301500	Campbelltown (C)	23	78	1 790	6	30 854	100	15 300	49.6	3 540	11.5	7 064	22.9	..	..	4 951	16.0
105308400	Wollondilly (S)	188	202	37 891	15	253 416	83	182 302	71.9	1 476	0.6	52 322	20.6	..	..	17 315	6.8
105450900	Blue Mountains (C)	26	110	2 871	2	141 786	87	137 327	96.9	922	0.7	311	0.2	..	..	3 226	2.3
105453800	Hawkesbury (C)	225	45	10 021	4	273 911	100	234 418	85.6	14 463	5.3	19 547	7.1	..	..	5 484	2.0
105456350	Penrith (C)	83	83	6 898	17	40 036	100	5 576	13.9	7 938	19.8	15 548	38.8	..	..	10 975	27.4
105500500	Baulkham Hills (S)	175	14	2 414	6	39 418	100	15 259	38.7	7 818	19.8	4 451	11.3	..	..	11 890	30.2
105500750	Blacktown (C)	91	85	7 692	32	23 726	100	4 726	19.9	8 059	34.0	2 849	12.0	..	..	8 091	34.1
105604000	Hornsby (S)	119	8	945	2	46 581	100	32 635	70.1	4 906	10.5	..	..	..	..	9 040	19.4
105703100	Gosford (C)	190	27	5 056	5	93 452	100	56 924	60.9	16 785	18.0	8 107	8.7	..	..	11 636	12.5
105708550	Wyong (S)	100	41	4 128	6	73 592	100	50 559	68.7	12 743	17.3	1 768	2.4	..	..	8 522	11.6
110051720	Cessnock (C)	121	300	36 256	19	193 760	100	153 300	79.1	35 532	18.3	4 928	2.5	..	..	..	..
110054650	Lake Macquarie (C)	43	49	2 097	3	63 312	100	42 776	67.6	12 842	20.3	..	..	..	..	7 694	12.2
110105650	Muswellbrook (S)	215	504	108 358	32	335 544	91	179 742	53.6	110 820	33.0	33 027	9.8	5 954	1.8	6 000	1.8
110107000	Singleton (S)	277	545	151 032	31	482 062	76	272 174	56.5	179 457	37.2	11 826	2.5	4 924	1.0	13 681	2.8
115054400	Kiama (M)	65	130	8 451	33	25 610	100	6 919	27.0	..	..	15 490	60.5	..	..	3 201	12.5
115056900	Shellharbour (M)	41	95	3 876	27	14 615	100	3 213	22.0	..	..	11 190	76.6	..	..	212	1.4
115058450	Wollongong (C)	30	62	1 847	3	67 642	100	36 845	54.5	..	..	10 550	15.6	..	..	20 247	29.9
115106950	Shoalhaven (C)	212	184	38 945	9	451 080	77	375 152	83.2	2 674	0.6	54 390	12.1	..	..	18 864	4.2
115108350	Wingecarribee (S)	255	200	51 103	19	266 292	90	155 610	58.4	5 429	2.0	95 333	35.8	..	..	9 920	3.7
140106750	Rylstone (S)	181	951	172 120	46	376 835	70	218 592	58.0	114 447	30.4	43 797	11.6	..	..	..	..
	Total	**2 867**	**232**	**666 200**	**20**	**3 353 669**	**95**	**2 189 781**	**65.3**	**548 157**	**16.3**	**424 076**	**12.6**	**10 878**	**0.3**	**180 777**	**5.4**

For footnotes, see end of table.

Table B.3: **Land area and land use by New South Wales biogeographic region and agricultural SLA[a] (continued)**

Code	*IBRA region and SLA*	*Holdings*	*Average size of holding*	*Area of holdings*	*Percent of total area*	*Total area*	*Percent of SLA in IBRA region*	*Parks, timber & shrub lands*		*Native and voluntary pastures*		*Improved pastures, croplands etc*		*Irrigated lands*		*Other, & unspecified*	
		no.	ha	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent
SEC	**South East Corner**																
145150550	Bega Valley (S)	283	324	91 714	15	630 720	96	457 128	72.5	53 899	8.5	105 796	16.8	..	..	13 896	2.2
145152750	Eurobodalla (S)	61	279	17 014	5	341 914	96	308 917	90.3	2 309	0.7	20 530	6.0	..	..	10 158	3.0
	Total	**344**	**316**	**108 728**	**11**	**972 633**	**96**	**766 045**	**78.8**	**56 209**	**5.8**	**126 326**	**13.0**	**..**	**..**	**24 054**	**2.5**
NET	**New England Tableland**																
130150100	Armidale (C)	3	447	1 340	40	3 384	100	..	..	..	..	3 384	100.0	..	..	..	..
130152650	Dumaresq (S)	259	1 189	307 881	75	412 096	69	166 630	40.4	77 931	18.9	167 534	40.7	..	..	..	..
130153000	Glen Innes (M)	20	271	5 419	82	6 599	100	..	..	6 448	97.7	151	2.3	..	..	..	..
130153650	Guyra (S)	354	875	309 808	72	431 418	89	132 682	30.8	143 449	33.3	145 881	33.8	..	..	9 405	2.2
130154202	Inverell (S) - Pt B	140	957	134 007	80	167 442	78	42 059	25.1	67 192	40.1	55 117	32.9	..	..	3 075	1.8
130156850	Severn (S)	395	863	340 733	63	543 068	86	224 909	41.4	219 527	40.4	93 744	17.3	..	..	4 888	0.9
130157400	Tenterfield (S)	438	1 003	439 312	63	700 675	49	346 504	49.5	218 485	31.2	115 743	16.5	..	..	19 944	2.8
130157650	Uralla (S)	244	959	234 085	75	313 759	99	25 818	8.2	110 277	35.1	177 664	56.6	..	..	..	..
130157850	Walcha (S)	330	1 079	356 176	58	614 823	65	294 352	47.9	114 514	18.6	205 958	33.5	..	..	..	..
	Total	**2 183**	**975**	**2 128 761**	**67**	**3 193 265**	**82**	**1 232 954**	**38.6**	**957 822**	**30.0**	**965 176**	**30.2**	**..**	**..**	**37 313**	**1.2**
SEC	**Nandewar**																
130100400	Barraba (S)	172	1 334	229 382	77	299 734	91	49 900	16.6	210 815	70.3	39 019	13.0	..	..	..	..
130100700	Bingara (S)	157	1 232	193 372	70	277 427	86	54 845	19.8	177 189	63.9	41 256	14.9	..	..	4 138	1.5
130104201	Inverell (S) - Pt A	381	1 266	482 444	72	671 343	64	191 071	28.5	286 485	42.7	166 488	24.8	..	..	27 299	4.1
130105100	Manilla (S)	162	937	151 802	70	215 425	84	42 344	19.7	98 622	45.8	70 988	33.0	..	..	3 471	1.6
130106000	Nundle (S)	110	938	103 209	65	157 691	64	72 367	45.9	55 745	35.4	29 579	18.8	..	..	..	..
130106300	Parry (S)	513	573	293 902	68	432 485	76	81 205	18.8	155 224	35.9	196 056	45.3	..	..	..	..
130107300	Tamworth (C)	39	213	8 288	46	18 211	100	2 952	16.2	10 499	57.7	4 760	26.1	..	..	..	..
	Total	**1 534**	**953**	**1 462 398**	**71**	**2 072 315**	**78**	**494 685**	**23.9**	**994 577**	**48.0**	**548 145**	**26.5**	**..**	**..**	**34 908**	**1.7**

For footnotes, see end of table.

Table B.3: **Land area and land use by New South Wales biogeographic region and agricultural SLA[a] (continued)**

Code	*IBRA region and SLA*	*Holdings*	*Average size of holding*	*Area of holdings*	*Percent of total area*	*Total area*	*Percent of SLA in IBRA region*	*Parks, timber & shrub lands*		*Native and voluntary pastures*		*Improved pastures, croplands etc*		*Irrigated lands*		*Other, & unspecified*	
		no.	ha	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent
SEH	**South Eastern Highlands**																
140050450	Bathurst (C)	76	296	22 497	95	23 789	100	1 141	4.8	..	..	17 714	74.5	..	..	4 935	20.7
140050851	Blayney (S) - Pt A	82	269	22 061	43	51 762	98	3 446	6.7	615	1.2	44 753	86.5	..	..	2 948	5.7
140051401	Cabonne (S) - Pt A	46	388	17 848	21	85 820	96	22 534	26.3	29 806	34.7	33 480	39.0	..	..	..	..
140052801	Evans (S) - Pt A	71	498	35 356	76	46 768	100	7 789	16.7	5 155	11.0	28 887	61.8	..	..	4 936	10.6
140056150	Orange (C)	124	173	21 480	76	28 093	100	44	0.2	7 847	27.9	20 202	71.9	..	..	..	..
140100852	Blayney (S) - Pt B	231	447	103 279	na	99 632	68	536	0.5	22 811	22.9	74 291	74.6	..	..	1 993	2.0
140101402	Cabonne (S) - Pt B	191	370	70 728	na	51 577	94	13 064	25.3	27 263	52.9	11 073	21.5	..	..	177	0.3
140102802	Evans (S) - Pt B	324	643	208 329	55	378 858	86	140 090	37.0	113 893	30.1	124 875	33.0	..	..	..	..
140103300	Greater Lithgow (C)	162	528	85 538	23	365 734	55	194 461	53.2	81 959	22.4	77 715	21.2	4 916	1.3	6 682	1.8
140106100	Oberon (S)	226	512	115 680	40	288 358	100	117 399	40.7	76 916	26.7	94 043	32.6	..	..	..	..
145102400	Crookwell (S)	439	607	266 453	74	358 898	75	90 160	25.1	146 028	40.7	122 709	34.2	..	..	..	..
145103150	Goulburn (C)	10	276	2 761	51	5 391	100	..	..	..	..	1 979	36.7	..	..	3 412	63.3
145103600	Gunning (S)	229	688	157 480	72	218 922	98	23 101	10.6	75 904	34.7	113 959	52.1	..	..	5 958	2.7
145105450	Mulwaree (S)	380	685	260 151	50	516 707	97	160 543	31.1	79 611	15.4	267 539	51.8	..	..	9 014	1.7
145107250	Tallaganda (S)	175	759	132 792	40	330 383	87	194 346	58.8	4 976	1.5	131 062	39.7	..	..	..	..
145108650	Yarrowlumla (S)	143	743	106 265	36	298 478	89	153 948	51.6	27 366	9.2	97 243	32.6	..	..	19 921	6.7
145108700	Yass (S)	315	730	229 902	71	325 841	69	62 808	19.3	104 666	32.1	148 415	45.5	..	..	9 952	3.1
145201000	Bombala (S)	217	908	197 104	49	398 289	63	151 777	38.1	107 553	27.0	128 249	32.2	..	..	10 711	2.7
145202050	Cooma-Monaro (S)	207	1 136	235 090	48	492 391	88	258 853	52.6	94 534	19.2	136 758	27.8	..	..	2 247	0.5
145207050	Snowy River (S)	222	1 134	251 649	42	604 898	59	288 273	47.7	129 540	21.4	165 541	27.4	..	..	21 544	3.6
150107500	Tumut (S)	278	419	116 578	31	378 545	56	242 272	64.0	86 044	22.7	45 243	12.0	..	..	4 987	1.3
155107450	Tumbarumba (S)	235	656	154 084	35	435 672	63	299 358	68.7	66 778	15.3	55 325	12.7	..	..	14 210	3.3
	Total	**4 383**	**642**	**2 813 104**	**49**	**5 784 805**	**84**	**2 425 944**	**41.9**	**1 289 264**	**22.3**	**1 941 055**	**33.6**	**4 916**	**0.1**	**123 625**	**2.1**

For footnotes, see end of table.

Table B.3: **Land area and land use by New South Wales biogeographic region and agricultural SLA[a] (continued)**

Code	*IBRA region and SLA*	*Holdings*	*Average size of holding*	*Area of holdings*	*Percent of total area*	*Total area*	*Percent of SLA in IBRA region*	*Parks, timber & shrub lands*		*Native and voluntary pastures*		*Improved pastures, croplands etc*		*Irrigated lands*		*Other, & unspecified*	
		no.	ha	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent
NSS	**South Western Slopes**																
135055400	Mudgee (S)	419	811	339 979	62	545 596	78	144 020	26.4	211 856	38.8	177 104	32.5	758	0.1	11 857	2.2
135058150	Wellington (S)	400	810	324 077	80	404 846	78	23 197	5.7	105 783	26.1	249 461	61.6	8 905	2.2	17 500	4.3
140150800	Bland (S)	601	1 309	786 841	93	846 865	72	74 472	8.8	107 686	12.7	664 706	78.5	..	..	..	..
140151403	Cabonne (S) - Pt C	513	670	343 497	75	456 526	96	85 795	18.8	73 193	16.0	289 510	63.4	8 029	1.8	..	..
140152350	Cowra (S)	423	494	208 980	75	277 400	95	50 171	18.1	59 406	21.4	148 255	53.4	16 687	6.0	2 881	1.0
140152900	Forbes (S)	451	992	447 566	96	466 288	99	16 157	3.5	66 091	14.2	349 730	75.0	29 364	6.3	4 945	1.1
140156200	Parkes (S)	541	898	485 712	83	586 262	96	78 787	13.4	90 876	15.5	411 670	70.2	..	..	4 929	0.8
140158100	Weddin (S)	334	820	273 980	81	339 019	100	59 117	17.4	96 768	28.5	183 134	54.0	..	..	..	..
145101050	Boorowa (S)	238	884	210 478	82	256 095	92	14 361	5.6	104 424	40.8	135 242	52.8	..	..	2 068	0.8
145103700	Harden (S)	238	665	158 300	85	185 601	100	2 322	1.3	22 802	12.3	160 477	86.5	..	..	..	..
145108750	Young (S)	400	659	263 432	99	266 439	100	12 526	4.7	22 898	8.6	231 015	86.7	..	..	..	..
150102000	Coolamon (S)	279	755	210 767	87	241 454	100	8 511	3.5	42 692	17.7	190 251	78.8	..	..	..	..
150102200	Cootamundra (S)	159	893	142 048	95	150 241	100	8 722	5.8	22 802	15.2	118 717	79.0	..	..	..	..
150103500	Gundagai (S)	234	859	201 033	82	244 427	93	17 374	7.1	162 814	66.6	64 239	26.3	..	..	..	..
150104300	Junee (S)	237	700	165 897	83	200 753	100	6 228	3.1	25 871	12.9	168 654	84.0	..	..	..	..
150104950	Lockhart (S)	332	774	256 864	89	288 933	100	4 985	1.7	34 131	11.8	249 817	86.5	..	..	..	..
150105800	Narrandera (S)	320	1 140	364 725	89	411 009	72	14 336	3.5	81 938	19.9	309 905	75.4	4 830	1.2	..	..
150107350	Temora (S)	304	792	240 793	87	277 948	100	27 419	9.9	23 394	8.4	222 173	79.9	..	..	4 962	1.8
150107750	Wagga Wagga (C)	569	684	389 305	81	481 011	100	38 338	8.0	130 469	27.1	312 060	64.9	145	0.0	..	..
155054050	Hume (S)	270	569	153 747	80	193 200	89	13 096	6.8	24 610	12.7	145 488	75.3	..	..	10 006	5.2
155102450	Culcairn (S)	264	552	145 704	92	159 197	100	2 596	1.6	6 374	4.0	145 232	91.2	..	..	4 995	3.1
155103900	Holbrook (S)	172	1 038	178 569	68	261 154	64	87 512	33.5	37 584	14.4	123 162	47.2	..	..	12 895	4.9
	Total	**7 698**	**817**	**6 292 293**	**83**	**7 540 264**	**90**	**790 042**	**10.5**	**1 554 462**	**20.6**	**5 050 003**	**67.0**	**68 718**	**0.9**	**77 040**	**1.0**
BHC	**Broken Hill Comp.**																
160101250	Broken Hill (C)	3	8 875	26 624	na	6 752	100	..	..	6 752	100.0	..	..	..	..	..	..
160108809	Unincorp. Far West	150	51 032	7 654 776	na	9 127 020	36	733 213	8.0	8 323 450	91.2	9 248	0.1	9 854	0.1	51 255	0.6
	Total	**153**	**50 205**	**7 681 400**	**84**	**9 133 773**	**68**	**733 213**	**8.0**	**8 330 202**	**91.2**	**9 248**	**0.1**	**9 854**	**0.1**	**51 255**	**0.6**

For footnotes, see end of table.

Table B.3: **Land area and land use by New South Wales biogeographic region and agricultural SLA[a] (continued)**

Code	*IBRA region and SLA*	*Holdings*	*Average size of holding*	*Area of holdings*	*Percent of total area*	*Total area*	*Percent of SLA in IBRA region*	*Parks, timber & shrub lands*		*Native and voluntary pastures*		*Improved pastures, croplands etc*		*Irrigated lands*		*Other, & unspecified*	
		no.	ha	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent
DRP	**Darling Riverine Plain**																
130205300	Moree Plains (S)	619	2 601	1 610 124	92	1 747 505	62	99 084	5.7	935 696	53.5	598 492	34.2	96 863	5.5	17 371	1.0
135055850	Narromine (S)	331	1 394	461 365	89	518 524	68	29 697	5.7	90 343	17.4	373 238	72.0	20 323	3.9	4 924	0.9
135102150	Coonamble (S)	337	2 612	880 241	90	972 714	91	94 302	9.7	434 867	44.7	427 421	43.9	..	..	16 124	1.7
135107900	Walgett (S)	355	5 631	1 999 030	91	2 186 161	97	284 209	13.0	1 648 370	75.4	227 667	10.4	25 915	1.2	..	..
135107950	Warren (S)	247	3 640	899 157	85	1 054 293	100	41 035	3.9	686 520	65.1	196 310	18.6	43 573	4.1	86 855	8.2
135151200	Brewarrina (S)	137	12 171	1 667 454	89	1 872 872	72	127 847	6.8	1 714 770	91.6	12 210	0.7	8 259	0.4	9 786	0.5
	Total	**2 026**	**3 710**	**7 517 371**	**90**	**8 352 068**	**82**	**676 175**	**8.1**	**5 510 566**	**66.0**	**1 835 336**	**22.0**	**194 932**	**2.3**	**135 060**	**1.6**
RIV	**Riverina**																
150151600	Carrathool (S)	289	5 453	1 575 954	84	1 868 549	54	254 065	13.6	1 114 321	59.6	443 835	23.8	51 163	2.7	5 164	0.3
150153450	Griffith (C)	726	273	197 841	na	162 178	58	4 060	2.5	9 829	6.1	48 566	29.9	85 072	52.5	14 651	9.0
150153850	Hay (S)	128	9 054	1 158 907	na	1 122 661	100	18 779	1.7	1 052 593	93.8	9 909	0.9	36 425	3.2	4 954	0.4
150154750	Leeton (S)	336	249	83 696	72	116 377	73	7 295	6.3	12 490	10.7	28 141	24.2	63 487	54.6	4 965	4.3
150155550	Murrumbidgee (S)	177	1 951	345 399	99	347 709	100	7 169	2.1	260 058	74.8	24 828	7.1	55 654	16.0	..	..
155102300	Corowa (S)	212	922	195 491	90	216 745	83	2 113	1.0	6 585	3.0	177 001	81.7	20 800	9.6	10 244	4.7
155107700	Urana (S)	141	2 161	304 717	91	334 026	61	8 280	2.5	141 095	42.2	173 079	51.8	11 571	3.5	..	..
155150650	Berrigan (S)	366	467	170 859	83	206 166	100	1 678	0.8	27 521	13.3	118 288	57.4	46 758	22.7	11 921	5.8
155151850	Conargo (S)	299	1 306	390 347	na	367 205	100	2 737	0.7	246 434	67.1	34 184	9.3	83 849	22.8	..	..
155152500	Deniliquin (M)	24	409	9 821	68	14 501	100	..	..	4 506	31.1	1 243	8.6	8 752	60.4	..	..
155154250	Jerilderie (S)	257	1 171	301 049	90	336 100	100	..	..	164 390	48.9	79 322	23.6	92 388	27.5	..	..
155155500	Murray (S)	292	1 122	327 603	76	433 242	100	60 236	13.9	132 291	30.5	133 444	30.8	89 519	20.7	17 752	4.1
155157800	Wakool (S)	401	1 530	613 370	82	748 390	93	71 211	9.5	327 685	43.8	151 410	20.2	171 419	22.9	26 665	3.6
155158300	Windouran (S)	88	4 225	371 782	74	503 505	100	8 636	1.7	463 570	92.1	32	0.0	31 266	6.2	..	..
	Total	**3 736**	**1 619**	**6 046 836**	**89**	**6 777 353**	**87**	**446 259**	**6.6**	**3 963 368**	**58.5**	**1 423 284**	**21.0**	**848 123**	**12.5**	**96 318**	**1.4**

For footnotes, see end of table.

Table B.3: **Land area and land use by New South Wales biogeographic region and agricultural SLA[a] (continued)**

Code	*IBRA region and SLA*	*Holdings*	*Average size of holding*	*Area of holdings*	*Percent of total area*	*Total area*	*Percent of SLA in IBRA region*	*Parks, timber & shrub lands*		*Native and voluntary pastures*		*Improved pastures, croplands etc*		*Irrigated lands*		*Other, & unspecified*	
		no.	ha	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent	ha	per cent
ML	**Mulga Lands**																
135151150	Bourke (S)	157	25 519	4 006 527	na	4 073 612	71	105 026	2.6	3 919 643	96.2	9 787	0.2	1 530	..	37 627	0.9
BBS	**Bigalow Belt South**																
110105250	Merriwa (S)	174	1 261	219 341	64	343 765	74	83 350	24.2	182 944	53.2	72 562	21.1	..	..	4 910	1.4
110105600	Murrurundi (S)	175	1 173	205 329	84	243 452	62	30 354	12.5	122 127	50.2	90 971	37.4	..	..	..	..
130103550	Gunnedah (S)	471	828	390 217	79	491 712	89	22 201	4.5	135 971	27.7	328 163	66.7	..	..	5 376	1.1
130106500	Quirindi (S)	252	1 057	266 461	89	298 208	73	29 661	9.9	140 236	47.0	127 365	42.7	..	..	945	0.3
130108600	Yallaroi (S)	316	1 334	421 424	81	521 689	72	27 509	5.3	214 582	41.1	276 741	53.0	2 725	0.5	132	0.0
130205750	Narrabri (S)	599	1 234	739 214	58	1 272 335	70	457 741	36.0	382 826	30.1	333 977	26.2	97 790	7.7	..	..
135051950	Coolah (S)	331	1 175	389 069	83	471 502	84	118 079	25.0	139 569	29.6	209 700	44.5	4 154	0.9	..	..
135052100	Coonabarabran (S)	376	1 150	432 367	58	739 268	99	280 711	38.0	240 727	32.6	217 830	29.5	..	..	..	..
135052600	Dubbo (C)	263	743	195 534	58	336 377	75	96 247	28.6	68 338	20.3	165 931	49.3	5 860	1.7	..	..
135052950	Gilgandra (S)	365	1 068	389 955	82	475 510	72	71 640	15.1	63 775	13.4	335 186	70.5	4 909	1.0	..	..
	Total	**3 322**	**1 098**	**3 648 911**	**70**	**5 193 817**	**77**	**1 217 493**	**23.4**	**1 691 096**	**32.6**	**2 158 425**	**41.6**	**115 439**	**2.2**	**11 364**	**0.2**
MDD	**Murray-Darling Dep.**																
155200300	Balranald (S)	157	13 998	2 197 692	na	2 145 155	56	378 324	17.6	1 685 688	78.6	71 823	3.3	1 264	0.1	8 056	0.4
155208200	Wentworth (S)	439	5 975	2 623 065	na	2 600 885	99	426 802	16.4	2 037 035	78.3	94 368	3.6	..	..	42 680	1.6
160101700	Central Darling (S)	147	35 134	5 164 625	98	5 251 277	42	296 365	5.6	4 878 600	92.9	19 603	0.4	..	..	56 708	1.1
	Total	**743**	**13 439**	**9 985 383**	**100**	**9 997 317**	**71**	**1 101 491**	**11.0**	**8 601 323**	**86.0**	**185 794**	**1.9**	**1 264**	**0.0**	**107 444**	**1.1**
CP	**Cobar Peneplain**																
135100950	Bogan (S)	215	5 739	1 233 823	86	1 432 321	80	246 839	17.2	1 066 729	74.5	118 753	8.3	..	..	..	..
135151750	Cobar (S)	172	20 238	3 480 959	78	4 479 604	70	1 496 068	33.4	2 925 874	65.3	54 082	1.2	..	..	3 580	0.1
140154600	Lachlan (S)	571	2 437	1 391 442	94	1 473 538	80	206 640	14.0	476 557	32.3	768 958	52.2	10 162	0.7	11 221	0.8
	Total	**958**	**6 374**	**6 106 224**	**83**	**7 385 463**	**78**	**1 949 547**	**26.4**	**4 469 160**	**60.5**	**941 793**	**12.8**	**10 162**	**0.1**	**14 801**	**0.2**

C City; S Shire

.. Nil or less than 0.5 (0.05).

na Not available.

a Agricultural areas include all SLAs with more than 100 hectares of land covered by agricultural holdings.

Sources: ABS (1995d), Conservation and Land Management (1995), National Resource Information Centre (1995), and Australian Nature Conservation Agency (1995).

Non-agricultural SLAs

The previous analysis excludes SLAs with less than 100 hectares of land covered by agricultural holdings. Generally, these SLAs are within the Sydney Basin although some country SLAs covering cities and townships also have less than 100 hectares of agricultural land (Table B.4).

Table B.4: **New South Wales non-agricultural SLAs**

SLA	*Percentage of SLA in IBRA region*	*SLA*	*Percentage of SLA in IBRA region*
	per cent		per cent
NSW SouthWestern Slopes		**Sydney Basin (contd)**	
Albury (C)	100	Mosman (M)	100
		Newcastle (C) - Inner	100
Sydney Basin		Newcastle (C) - Remainder	100
Ashfield (M)	100	North Sydney (M)	100
Auburn (M)	100	Parramatta (C)	100
Bankstown (C)	100	Randwick (M)	100
Botany (M)	100	Rockdale (M)	100
Burwood (M)	100	Ryde (M)	100
Canterbury (M)	100	South Sydney (C)	100
Concord (M)	100	Strathfield (M)	100
Drummoyne (M)	100	Sutherland (S)	100
Holroyd (C)	100	Sydney (C) - Inner	100
Hunter"s Hill (M)	100	Sydney (C) - Remainder	100
Hurstville (C)	100	Warringah (S)	99
Kogarah (M)	100	Waverley (M)	100
Ku-ring-gai (M)	100	Willoughby (C)	100
Lane Cove (M)	100		
Leichhardt (M)	100		
Manly (M)	100	**South Eastern Highlands**	100
Marrickville (M)	100	Queanbeyan (C)	

Source: See Table B.3.

Annex B1: Description of IBRA regions covering New South Wales[a]

Region	*Description*
AA Australian Alps	A series of high elevation plateaux capping the South Eastern Highlands (Region SEH) and southern tablelands of New South Wales. The geology consists largely of granitic and basaltic rocks. Vegetation is dominated by alpine herbfields, and other treeless communities, snow gum woodlands and montane forests dominated by alpine ash.
BBS Brigalow Belt South	Predominantly Jurassic and younger deposits of the Great Artesian Basin and Tertiary deposits with elevated basalt flows. Subhumid. Eucalyptus woodlands and open forests of ironbarks, poplar box, spotted gum (*E. maculata*), cypress pine (*Callitris glaucophylla*), Bloodwoods (eg. trachyphloia, *E. hendersonii ms*) brigalow-belah forests (*E. harpophylla*, *Casuarina cristata*) and semi-evergreen vine thicket.
BHC Broken Hill Complex	Hills and colluvial fans on Proterozoic rocks; desert loams and red clays, lithosols and calcareous red earths; supporting chenopod shrublands *Maireana spp.* - *Atriplex spp*. shrublands, and mulga open shrublands *Acacia aneura*.
CHC Channel Country	Low hills on Cretaceous sediments; forbfields and Mitchell grass downs, and intervening braided river systems of coolibah. *E. coolibah* woodlands and lignum/saltbush *Muehlenbeckia sp./Chenopodium sp.* shrublands. (Includes small areas of sandplains.)
CP Cobar Peneplain	Plains and low hills on Palaeozoic rocks; earths, lithosols; *E. populnea* and *E. intertexta* woodlands.
DRP Darling Riverine Plain	Alluvial fans and plains; summer/winter rainfall in catchments, including occasional cyclonic influence; grey clays; woodlands and open woodlands dominated by *Eucalyptus spp*.
ML Mulga Lands	Undulating plains and low hills on Cainozoic sediments; red earths and lithosols; *Acacia aneura* shrublands and low woodlands.
NAN Nandewar	Hills on Palaeozoic sediments; lithosols and earths; *Eucalyptus albens* woodlands; summer rainfall.
NET New England Tableland	Elevated plateau hills and plains on Palaeozoic sediments, granites and basalts; dominated by stringy bark/peppermint/box species, including *E. caliginosa*, *E. nova-anglica*, *E. melliodora* and *E. blakleyi*.
NNC New South Wales North Coast	Humid; hills, coastal plains and sand dunes; *Eucalyptus-Lophostemon* confertus tall open forests, *Eucalyptus* open forests and woodlands, rainforest often with *Araucaria cunninghamii* (complex notophyll and microphyll vine forest), *Melaleuca quinquenervia*. wetlands, and heaths.

Annex B1: Description of IBRA regions covering New South Wales[a] (continued)

Region	*Description*
NSS New South Wales South West Slopes	An extensive area of foothills and isolated ranges comprising the lower inland slopes of the Great Dividing Range extending through southern New South Wales to western Victoria. Vegetation consists of wet/damp sclerophyll forests, peppermint forests and box/ironbark woodlands.
RIV Riverina	An ancient riverine plain and alluvial fans composed of unconsolidated sediments with evidence of former stream channels. Vegetation consists of river red gum and black box forests, box woodlands, saltbush shrublands, extensive grasslands and swamp communities.
SB Sydney Basin	Mesozoic sandstones and shales; dissected plateaus; forests, woodlands and heaths; skeletal soils, sands and podzolics.
SEC South East Corner	A series of deeply dissected near coastal ranges composed of Devonian granites and Palaeozoic sediments, inland of a series of gently undulating terraces (piedmont downs) composed of Tertiary sediments and flanked by Quaternary coastal plains, dunefields and inlets. The regional climate is strongly influenced by the Tasman Sea and the close proximity of the coast to the Great Dividing Range. Vegetation consists of high elevation woodlands, wet and damp sclerophyll forests interspersed with rain-shadow woodlands in the Snowy River Valley. Lowland and coastal sclerophyll forests, woodlands, warm temperate rainforest and coastal communities occur in the lower areas.
SEH South Eastern Highlands	Steep dissected and rugged ranges extending across southern and eastern Victoria and southern New South Wales. Geology predominantly Palaeozoic rocks and Mesozoic rocks. Vegetation predominantly wet and dry sclerophyll forests, woodland, minor cool temperate rainforest and minor grassland and herbaceous communities.
SSD Simpson-Strzelecki Dunefields	Arid dunefields and sandplains with sparse shrubland and spinifex hummock grassland, and cane grass on deep sands along dune crests.

a Many of the regions in New South Wales overlap with adjoining states, see Table B.1.
Source: Thackway and Cresswell (1995).

Annex B2: Description of land use categories

Parks timber and shrub lands

Nature park and nature reserve
Land in public ownership and reserved for the protection of flora and fauna. This land is essentially undisturbed.
Timber and shrub lands
Unlogged forests and previously cleared land which is reverting to native forest. Land used for logging, agricultural and pastoral uses is not included.
Logged native forest
Stands of native forest logged within the last 10 to 20 years.
Hardwood plantation
Land previously cleared and now covered with a plantation of native hardwood species.
Softwood plantation
Land previously cleared and now covered with a softwood plantation.

Native and voluntary pastures

Native pasture
Cleared country or woodland with ground cover of native or naturalised exotic grasses or legumes used for grazing.

Improved pasture and croplands etc

Improved pasture
Cleared or lightly wooded land with a sown ground cover of exotic grasses or legumes and used for grazing.
Cropping - frequent
Land regularly cultivated for agricultural production (eg three years of cultivation followed by one year pasture). Land cultivated for vegetables, flowers or orchards is not included.
Cropping infrequent
Land used for occasional cultivation (eg one year cultivation followed by three years of pasture).
Orchard and vineyards
Land used for the production of fruit and nut trees or vines.
Vegetables and flowers
Land used for the production of vegetables and flowers.

Irrigated lands

Irrigation - spray
Land irrigated by fixed or travelling spray irrigation systems
Irrigation - flood
Land irrigated within bays usually by covering the whole area with a layer of water.

Other land uses

Urban
Land within cities or towns including residential and commercial areas.
Industrial
Land used for manufacturing or the processing of goods.
Quarrying and mining
Land used for extractive industries.
Water
Water bodies including rivers and lakes but not including offshore or estuarine water bodies.
Swamp Swamp land currently under water or with a water table close to the surface; and swampland dry at the time of the survey.

Source: Soil Conservation Service of New South Wales (1989).

APPENDIX C
THE EXTENT OF LAND DEGRADATION IN AUSTRALIA

C.1 Introduction

The extent of land degradation in Australia has been of interest over an extended period. This interest has prompted a range of studies. State soil conservation authorities began degradation assessments in the 1930s aimed at promoting soil conservation measures and establishing soil conservation priorities (Woods 1983). This appendix reports summary results from published studies of land degradation. Degradation in each state is covered although the presentation varies with the source of data. The earliest data reported is from the erosion survey of New South Wales (Kaleski 1945). There is now quite a body of information about the extent of various types of degradation available for periods around the late 1980s and early 1990s. In addition, estimates are becoming available about the rate of advance of land degradation under current farm management practices.

The information presented in this appendix provides an overview of the extent of land degradation in Australia. Section C.2 reports the results of a national degradation study and results of State wide analyses for New South Wales, Victoria, Western Australia and Tasmania. Section C.3 considers the extent of particular forms of land degradation, problems encountered in comparing studies and in the overall measurement of degradation, through review of a selection of special purpose studies. It is in this latter group of studies that estimates of the advance of degradation are mostly found.

C.2 Estimates of land degradation provided in general studies

Australia-wide degradation study (1975)

Woods (1983) provided information about the incidence of land requiring treatment or works to ameliorate degradation in respect of the reference year 1975. Although now somewhat dated, the study indicates that the concept of land degradation and its repair was well established and that, with effort, information could be harnessed to provide an economy-wide perspective on degradation. The published information was drawn from a national degradation assessment carried out by the Commonwealth and States over the period 1975 to 1977 in what is known as the Collaborative Soil Conservation Study. To date, a follow up Australia-wide study of degradation using contemporary survey estimation and measurement techniques has not been made.

The treatment/works approach was adopted for the 1975 survey because it was assessed at the time that such information would have an immediate application in agricultural land management and that information on a degradation inventory basis could not be readily assembled. Although the study provided information on areas requiring work, it did not provide judgements concerning the net benefits of that work, whether the work was likely to be undertaken in the normal course of land management or whether special policy or administrative action was required to initiate the work.

The study estimated that a total of 16 per cent (around 80 million hectares) of agricultural land required amelioration work (see Table C.1). Over two thirds of this was because of water erosion (including gully, and sheet and rill erosion) with the incidence being concentrated in New South Wales. Other forms of degradation were also identified in the study. For example, large areas of vegetation decline were apparent in Queensland, New South Wales and the Northern Territory. In the study, vegetation decline was defined as:

> reductions in plant density, plant vigour, the proportion of desirable species and surface cover which allow soil erosion to accelerate or undesirable species to invade the plant community. (Woods 1983, p. 55)

Vegetation decline occurred in the more arid areas and aspects of it are more popularly referred to in current studies as ‘woody weed invasion’. Dryland salinity was also identified as a category of degradation, but the fact that no estimate for this category was reported against New South Wales or Queensland suggests that either there was no problem acidity at the time or that identification/measurement techniques were not adequate to fully report the incidence of acidity in a national survey. The large ‘other’ category for New South Wales also indicates identification problems. This final catch-all category included loss of soil structure, loss of soil fertility and soil pollution.

A substantial amount of information was given about the extent of degradation. However, one of the conclusions of the study was that information on the loss of productivity, increased land management cost due to degradation, and the extent and significance of loss of soil structure and fertility was limited.

Table C.1: **Estimated area of degradation requiring treatment, 1975** (thousand hectares)

Form of degradation	*NSW*	*Vic.*	*Qld*	*WA*	*SA*	*Tas.*	*NT*	*ACT*	*Australia*
Area in use (a)	30 300	16 800	78 000	21 500	13 000	2 600	18 000	110	180 310
Area not requiring work	4 100	6 900	52 500	11 200	9 400	2 500	12 000	30	98 630
Area requiring work									0
Water erosion	19 900	5 800	19 800	7 000	1 700	83	3 400	77	57 760
Wind erosion	..	2 600	..	1 300	1 800	2	..	..	5 702
Combined wind and water erosion	4 100	..	41	1 400	..	8	..	..	5 549
Vegetation degradation	810	..	5 700	270	..	..	2 400	..	9 180
Dryland salinity	..	650	na	270	56	..	..	..	976
Irrigation salinity	60	830	..	..	11	..	..	..	901
Other	1 300	42	6	70	1	..	..	..	
Total	**26 170**	**9 922**	**25 547**	**10 310**	**3 568**	**93**	**5 800**	**77**	**80 068**
Percentage of agricultural holdings	*40%*	*69%*	*16%*	*9%*	*6%*	*4%*	*8%*	*ns*	*16%*
Area of agricultural holdings (b)	**64 938**	**14 376**	**157 159**	**114 662**	**62 777**	**2 186**	**75 963**	**70**	**492 131**
Degraded area as percentage of State	*33%*	*44%*	*15%*	*4%*	*4%*	*1%*	*4%*	*32%*	*10%*
Total area	**80 160**	**22 760**	**172 720**	**252 550**	**98 400**	**6 780**	**134 620**	**240**	**768 230**

.. Nil or less than 500 hectares.

a The analysis provided in Woods related to non-arid grazing, extensive cropping and intensive cropping areas. Arid grazing areas were not included in the published tables.

b Area of agricultural holdings is as reported in 1983, the time the study was published.

Sources: Woods (1983), ABS (1983), and ABS (1995a).

New South Wales

Early state-wide studies

Studies were undertaken in respect of the Eastern and Central divisions of New South Wales for the years 1941–1943 and 1967 under the auspices of the Soil Conservation Service (Kaleski 1945, Stewart 1968). One impetus to the 1967 survey was the need to determine the change, if any, in the extent of soil erosion from the earlier period, in the presence of divergent views concerning the advance of erosion and its control. Overall, the survey showed that there had been an increase in the area in which no appreciable erosion appeared, although there was an increase in the area of moderate gully erosion (see Table C.2). The increase in moderate gully erosion was attributed to increased clearing and wheat growing on the Slopes and Plains (approximated by the biogeographical regions BBS, NSS, DRP, CP, RIV, and the MDD (see Appendix B)). The general improvement in land condition was attributed to the spread of pasture improvement, use of fertilisers, rabbit control, change from monoculture of wheat to crop rotation, including a clover or lucerne phase, and improved pasture management. It is noteworthy that use of some fertilisers, and clover and lucerne agricultural systems are now identified with induced acidity and its consequential loss of soil fertility.

The survey focused on the most visible forms of erosion while some of the more recent concerns relating to the less visible dry land salinity, soil structure decline and acidification were not reported at the time.

Table C.2: **Incidence of land degradation in Eastern and Central Divisions of NSW,[ab] 1941–1943 and 1967**
(thousand hectares)

Class	*1941-1943*	*1967*	*Difference*
Gully erosion			
Moderate	7 814	8 588	774
Severe and extensive	228	214	- 15
Sheet erosion	9 668	5 443	- 4 225
Wind erosion			
Moderate	7 124	5 159	- 1 965
Severe	256	168	- 88
No appreciable erosion	21 925	27 444	5 519
Total area assessed	**47 016**	**47 016**	**na**

na Not applicable.
a The Eastern and Central Divisions of NSW covers: the coastal areas and Hunter Valley (approximate biogeographic regions NNC, SB, and SEC); the Tablelands (NET, NAN, NSS and SEH); Slopes (BBS and NSS); and the Nearer Western Plains (DRP, CP, RIV and MDD). See Appendix B for definition of biogeographic regions.
b Estimates converted from square miles using the conversion factor 1 square miles to 259 hectares (ie 1 square mile to 2.29 square kilometres).
Source: Stewart (1968).

The 1987–1988 Land Degradation Survey

The 1987–1988 Land Degradation Survey was also conducted by the Soil Conservation Service of New South Wales (Graham 1989, SCS-New South Wales 1989). This survey assessed the extent of soil erosion considered in the earlier studies and extended the coverage of land degradation to new degradation problems such as induced acidity, dryland and irrigation salinity and structural decline. To some extent, these problems arose from efforts to ameliorate earlier soil erosion problems and improve farm productivity (eg nitrogenous fertilisers and legumes with soil acidification, and heavy farm equipment and cultivation with soil structure decline). The survey differed from the Woods study, in that it took an inventory approach to the measurement of degradation. The intended uses of the survey results were to provide a comprehensive benchmark for future degradation assessments and the provision of information for the targeting of programs for the prevention and control of degradation.

The survey estimated that over 10 per cent of New South Wales suffers from severe soil structure decline or gully erosion and around 4 per cent of the state suffers from severe induced soil acidity and woody shrub infestation. Although the forgoing surveys are not easily compared at the detailed level, it is evident that gully erosion and vegetation degradation have been recognised problems for some time.

Four of the most frequently occurring forms of degradation — induced soil acidity, soil structure decline, gully erosion and wind erosion — are location specific and therefore largely within the control of individual land holders. At its initial stages, woody shrub infestation might also be regarded as being identified with individual planting or outbreak location(s). However, once established it takes more of a regional dimension, spreading over river catchments or whole biogeographic regions. On the other hand, some of the degradation forms such as dryland and irrigation salinity have a more regional character and individual farmer decisions will have less influence in reducing degradation levels. These tend to be among the less frequently recorded forms of degradation and more geographically concentrated. Nevertheless, for each form of degradation assessed, over three quarters of the state had recorded nil or minor levels.

Table C.3: **Incidence of land degradation in NSW, 1987–1988** (thousand hectares)[a]

Type of degradation	*Severity*	*thousand hectares*	*percent of State*
Dryland salinity[b]	Nil to minor	na	98.7
	Moderate	na	0.6
	Severe	na	0.7
Irrigation salinity[b]	Nil to minor	na	99.1
	Moderate	na	0.6
	Severe	na	0.3
Induced soil acidity	None	71 721	89.4
	Potential to become acid	5 570	7.0
	Severe	2 850	3.6
Soil structure decline	Nil to minor	65 446	81.7
	Moderate	5 460	6.8
	Severe	9 235	11.5
Surface scalding	Nil to minor	71 902	89.7
	Moderate	7 538	9.4
	Severe	701	0.9
Sheet and rill erosion	Negligible	70 065	87.5
	Minor	7 788	9.7
	Moderate	1 537	1.9
	Severe	482	0.6
	Very severe	269	0.3
Gully erosion	No appreciable	61 512	76.8
	Minor	1 830	2.3
	Moderate	45 500	9.2
	Severe	38 490	6.0
	Very severe	5 400	5.1
	Extreme	570	0.7
Mass movement of slopes[c]	Not present	na	97.1
	Present	na	2.9
Wind erosion	Nil to minor	60 096	75.0
	Moderate	11 124	13.9
	Severe	7 648	9.5
	Very severe	1 273	1.6

continued/...

Table C.3: **Incidence of land degradation in NSW, 1987–1988** (thousand hectares) **(continued)**

Type of degradation	*Severity*	*thousand hectares*	*percent of State*
Woody shrub infestation	Nil	57 369	71.6
	Minor	10 208	12.7
	Moderate	9 273	11.6
	Severe	3 291	4.1
Occurrence of perennial bush	Dense	691	0.9
	Frequent	3 148	3.9
	Scattered	5 489	6.8
	Nil	70 813	88.4

na Not available.

a Each form of degradation is described in Appendix A.

b The incidence of dryland salinity and irrigation salinity was assessed within a 100 hectare circle centred on a sample point. If salinity was observed in the area, this type of degradation was recorded as present and classified by its most severe manifestation around the survey point. The percentage reported refers to the proportion of survey points with the degradation characteristic and degree of degradation against all survey points.

c The incidence of mass movement was also assessed within a 100 hectare circle centred on a sample point. If mass movement was observed within that area, this type of degradation was recorded as being present. The percentage reported refers to the proportion of survey points reporting mass movement against all survey points.

Source: SCS-New South Wales (1989).

Regional disaggregation of degradation using survey data

The above analysis provides an aggregate, state-wide view of degradation in New South Wales. This broad view was obtained from aggregated information about the degradation characteristics of about 13 000 individual survey data points. This data point information can also be rearranged to obtain a regional disaggregation. Such a disaggregation is essential for the estimation of the effects of degradation.

In order to analyse degradation at the regional level, the Commission has estimated an index of degradation for each SLA (see Box C.1). This index takes values ranging from one to three with an index of one indicating that all survey points in an SLA have no or minimal degradation and an index of three indicating that all survey points have severe to very severe degradation. A composite index for all degradation types shows that no SLA has all points with maximum degradation (see Figure C.1). It is also the case that no SLA is completely free of degradation. From the low degradation regions the index increases steadily towards a final group of SLAs with the more degraded land for which the index of degradation increases sharply. The SLAs with the highest levels of degradation lie in an area extending from Goulburn in the

South Eastern Highlands across SLAs in the South Western Slopes to the Riverina (see Table C.4).

Box C.1: **Calculation method for an index of degradation by SLA**

Degradation information was collected for individual Land Degradation Survey data points. A method is required to aggregate information from these points to form an SLA index which facilitates SLA comparisons. Walpole *et al.*(1992) suggested a method for ranking data from the same survey and that method is adopted here.

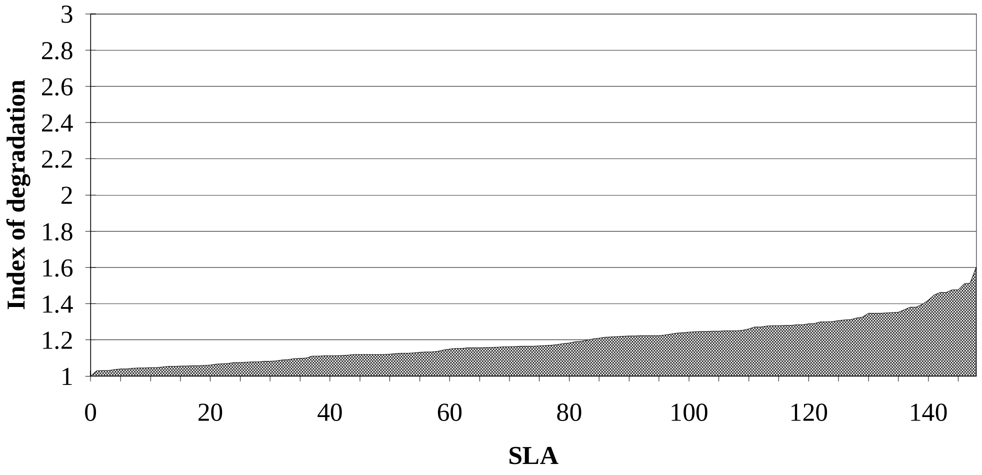
The index of degradation is adopted to rank SLAs according to the severity of degradation using a weighted average of survey points within the SLA. The level of severity at each point provides the appropriate weight. An SLA specific index is calculated according to the formula:

$$D_s = \frac{(1*k_s) + (2*l_s) + (3*m_s)}{n_s}$$

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). The formula is applied in this study to calculate an index for selected forms of degradation and for all degradation (ten categories) combined.

Each type of degradation was measured on its own scale that did not necessarily have three categories. This necessitated the reduction of each scale to a three point scale which generally involved dividing the categories into even groups of three. When there was only two points on the scale (eg mass movement) category one was given the weight of one and category two the weight of three. This general approach was modified for induced acidity for which problem acid soils were assigned to category three and none or potential acid soils were given the weight of one. A similar treatment was adopted for soil structure decline. This treatment was adopted because the description of the intermediate category in the survey (ie Potential acid and Moderate soil structure decline) did not necessarily imply a progressive loss of agricultural productivity. It was therefore most appropriately assigned to category one.

Figure C.1: **SLAs in New South Wales ranked by the index of land degradation (ten types), 1986–1987**



Source: Based on New South Wales land degradation information.

Table C.4: **Ten SLAs with highest indices of degradation in New South Wales in rank order, 1987–1988**

SLA	*Bio-geographic region*	
Goulburn	SEH	South Eastern Highlands
Coolamon	NSS	NSW SouthWestern Slopes
Junee		as above
Lockhart		as above
Corowa	RIV	Riverina
Boorowa	NSS	NSW SouthWestern Slopes
Leeton	RIV	Riverina
Forbes	NSS	NSW SouthWestern Slopes
Griffith	RIV	Riverina
Harden	NSS	NSW SouthWestern Slopes

Source: Based on New South Wales land degradation information.

Focusing on four types of degradation, it is found that the incidence of dryland salinity, irrigation salinity, induced acidity and soil structure decline across SLAs differs substantially (see Figure C.2). For both dryland and irrigation salinity severe degradation is clustered into a small group of SLAs. The most severe dry land salinity extends from SLAs in the Sydney Basin across the South Eastern Highlands to the South Western Slopes (see Table C.5). The incidence in these regions is consistent with the high levels of cleared land, high rainfall and sloping countryside — areas vulnerable to dryland salinity. Predictably, irrigation salinity is concentrated in the irrigation areas of the Riverina.

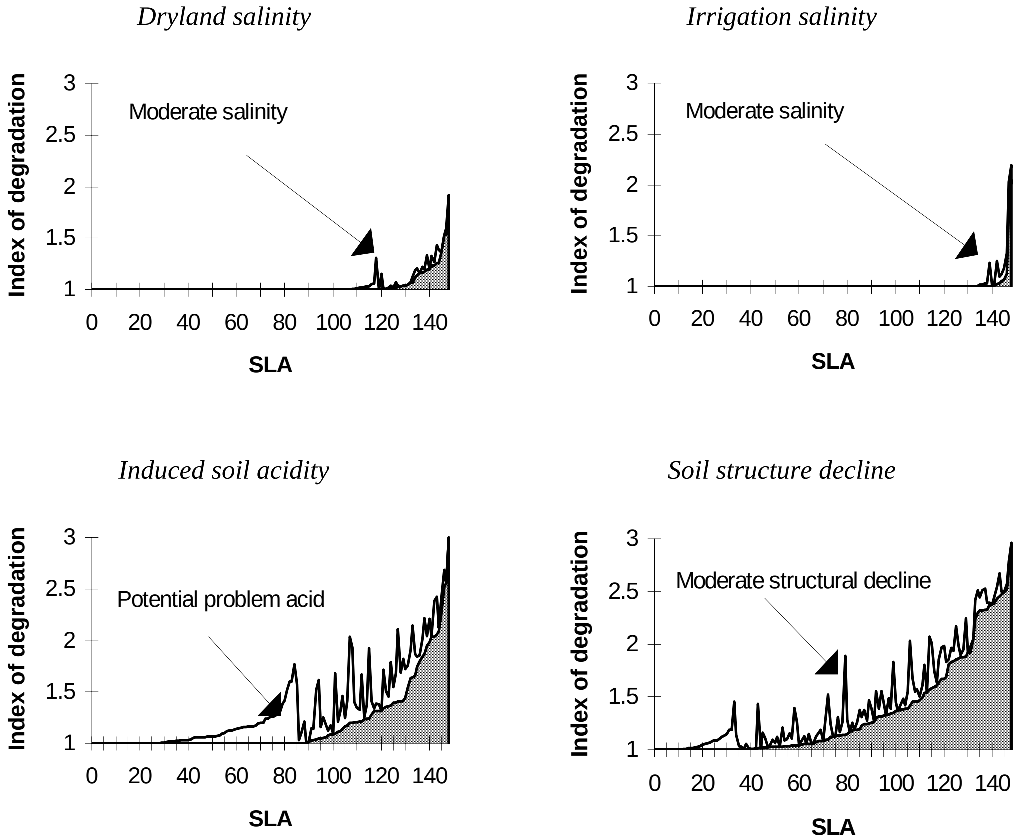
The incidence of severe induced soil acidity and structural decline is much more widespread (see Figure C.2). While severe induced acidity affects around one third of SLAs in New South Wales (concentrated in the Sydney Basin, South Eastern Highlands, the South Western Slopes and Riverina (see Table C.5)), there is a substantial group of SLAs poised with a high incidence of potential problem acid soils.

Severe soil structure decline is even more prevalent, with a substantial number of SLAs poised with moderate levels of structural decline. This form of land degradation is most prevalent in areas within the biogeographical regions of the Sydney Basin, South West Slopes and Riverina.

Overall, the highest incidence of severe degradation occurs in the South Eastern Highlands, South Western Slopes and the Riverina areas of New South Wales. Some SLAs appears in the top listed groups only once (eg Mudgee, Wakool, and Parkes) whilst others appear under several degradation headings (eg Goulbourn, Yass and Leeton). Over the four degradation types analysed in detail, the most widespread types in New South Wales are those that are largely location specific (ie induced soil acidity and soil structure decline).

A list of the ten SLAs most affected by each of the four types of land degradation are given below with their biogeographic locations (see Table C.5).

Figure C.2: **SLAs in New South Wales ranked by the index of land degradation, by type of degradation,[abc] 1986–1987**



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 that 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 (category *m* for each type of degradation in Box C.1). 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 (category *l* in Box C.1 for each type of degradaton) for each SLA is shown by the line above the shaded area, as marked on each graph.
Source: Based on New South Wales land degradation information.

Table C.5: **Ten most degraded SLAs in rank order**

	SLA	*Biogeographical region*	
Dryland salinity	Gunning	SEH	South Eastern Highlands
	Boorowa	NSS	NSW SouthWestern Slopes
	Camden	SB	Sydney Basin
	Goulburn	SEH	South Eastern Highlands
	Campbelltown	SB	Sydney Basin
	Yass	SEH	South Eastern Highlands
	Mulwaree		as above
	Penrith	SB	Sydney Basin
	Singleton		as above
	Mudgee	NSS	NSW South Western Slopes
Irrigation salinity	Griffith	RIV	Riverina
	Leeton		as above
	Wakool		as above
	Deniliquin		as above
	Murray		as above
	Conargo		as above
	Jerilderie		as above
	Murrumbidgee		as above
	Windouran		as above
	Narrandera	NSS	NSW SouthWestern Slopes
Induced soil acidity	Goulburn	SEH	South Eastern Highlands
	Shellharbour	SB	Sydney Basin
	Harden	NSS	NSW SouthWestern Slopes
	Kiama	SB	Sydney Basin
	Young	NSS	NSW SouthWestern Slopes
	Gunning	SEH	South Eastern Highlands
	Boorowa	NSS	NSW SouthWestern Slopes
	Leeton	RIV	Riverina
	Yass	SEH	South Eastern Highlands
	Griffith	RIV	Riverina
Soil structure decline	Fairfield	SB	Sydney Basin
	Corowa	RIV	Riverina
	Coolamon	NSS	NSW SouthWestern Slopes
	Blacktown	SB	Sydney Basin
	Deniliquin	RIV	Riverina
	Forbes	NSS	NSW SouthWestern Slopes
	Leeton	RIV	Riverina
	Bland	NSS	NSW SouthWestern Slopes
	Parkes		as above
	Narrandera		as above

Source: Based on New South Wales land degradation information.

Victoria

Historical accounts of degradation in Victoria extend back to the earliest days of settlement (Office of the Commissioner for the Environment — Victoria 1991). According to contemporary assessments, the most visible forms of erosion have been substantially reduced and controlled through better land management, as indicated by:

> Much of the area used for broadacre cropping is of insignificant or low or inherent susceptibility to all forms of water erosion, but of low, medium or high susceptibility to wind erosion. While clearing, cultivation and fallowing of croplands have promoted wind and water erosion, land management is continually evolving to minimise these impacts. (Office of the Commissioner for the Environment — Victoria 1991, p. 146)

and

> The establishment of introduced pasture species to replace native grasses adversely affected by grazing, and erosion works to counter land degradation initiated during the 19th Century has meant that water erosion has diminished as a problem for most land under permanent pasture. (Office of the Commissioner for the Environment — Victoria 1991, p. 164)

Available estimates of the extent of agricultural land degradation in Victoria indicate that induced acidity and soil structure decline are widespread (see Table C.6). For example, 58 per cent of dry land pasture is assessed as strongly or extremely acid, while around 40 per cent of broadacre cropland and 90 per cent of irrigated pasture is assessed as subject to severe soil structure decline. Both these forms of degradation are farm specific and their extent, in effect, reflects the outcome of land management systems adopted with respect to the operation of individual farms.

Table C.6: **Incidence of land degradation (other than salinity and surface scalding) in Victoria, 1991[ab]**

Type of degradation/ severity	*Broadacre cropping*		*Dryland pasture*		*Horticulural land*		*Irrigated pasture*	
	'000 ha	per cent	'000 ha	per cent	'000 ha	per cent	'000 ha	per cent
Land use area	5 807	100	7 200		200		530	
Water erosion - sheet and rill								
Insignificant/low	4 982	86	5 347	74	143	72	451	85
Moderate	869	15	1 607	22	26	13	53	10
Severe	28	..	174	2	28	14	26	5
Water erosion-gully tunnell								
Insignificant/low	5 721	99	3 983	55	167	84	..	..
Moderate	516	9	2 523	35	27	14	..	..
Severe	2	..	611	8	3	2	..	..
Wind erosion								
Insignificant/low	4 401	76	7 006	97	177	89	524	99
Moderate	1 313	23	93	1	20	10	6	1
Severe	75	1	30	..	0	..	0	..
Soil acidification								
Slightly acid	4 670	80	423	6	58	29	403	76
Moderately acidic	376	6	1 851	26	34	17	104	20
Strongly acid	283	5	3 714	52	47	24	22	4
Extremely acidic	125	2	455	6	1	1	1	..
Soil structural decline								
Insignificant/low	2 548	44	1 241	17	58	29	8	2
Moderate	907	16	4 386	61	72	36	48	9
Severe	2 334	40	1 502	21	64	32	474	89

.. Nil or less than 500 hectares (0.5 per cent).

a 1991 refers to the year of publication of the estimates.

b The total area in Victoria is estimated to be 22 760 thousand hectares. The area of agricultural holdings is 11 857 thousand hectares (1991).

Source: Office of the Commissioner of the Environment (1991).

The area subject to dryland and irrigation salinity is substantially less than that subject to structural decline and induced acidity. In the case of irrigation salinity, the estimated area of salinity occurrence (140 000 hectares) is one fifth of the area of irrigated pasture and horticulture land. The assessed (see Table C.7) area subject to dryland salinity is also small relative to agricultural land in Victoria.

Table C.7: **Incidence of land degradation (saline seepages and salt scalds) in Victoria, 1991[ab]**

	'000 ha
Total area affected by human induced saline seepages and salt scalds	290
Occurrence of dryland salinity	135
Occurrence in irrigation areas	134 to 140

a 1991 refers to the year of publication of the estimates.

b As the estimates of salination in dry land and irrigation areas are not consistent with the total, the estimates should be treated as indicative orders of magnitude.

Source: Office of the Commissioner of the Environment (1991).

Western Australia

Estimates of the extent of land degradation in Western Australia are provided in a departmental submission to a State Parliamentary inquiry (Department of Agriculture (Western Australia) 1988). These estimates show that the most extensive forms of degradation in Western Australia are vegetation decline and erosion in the rangelands (see Table C.8). With respect to degradation associated with intensive land use, soil structure decline (as generally defined in Appendix A and including the Western Australian items: soil structure decline; subsoil compaction; and water repellence) is the most widespread, covering up to 7 per cent of the area of the State or around 16 per cent of agricultural land holdings.[1] While only a relatively small area is recorded as being affected by dryland salinity, the area that could be potentially affected is six times greater, covering 1 per cent of the state area.

In terms of future concerns with respect to land degradation, the Department of Agriculture assessed that dryland salinity was progressing relatively slowly in the dry inland areas, but that widespread acidity in the coastal areas could occur in the next 30 to 50 years. However, a more serious concern relates to soil structure decline and acidification. At the time the report was written (1991), it was assessed that these forms of degradation posed greater cost penalties on farmers and that there were no economically viable means of control (Legislative Assembly, Western Australia 1991).

1 As individual areas may be subject to each form of degradation, this estimate which is based on a simple aggregation of the area covered by each form of degradation, is an upper limit.

Table C.8: **Incidence of land degradation in Western Australia, 1988[a]**

Land area and form of land degradation	*Thousand hectares*	*Percentage of state*
Estimated area of the State	252 550	100.0
Estimated area of agricultural land holdings (1991)	110 652	43.8
Dry land salinity		
Assessed	433	0.2
Potential	2 447	1.0
Water logging		
Under cropping (average year)	500	0.2
Under pasture (average year)	1 300	0.5
Soil acidification	375	0.1
Soil structure decline	3 500	1.4
Subsoil compaction	8 500	3.4
Water repellency	5 000	2.0
Water erosion	750	0.3
Wind erosion	50	0.0
Wind and water erosion in rangelands	7 300	2.9
Vegetation decline in rangelands	19 600	7.8

a 1988 refers to the year of publication of the estimates.
Sources: Department of Agriculture (1988), and ABS (1995a).

Tasmania

Estimates of degradation in Tasmania are provided in an assessment of soil and land degradation on private freehold land in Tasmania for the year 1992–1993 (Grice 1995). The survey provides the first comprehensive assessment of soil and land degradation for the two million hectares of private freehold land in Tasmania. Eight forms of land degradation were assessed: dryland salinity; soil structure decline; sheet and rill erosion; gully erosion; tunnel erosion; mass movement; wind erosion; and tree decline. The survey follows a series of soil erosion assessments dating back to 1941. The most recent assessment before the current effort, was for the Inter-Departmental Standing Committee on Soil Conservation in Tasmania in 1988 which estimated the extent and severity of degradation statewide.

The 1992–1993 survey used a modification of the Draft National Land Degradation Survey Methodology (Graham 1989) applied in New South Wales for the reference years 1987–1988 (discussed above). Although the Graham methodology was compiled for a nation-wide survey, Grice points out that it has only been applied in New South Wales and Tasmania. The methodology applied in Tasmania departed from that proposed for the national survey by using land systems as sample points rather than regular grid sample points.

It was found that almost all private land suffers from, or with current land use is subject to a hazard from, at least one form of degradation. However, in all cases other than tree decline, over 80 per cent of private freehold land has nil to minor degradation (see Table C.9). For tree decline, 50 per cent of the land has nil to minor. The most extensive occurrence of any form of degradation was tree decline with about 40 per cent of land affected by moderate to extreme decline, while the most limited occurrence was tunnel erosion for which 5 per cent of the land was affected by shallow to deep tunnels.

In terms of potential long-term damage, Grice concluded that tree decline and soil structure decline are less serious problem since both may be treated and land returned to its former productivity. On the other hand, sheet and rill, gully, tunnel and wind erosion hazard, although they too may be treated, are potentially more serious. Soil transferred when these forms of erosion are active, represents a permanent loss to the productive potential of the affected areas.

Table C.9: **Incidence of land degradation on private freehold land in Tasmania, 1992–1993**

Type of degradation/ severity	*Thousand hectares*	*Degradation as percentage of area assessed*
Land area in Tasmania	6 780.0	
Land area assessed	2 062.0	100
Dryland salinity		
Nil	1 884.6	91
Moderate	169.2	8
Severe	8.2	..
Soil structural decline hazard		
Nil to minor	1 746.0	85
Moderate	295.0	14
Severe	21.6	1
Sheet and rill erosion hazard		
Nil to minor	1 836.0	89
Moderate	210.5	10
Severe	8.0	..
Very severe	6.3	..
Extreme	1.2	..
Gully erosion		
Nil	1 150.0	56
Minor	673.8	33
Moderate	224.8	11
Severe	12.6	1
Tunnel erosion		
Nil	1 959.0	95
Shallow tunnels	76.0	4
Deep tunnels	27.0	1
Mass movement		
Nil	1 793.0	87
Terracetting	79.0	4
Mass movements	191.0	9
Wind erosion hazard		
Nil to minor	1 741.0	84
Moderate	305.0	15
Severe	16.0	1
Tree decline		
No assessment	162.0	8
Nil to minor	1 039.0	50
Moderate	648.0	31
Severe	161.0	8
Extreme	52.0	3

.. Nil or less than 500 hectares (0.5 per cent).
Source: Grice (1995).

C.3 Estimates of land degradation provided in selected published studies

Some specialist studies provide information about individual types of land degradation and the rate of advance of that degradation given land management practices at the time. The studies are not compiled using a common methodology or reference periods when compared to either each other or the state-wide studies. Therefore, the results from individual studies cannot be easily used to prepare a national inventory of land degradation. Nevertheless, they individually provide information about land degradation that should assist in the development of an overall view of land degradation in relation to land management. The approach adopted in this section is to report three official studies relating to irrigation salinity, dryland salinity and soil acidification — topics which are further analysed in the state-wide study of New South Wales agriculture. Other studies are available and could also be drawn upon to provide a fuller exposition of the extent of land degradation and issues in its measurement. For example: Tothill and Gillies (1992) provide a detailed study of pasturelands in northern Australia including estimates of the extent of vegetation decline; and Graetz *et al.* (1995) and the Department of the Environment, Sport and Territories (1995b) provide estimates of the area of land clearance and the occurrence of selected feral animals in a study of landcover disturbance in Australia.

Irrigation salinity

Irrigation salinity is associated with the rise in water tables as water accessions exceed plant use and runoff. The New South Wales survey measured the severity of salination. While not necessarily measuring the extent and severity of salination, studies have been made of changing water tables in the Murray-Darling Basin irrigation areas. These studies indicate that without intervention water tables in the Riverine Plains Zone will continue to rise, and 30 to 50 year projections are provided (see Table C.10). The estimates show that the rate of increase in the area subject to high water tables differs between regions. In the New South Wales irrigation areas of the Riverine Plains Zone, using these growth rates, the area with high water tables could increase by around 3 per cent per year during the 1990s. Because high water table areas are already widespread in Victorian but less so in New South Wales, the potential increase in high water tables areas is less in Victoria (ie estimated to be below 1 per cent per year during the 1990s) than in New South Wales.

However, the presence of irrigation does not always imply that waterlogging and salinity are advancing. As indicated for the Mallee Zone of the Murray-Darling Basin, water tables are reported to be stabilised for much of this area.

Table C.10: **Some estimates of the rates of change in selected NSW and other areas in the Riverine Plains and Mallee Zone water tables without intervention, 1985 forward**

Zone and locality	*Water table situation*	*Approximate rate of advance*
Riverine Plains Zone		
Wakool, Deniliquin and Murrumbidgee regions in NSW; and Kerang and Shepparton regions in Victoria	Flat plain mainly of clay soils, with major aquifer systems in underlying sediments.	*Estimates released 1987*[a] NSW: 10 000 hectares per year for the next 30 years. Victoria: 3300 hectares per year for the next 30 years. *Estimates released 1990*[b] Whole region: 13 500 hectares per year to reach 2 metre point per year for the next 55 years
Mallee Zone		
Sunrasia Region covering irrigated areas in Victoria and NSW centred on Mildura and the Riverland Region of SA.	Soils generally sandy and permeable. Sub-surface drainage to most areas. Ground-water mounds exist in horticultural areas adjacent to the Murray River and Murray Trench.	Saline scalds associated with dryland farming are decreasing. Water tables largely stabilised: except around Loxton and Golden Heights (SA).

a In NSW, high water tables were expected to increase from 200 thousand hectares in 1985 to 300 thousand by 1995 reaching 500 thousand hectares by 2015. In Victoria, an increase in high water table areas from 360 thousand to 460 thousand in the next 30 years is projected. It is assumed that the area subject to salinity would increase linearly, at the constant amount reported.

b Based on shallow water tables rapidly increasing. Water tables within about 2 metres of surface cover approx. 560 thousand hectares. By the year 2040 about 1.3m hectares could be affected. (See Gutteridge, Haskins and Davey *et al.* 1990.)

Sources: Murray Darling Basin Ministerial Council (1987), and Gutteridge, Haskins & Davey *et al.* (1990).

High water tables can lead to waterlogging and salinity. Nevertheless, the area actually predisposed to salination is generally much larger than the area affected by visible salination. As a measure of degradation severity, visible salinity could be defined as moderate to severe salinity according to the classification scheme outlined in Appendix A. In New South Wales visible salination is estimated to affect around 4 per cent (ie 9 /202 thousand hectares) of land with high water tables (see Table C.11). That is, less than 2 per cent (ie 9 /510 thousand hectares) of irrigated land in New South Wales. In Victoria, the degradation process is much further advanced. Visible salination is estimated to affect about one quarter of the area with high water tables or around 20 per cent of the irrigated land area.

The spillover effects of irrigation farming systems are evident from the information for the Kerang region in Victoria. For that region, the area actually affected by high water tables exceeds the area irrigated.

Although waterlogging comes with high water tables, the estimates do not indicate the proportion of land suffering from 'severe' waterlogging as evaluated from the point of view of changes in the productivity of the soil.

Table C.11: **High watertables, waterlogging and land salination problems in the Riverine Plains Zone** (thousand hectares)

			Area affected by high watertables			
Region	*Area*	*Area irrigated*	*1985*	*2015*	*Visible salinisation 1985*	*Area predisposed to salinisation*
New South Wales						
Wakool	341	72	34	39	4	249
Deniliquin	374	214	22	90	4	168
Murrumbidgee	550	207	143	250	2	na
Lachlan (a)	89	17	3	30	na	na
Sub-total	**1354**	**510**	**202**	**409**	**9**	**na**
Victoria						
Kerang	334	211	240	240	83	na
Shepparton	500	243	120	220	4	na
Subtotal	**834**	**454**	**360**	**460**	**87**	**na**
Total	**2188**	**964**	**562**	**869**	**96**	**na**

na not available.
a The area in Lachlan is subject to intermittent salt effects.
Source: Murray Darling Basin Ministerial Council (1987).

Comparison between studies is not always possible. In the case of irrigation salinity, the SCS-New South Wales study assessed the severity of salinity on the basis of the number of survey points effected (see Table C.3) whereas the estimates presented in the Murray-Darling Basin Ministerial Council study were expressed in terms of area affected.

Dryland salinity (salt scalds and saline seepage)

An Australia-wide study conducted for the Land and Water Resources RDC *et al*. (1992) indicates that salt scalding and saline seepage (referred to in the study under the collective title of 'dryland salinity') is most widespread in South Australia and Western Australia and that, in all states, the estimated area affected by dryland salinity is about half of the total area at risk (Table C.12). The areas effected and at risk are a small portion of the total state areas.

Table C.12: **Dryland salinity (salt scalds and saline seepage) by state, 1992[a]** (thousand hectares)

State	*Area affected*	*Area at risk*	*Proportion of divertable water supplies not potable*	*Area affected as a proportion of state area*	*Area at risk as a proportion of state area*
			per cent	per cent	per cent
NSW	22.0	b	na	..	b
Victoria	100.0	198.6	na	0.4	0.9
Queensland (c)	30.0	70.0	na	..	..
Western Australia (d,e)	900.0	2 400.0	0.1	0.4	1.0
South Australia (f)	225.0	na	..	0.2	na
Tasmania	na	na	na	na	na
Northern Territory	na	na	na	na	na
ACT	na	na	na	na	na
Total	**1 277.0**	**2 668.6**	**na**	**0.2**	**0.3**

.. Nil or less than 0.5.
a Estimates published in 1992.
b Reportedly there is a much larger area at risk than currently affected, especially in cropping areas.
c Most outbreaks are small (30 ha) and dispersed. The summer rainfall pattern means that there is more runoff and less groundwater recharge compared to winter rainfall areas.
d Saline seeps affect 443 000 hectares and saline scalds 340 000 hectares.
e Estimate of salinity in water relates to the south west of the State.
f The estimated range affected is between 225 000 and 300 000 hectares.
Source: Land and Water Resources RDC *et al.* (1992).

The estimated areas affected by dryland salinity in this study differ substantially from the estimates in other studies. This may be because it is a combination of two forms of degradation. Induced saline seepage generally follows from land clearing and is typical of higher rainfall areas, whereas saline scalds often follow from overgrazing and occur mainly in arid and semi-arid areas (Appendix A). The fact that both forms of salinity can occur naturally or be induced by land management decisions may also contribute to the difficulty in obtaining integrated estimates from different studies.

The difference between studies is marked. In Victoria, the study indicates 100 000 hectares are affected compared to the state study estimate of 135 000 hectares — a one third difference. For Western Australia, the area affected could be as high as 900 000 hectares according to the Land and Water Resources RDC *et al.* (1992) review. Estimates of the components of this total suggest that there is 443 000 hectares of saline seepage and 340 000 hectares of scalding — leaving a reconciliation difference of around 200 000 hectares. The estimated saline seepage is similar to the Department of Agriculture-Western Australian estimate of 433 000 hectares (see Table C.8) while the estimate of saline scalding is not shown separately in the state departmental assessment. The area at risk in the two reports is similar.

The Land and Water Resources RDC *et al.* (1992) review puts the area affected by dry land salinity in New South Wales at 22 000 hectares. The SCS–New South Wales study separates saline seepages and scalding (ie dryland salinity) and surface scalds (a form of degradation typical of soil erosion in arid areas). The New South Wales study did not make area estimates for dryland salinity due to difficulty in projecting the area affected from data collected at individual survey points.

In addition, for five of the states and territories, no estimates of the area at risk are provided.

Soil acidification

The extent of soil acidification was estimated as part of a Land and Water Resources RDC investigation into the amelioration of soil acidification (AACM 1995). As the survey relates to naturally acid soils rather than induced acidification, the study does not provide a good indication of the level of land degradation for two reasons. First, it does not show the shift due to land management decisions from potentially acid soils to problem acid soils, and secondly, it does not show any shift due to land management systems designed to improve the productivity of the land for certain crops and pastures from naturally acid soils to less acid soils . As the net movement toward increasingly acid soils is of prime concern for studies focused on the productivity of the land, the first consideration receives attention in studies relating to agricultural land degradation.

Some indication of the implications of the difference between the area of natural and induced acidity for the measurement of land degradation can be obtained from a comparison between the SCS-New South Wales study and the AACM study. Such a comparison is possible because the ‘severe’ and ‘highly acidic’ categories have similar definitions. The NSW study estimates that induced acidity affected around 2.8 million hectares (see Table C.3) whereas the AACM study found that there is around 13.5 million hectares of highly acidic soils (see Table C.13). Similarly, in Western Australia the area of acid soils is put at around 0.4 million hectares in the state study (see Table C.8) which compares to 4.7 million hectares in the AACM study (see Table C.3). The direction of difference is not always the same however. For Victoria, the state study estimates for land that is ‘strongly acid’ to ‘extremely acid’ is 4.6 million hectares compared to the specialist study of around 3 million hectares.

Table C.13: **Extent of acid soils in Australia 1995**[abc]
(thousand hectares)

State	*Highly acidic (pHca<4.8)*		*Moderate acidity (pHca 4.9-5.5)*		*Slight acidity (pHca 5.6-6.0)*	
		per cent		per cent		per cent
New South Wales	13 500	17	5 700	7	5 100	6
Victoria	3 000	13	5 600	25	5 500	24
Queensland	8 400	5	32 000	19	na	na
Western Australia	4 700	2	4 700	2	na	na
South Australia	2 800	3	na	na	na	na
Tasmania	1 000	15	na	na	na	na
Northern Territory	na	na	na	na	na	na
Australian Capital Territory	na	na	na	na	na	na
Total (of available estimates)	**33 400**	**4**	**48 000**	**6**	**10 600**	**1**

Percentages relate to share of total area.

a Refers to the date of publication.

b The data were drawn by AACM from earlier data prepared by Porter and McLaughlin (1992), Evans (1991) and Helyar *et al.* (1990). Because the definition of high medium and low levels of acidity may vary between studies, the information from each study and for each state may not be strictly compatible. In addition, there is little data available to estimate the current state of soil acidity in subsoils (ie .10cm depth).

c These data do not distinguish between naturally acidic soils and soils (both acidic and alkaline) which are degrading because of acidification due to use in agricultural production.

Source: AACM (1995).

Overall, New South Wales is reported as having the largest part of its surface area subject to highly acid soils, followed by Tasmania. In addition, slightly acid and moderately acid soils predominate in Victoria and Queensland.

Degradation in this study is concerned with changing levels of soil acidification due principally to agricultural use. Concerning the advance of soil acidification, the AACM study indicates that:

- higher rainfall areas in south western and eastern Australia have the highest risk of soil acidification;
- more than 55 million hectares of moderately or slightly acidic land (pH_{Ca} 4.9–6.0) across Australia have the potential to degrade to highly acidic conditions (pH_{Ca} <4.8);
- many soils in north east Victoria have acidified by 1 pH unit during the last 30 to 40 years; and
- modest rates of acidification in New South Wales will result in subsurface acidification of 1 pH unit within 23 years for sandy soils and 113 years for clay soils.

In order to provide indicative measures of the possible rate of advance of acidification, with no change in soil management, the advances reported in points three and four in the previous paragraph, are calibrated to a (hypothetical) one fifth increase from a slightly to moderately acidic base, over the period mentioned for each region.[2] The indicative rates of advance calculated on that basis are:

- 0.5 percentage points each year for north eastern Victoria for the last forty years;
- 1 percentage point each year for the next 20 years for sandy soils in NSW; and
- 0.2 percentage point each year for the next 110 years for clay soils in NSW.

[2] One fifth (ie 0.2) is estimated as 1pH over a base of 5.5 pH which is the average of the range of moderate to slight acidity as reported in Table C.13. The percentage points change in acidity from a base of 5.5=100 is therefore given by $\frac{1}{5.5}*\frac{100}{yrs} \approx \frac{0.2}{yrs}*100$ where *yrs* refers to the number of years over which the expected acidification is forecast to occur. For example, the percentage points change in acidification over the last 40 years in Victoria is given by $\frac{1}{5.5}*\frac{100}{40} \approx 0.5$ per annum.

These projections indicate that the annual rate of change is sensitive to soil types and that even for the soils most vulnerable, the rate of degradation may appear slow. Although induced acidity may be farm specific, identifying the effects of degradation on farm productivity and managing appropriate amelioration strategies may be difficult.

APPENDIX D
CONCEPTUAL MODEL OF LAND DEGRADATION, FARM OUTPUT AND PROFITS

D.1 Introduction

From the point of view of agricultural land use, most land resources subject to degradation are renewable either through human conservation efforts or natural processes (see Appendix A). While topsoil is normally regarded as a non-renewable resource, its vulnerability to soil erosion (or soil erosion hazard) due to the action of wind and water can be reduced through conservation efforts.

Sustainable land use in agriculture is therefore 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 expenditure and natural regeneration can renew those resources and improve productivity for future use. This appendix uses a stylised model of natural resource use to consider the salient features of this two way process. It is also used to consider how the bio-physical process of land degradation and conservation inter-relate with farm outputs and profits. A more formal presentation of the basic ideas considered in this appendix can be found in studies by Clarke (1992), Sweeney (1993) and Pagiola (1993) while the presentation used to develop this discussion of land degradation is adapted from Pearce and Turner (1990).

In principle, there are many levels of land resource use, conservation effort and degradation consistent with the profitable operation of farming enterprises and sustainability of the agricultural industry. The principles, however, do not provide prescriptions concerning what those levels should be. That is an empirical question which is considered in other parts of this information paper.

Section D.2 sets out a typical pattern of regeneration of the land condition and fertility following some process of land degradation while Section D.3 links agricultural activity to changes in land condition and fertility. Distinctions are made between exploitative and conservation effort, and natural regeneration. Section D.4 places a cost on exploitation effort and Section D.5 discusses possible production outcomes from farmer effort and from the use of land resources in various stages of degradation. Section D.6 then links the discussion of agricultural revenues and costs to define profits from land use, and the limits likely to be placed on degradation by standard commercial incentives to maximise profits. The framework discussion provided in Sections D.2 to D.6 is placed in a broader environmental and economic context in Section D.7 which considers some of the simplifying assumptions of the stylised model and some general ecological issues that are not necessarily taken into account in agricultural land management decisions. Section D.8 provides a summary.

D.2 Typical pattern in the regeneration of land resources

The processes of land use and regeneration move forward in time and at any point in that continuum, land condition and fertility can be represented as some stock which has value for human or environmental use. The condition of the land does not stand still even without human intervention. Nevertheless, it is generally agreed that the intensive use of land by humans speeds and modifies the processes of change. This means that there is a requirement for conservation effort if the productivity of the land is to be maintained for future use.

In this dynamic context, sustainability of agriculture requires the maintenance of the productive capacity of land through time; with the farmer setting out to achieve some economic yield over the years. However, there are both bio-physical forces and economic imperatives at work so that the farmer does not face a static situation. The difficulty with defining a framework for evaluating the potential for sustainability is therefore in linking the bio-physical process of land use with the economic processes that determine the incentives for that use. A useful starting point is the regeneration potential of land condition and its fertility. This starting point establishes a reference against which the resource using effects of agricultural production can be related to the regeneration effects of conservation and natural processes.

The regeneration potential of land resources are likely to differ depending on the prevailing condition of the land, with regeneration processes being slow with highly degraded land. As land conditions improve, the potential for further improvements in condition and fertility as natural processes begin to replace nutrients and chemical, repair soil structure etc, would also improve (see Figure D.1a). This process could continue until, at the other end of the spectrum, the land resource reaches its potential fertility level and the scope for further improvement no longer exists.

By evaluating the expected improvement in land condition and fertility for each resource level, it is possible to define the rate of regeneration that would occur with the elapse of time (Figure D.1b). The rate of regeneration so determined is again depicted as being smallest when the land condition and fertility levels are closest to their minimum or maximum levels. The rate of regeneration is at its peak when the feasible improvement in land condition and fertility for any period of time is at its maximum (ie at resource level Z_0). In order for an activity to be sustainable, the bio-physical processes of soil utilisation and regeneration need to be in balance. Such a balance could occur at any point along the curved line depicted in Figure D.1b.

Figure D.1: **Stylised growth curve for the renewable resource — fertile land, and the rate of natural regeneration of land resources**

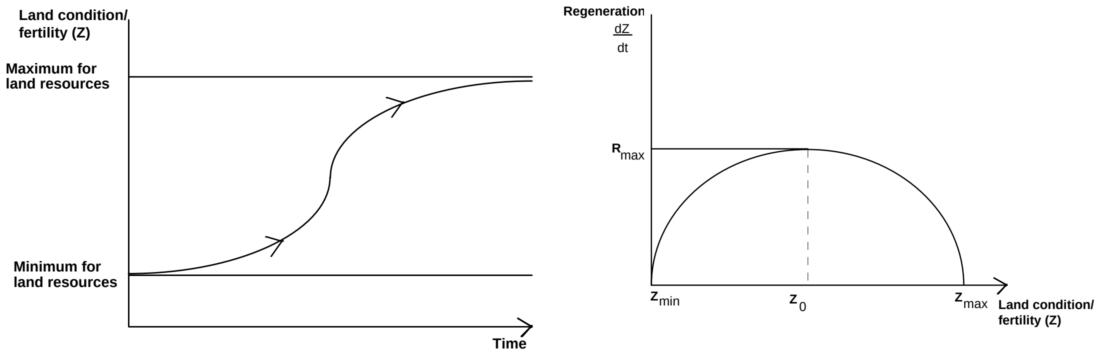


Figure D.1a

Even though regeneration can occur on highly degraded land, there would be some level of degradation beyond which regeneration, for all practical purposes will not occur. In the hypothetical situation depicted here, regeneration commences slowly as natural processes begin to replace nutrients chemicals etc. It then accelerates and finally slows down again as soil condition reaches full restoration.

Figure D.1b

The rate of regeneration is at its maximum at Z_0. The regeneration model in this presentation is useful for integrating the economic and environmental analysis of land use.

The hypothetical resource and growth curves are represented as smooth and symmetric (Figure D.1). In practice, they may not be smooth or symmetric and the regeneration periods and implications for agricultural sector productivity may differ substantially between forms of degradation. As the rates of resource depletion and renewal determine the potential levels of sustainable output, as will be discussed below, a major part of agricultural land management involves the assessment of land fertility changes due to different farming activities according to their locality.

Available information indicates that the actual regeneration periods for the land resources differ substantially between types of degradation. The Ecologically Sustainable Development Working Groups (1991) reported natural regeneration periods ranging from around five years for forms of degradation relating to soil nutrient exhaustion and induced top soil acidity to periods approaching 100 years for water logging and salinity. These periods relate to bio-physical processes and do not capture the nature or direction of changes in agricultural sector productivity or profitability. While loss of topsoil is treated as a permanent loss of land resources by the Working Group, the vulnerability of the land to erosion and, through this, topsoil loss, can be treated as a renewable resource within the framework being outlined.

D.3 The link between agricultural land use and changes in land resources

In order to maintain a sustainable system of agriculture (for a given technology), it would be necessary for the use of land resources to be matched by the rate of regeneration. Where this matching occurs there will be a steady state that is sustainable. The curve showing fertility yielded (a flow measure) against land condition/fertility (a measure of the resource stock) depicts all those points at which yield matches regeneration (see Figure D.2). Each of those points is sustainable in a steady state. However, there is only one combination of resource yield (say in the production of wheat) and land resource stocks that is consistent with a steady state maximum sustainable land resource use. This occurs at the point when the regeneration capability of the land is at its maximum. The soil condition and fertility level associated with the maximum sustainable yield (or renewable resource use) is depicted by Z_2 with potential yield being Y_2 in Figure D.2.

Use of the land resource to obtain some yield from the soil involves effort on the part of the farmer through the commitment of labour and the deployment of capital equipment and materials. The yield obtained by the farmer is therefore jointly determined by his or her effort and the condition of the soil. Figure D.2 depicts how the choice of effort level will determine both yield and resource stock level. It does this by showing yield as a function of effort (E) and resource stocks (Z), that is $Y = f(\overline{E}_n, Z)$. In this set up, the level of effort E is chosen by the farmer, while yield and the resource stock vary according to that choice.

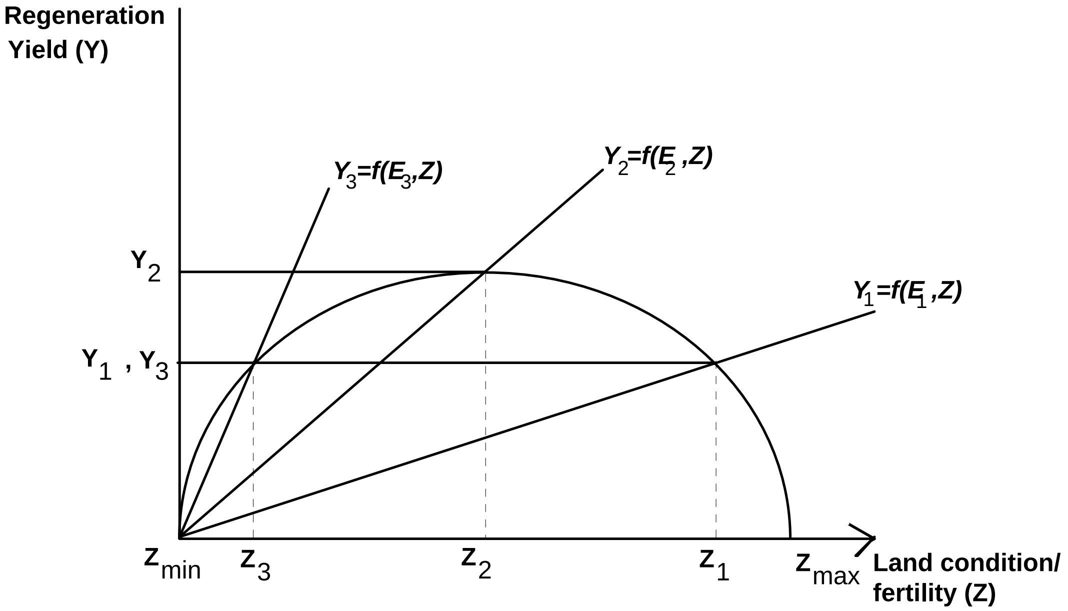
The agricultural industry effort necessary in this set up to obtain maximum sustainable yield is level E_2 (Figure D.2). With this amount of effort, yield and resource stock levels adjust so that yield equals the highest possible level of regeneration. This is depicted in Figure D.2 by the intersection of the yield line with the land regeneration curve. Effort level E_2 could also be committed when the land has higher (towards Z_{max}) or lower (towards Z_{min}) levels of fertility to give differing yields. However, with those effort-resource combinations, regeneration and yield would not coincide and the resource stock would be either increasing or declining, depending on the circumstances. For example, if land condition and fertility were above Z_2, the level of effort being applied would cause resources to be used at a rate above that at which they could regenerate and there would be a net depletion of the resource stock. On the other hand, if the land condition and fertility level were below Z_2, the amount of effort would cause the resource stock to be used at a rate below that at which it could regenerate, and there would be a net addition to the resource stock.

Maximum sustainable resource yield is only one of many different possible levels of yield. However, the other possible sustainable yields would be associated with a different levels of land condition and farmer effort. For example, an hypothetical increase in farmer effort — depicted as a shift of effort from level E_2 to a higher level of effort E_3 — could initially yield a temporary increase in production as the resource stock was mined. However, because regeneration could not keep up with the resource depletion brought about by the additional effort, the natural resource stock would decline. Providing exploitative effort did not change, a new point on the regeneration/yield curve would be reached where the resources yielded would be again matched by the rate of regeneration. However, in the case depicted in Figure D.2, the new higher level of effort sustains lower yields.

In agriculture, higher levels of effort may be reflected in higher harvesting costs per unit of output as the crop quality and pasture yields decline with deteriorating land condition and fertility (ie as the resource stock moves toward Z_{min} in the analytical framework depicted in Figure D.2). For livestock, higher animal husbandry and mustering costs per animal are likely as animals are grazed on larger areas due to declining pasture quality that comes with degradation.

If farmer effort is reduced (eg from E_2 to E_1), the exploitative use of the land would decrease and land condition and fertility would increase to Z_1.

Figure D.2: **The rate of natural regeneration of land resources and degradation associated with agricultural industry production effort, by stock of the land resource**



An increase in exploitative effort (ie from E_1 to E_3) would increase degradation and reduce the land resource stock. There are many combinations of yield and effort possible. Maximum sustainable yield would occur when level of effort E_2 is chosen by the farmer. That level of effort would yield Y_2 and be associated with land condition Z_2

In addition to exploitative effort, some agricultural industry effort and expense may be directed at environmental conservation activities (eg fertilising, planting of trees and works). These activities complement natural regeneration, which for any given level of exploitative effort, raises the potential level of the land resource. The advantage to farmers of conservation effort is that additional land resource stocks may be consumed at some future time. The conservation effort is one way of augmenting the natural processes of regeneration so that the potential fertility yield (ie productivity) of a particular area of land is increased, albeit at the cost of the conservation effort.

This hypothetical analysis shows that there are many levels of farm effort and land resource stocks that afford an equilibrium between land resource use and regeneration. It also shows that neither the highest possible farm effort nor the maintenance of the highest possible level of resource stocks would necessarily lead to the highest possible yield from land resources to farming enterprises. In order for decisions to be made about optimal farmer effort, soil condition and fertility, the economic benefit from alternative resource use decisions needs to be considered.

D.5 Production from the use of land resources

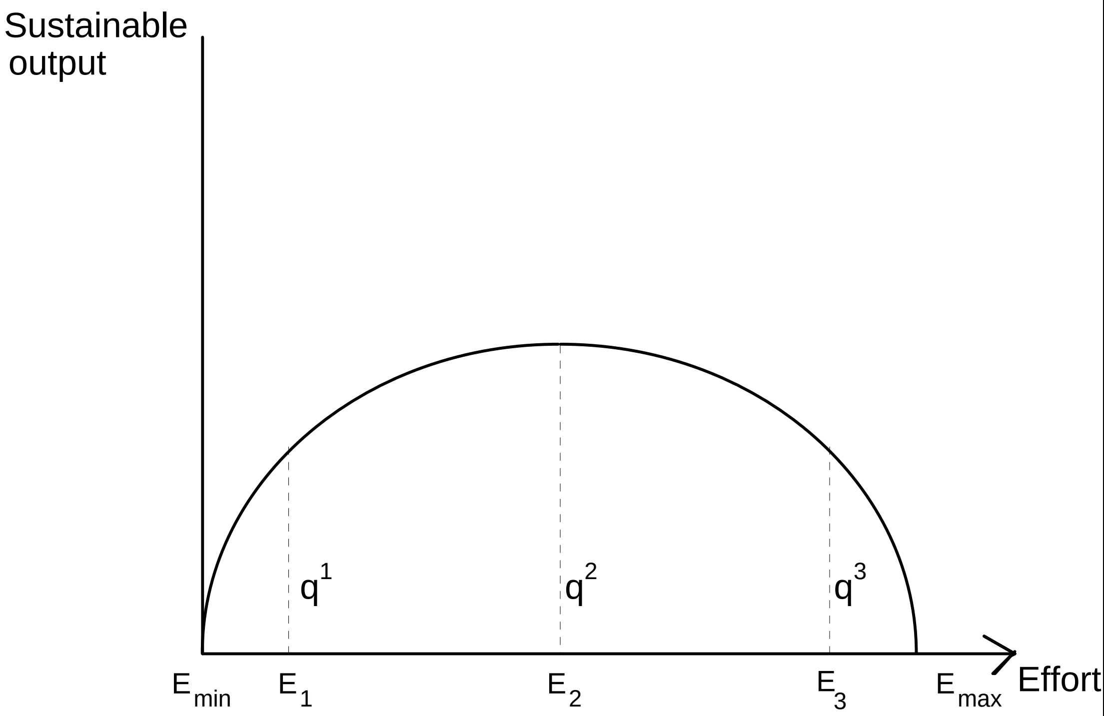
In this section, the bio-physical framework which emphasised the relationship between land condition and fertility, resource use and farmer effort is translated into an economic framework that emphasises the relationship between those inputs and farm output in the form of food and fibre. How farm outputs vary with changes in farm inputs, given land resources, is determined by the available technology of production.

Where farmer effort (as measured by inputs of materials, labour and capital) is low, so to would be the production of food and fibre. The low levels of inputs and outputs would make few demands on the environment and land condition and fertility would approach the maximum potential level. In Figure D.3, this is depicted by production level q^1 generated by effort E_1 (noting that Figure D.2 depicts land as having maximum fertility when exploitation effort is at the lowest levels.) In Figure D.3, the horizontal axes now refers to farm effort while the vertical axes refer to output, production revenue and costs. Underlying the effort at E_1, is the prevailing condition of the land and its fertility which is described as Z_1 in Figure D.2.

As farmer effort increases through the use of additional inputs, feasible production also increases to some maximum (ie q_2). However, as production is increased additional pressure is placed on the land as nutrients are drawn from the soil and the land is put under increasing stress. Eventually, the repair capacity of the land (even with conservation) would not support increased production, even if farmer effort was increased. For example, as farm effort is increased from E_2 (coinciding with maximum sustainable yield) to E_3 farm output of food and fibre would decline from q_2 to q_3. There would be a corresponding decline in the condition of the land and its fertility from Z_2 to Z_3 (see Figure D.2).

Within an economic framework, each feasible level of physical production would yield some revenue while the industry effort comes at some cost as it uses materials and employs labour and capital. Agricultural enterprises would continue to use land resources in agriculture while it is profitable for them to do so.

Figure D.3: **Agricultural industry output and effort**



Agricultural production is at its highest sustainable level when the capability of the land to regenerate is also at its highest level. This point, or the maximum sustainable yield, would occur at effort level E_2 and not normally when agricultural industry effort is at its maximum (ie the right of E_3 with stocks at their minimum) nor when effort is at its minimum (ie to the left of E_1 and resource stocks at their maximum).

D.6 Production revenue, costs and profits from land use

Individual farms operate in competitive markets and have little or no control over the prices that they receive for their outputs or pay for their inputs. In this economic environment, revenue varies in proportion to farm output. Costs also vary 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.

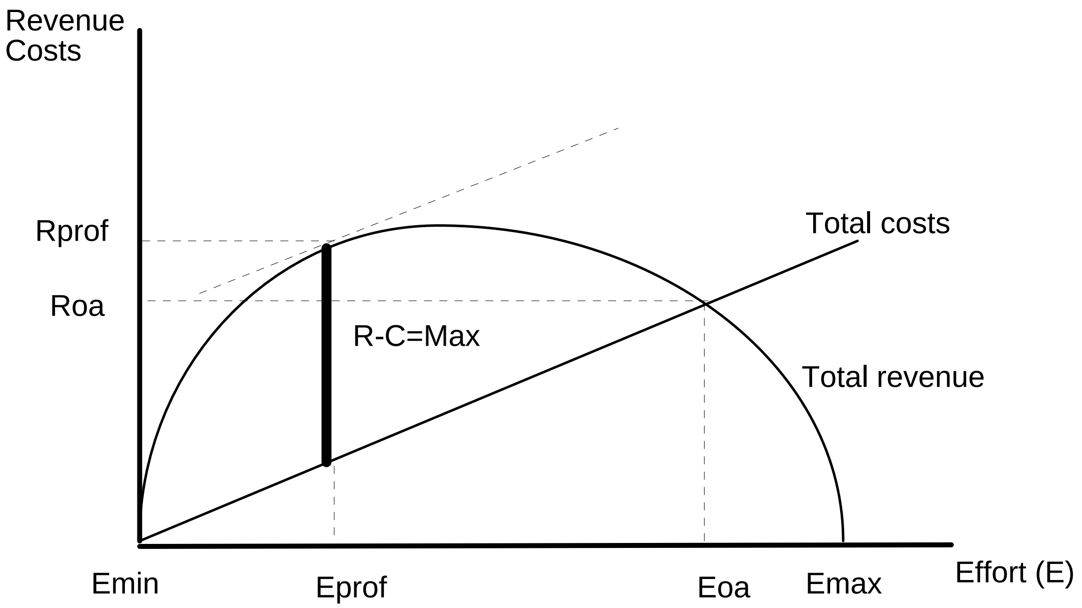
Within the static framework adopted for this analysis, each farmer would set out to achieve the same yield in each year. If nothing else changes (the *ceteris paribus* assumption) the farmer's profits from land use would not vary from year to year. Returns to the farmer from farm land use would be at 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 Figure D.4. 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.

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 will be 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 the land holding which they control would be limited. Thus, a resource that is open to all without restriction (such as with common grazing land or the unregulated flows of water in streams), affords individuals few opportunities to appropriate any economic yields, except in the very short term. 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_{oa} (see Figure D.4). At this point, the individual farmer would have no ownership rights over the farming resource.

In practice, the true situation is likely to lie somewhere between the two conceptual 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.

Figure D.4: **Farm revenue, effort and costs and profit from the use of land resource[ab]**



a The profit, or economic yield, to the farmer from the uses 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.

Importantly, from the perspective of resource conservation, neither the profit maximising solution nor the open access solution to the use of natural resources necessarily implies the complete exhaustion of land resources. At points to the right of E_{oa} (Figure D.4), 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, enterprises would be expected to vacate the activity.

This stylised model sets out in a simplified framework the basic ideas behind the management of resources on a sustainable basis. The model illustrates the reasons why some degradation of land condition and fertility is likely to occur. However, the model is based on a number of simplifying assumptions. In particular, it fails to take account of the effects of time on farmer decisions and looks at land use from an individual farmer’s point of view. It is useful to look behind some of the restrictive assumptions and simplifications of the stylised, static model as it has been presented.

D.7 Some broader implications of agricultural land use

In a dynamic context, the sustainability of agriculture requires the maintenance of the productive capacity of the land through time. The availability of information to the individual farmer about the process of degradation, the effects of discounting, and the availability of alternative land uses, mean that the simplified model does not capture all of the dynamic changes that effect agriculture.

Degradation is a dynamic process with the rate of change in the condition of the land and its fertility being the result of past farming decisions taken over many years. Because the process of degradation is generally regarded as being slow, its effects on farm productivity may only emerge gradually. They would also be intermingled with the effects of other changes such as the weather and technology over which individual farmers have little or no control. As part of this dynamic process, the forms of degradation may also change so that there can be lags between the incidence of degradation, initial recognition and the development of conservation strategies. The degradation problems of one generation may have been the solution to previous problems or efforts to improve farm productivity (eg induced soil acidity is associated with the introduction of improved subterranean clover pastures and the use of superphosphate and ammonium fertilisers intended to stabilise topsoil and improve productivity). Farmers may not always be in possession of all the information needed to maximise economic yields from land resources.

Discounting is used to capture both social and private time preferences and is relevant to the assessment of degradation and its effects which are spread over many years. As social and private discount rates are usually positive, the effect of discounting would lead farmers and the community to value current production above future production. In doing this, private and social discount rates would raise agricultural industry effort above the level that would provide the static maximum sustainable economic yield occurring at E_{prof} (see Figure D.4). The static model, therefore, implicitly assumes that the farmers' discount rate is zero with farmers giving equal weight to present and future returns. On the other hand, if farmers give little weight to income from land use in the future, they would tend to give little value to the future productive capacity of the land and would expand production so that only current material, labour and capital costs are covered (ie the open access outcome in the static model). Traditionally, social discount rates are deemed to be lower than private discount rates, indicating that, all other things being equal, the community would give higher weight to resource conservation for some future use than individual farmers.

Because prevailing discount rates are neither zero or approaching infinity (ie very large), the actual land resource use outcome would fall between the two extremes indicated by the static model. In broad terms, a farming activity would only be sustainable from a farmer point of view if the rate of regeneration of land resources used in agriculture was at least equal to the prevailing private discount rate.

The model as depicted in this appendix only refers to a single commodity and production technology. In practice, farmers may be able to choose between a number of farming activities that are suited to a locality. They may also be able to choose between continuing farming in the locality or vacating the land to an alternative use (such as housing, mining or secondary industry). A farming activity would only be sustainable if the present value of its returns were: (i) positive; and (ii) higher than alternative activities not requiring the conservation of the land's productive capacity through time (Pagiola 1993).

From the perspective of the general ecology of farming regions (including natural ecological systems), the stylised model does not address all potential concerns. In the model, the productivity of land resources is considered from the perspective of their use for the production of food and fibre. Where there are natural ecological systems that require preservation to satisfy other community needs and depend on land resources not necessary for farming, their valuation for farming could be below that of the community. Non-agricultural uses that could be given a high value include the use of landscapes as habitats for native species, water catchments and areas of scenic beauty.

D.8 Summing up

The bio-physical processes of agricultural land use and land degradation can be linked conceptually to commercial incentives faced by farmers. At a conceptual level, this framework illustrates that with freedom of entry to and exit from the farming industry, farming decisions based on purely commercial grounds will not lead to the total degradation of land resources relevant to farming.

However, farming activities rival traditional ecosystems for the use of all resources within the landscape, and clearly any commercial incentives to preserve all aspects of the landscape are likely to be only incidental to farming decisions. Modification of the landscape to suit farming enterprises, even if sustainable from a farming point of view, could exclude pre-farming ecosystems of a region. Decisions based on achieving the highest level of farm enterprise profits will therefore not necessarily provide the same outcomes as decisions based on community values that take into account other land uses including the preservation of traditional ecologies, natural landscapes, residential development and the growth of mining and secondary industries.

APPENDIX E
PRODUCTION EQUIVALENT OF DEGRADATION, AND COSTS AND BENEFITS OF AMELIORATION

E.1 Introduction

Implicit in the concept of land degradation is the notion that agricultural land use removes something from the soil. Without natural regeneration or land management, the productivity of the land would be reduced. Appendix E outlines economic concepts which show that levels of production, profit and degradation are linked and that because of these links, a balance exists between increasing production and allowing more degradation.

Estimates of production lost from degradation and the costs and benefits of amelioration provide information that illustrates the trade-off between higher production and degradation.

The level of degradation can simply be reported as lost productivity (ie a cost). One benchmark against which lost productivity could be assessed would be potential productivity of the land, without degradation, in its current use. This static concept is useful in translating bio-physical measures of degradation into a standardised numeraire, that is, dollars of production or net revenues. The production equivalent measure does not, however, provide an estimate of the cost of achieving a benchmark level of production or indeed, the practicability of reaching such a target. For example, a zero degradation measure might only be achievable by retiring land from its current use (eg reverting from irrigation farming to dry land farming to ameliorate irrigation salinity). Alternatively, it might be achieved through soil treatment programs (eg liming problem acid soils).

Cost-benefit studies of land management and amelioration possibilities are more forward looking and are undertaken to examine the feasibility of repair and conservation efforts under various plausible options of land management. Cost-benefit studies provide an account of expected future costs and benefits of a land management or amelioration project in current period values through a process of discounting. The benchmark for such an analysis would be no amelioration project. A cost-benefit approach is therefore concerned with gains from future repair and conservation actions.

Degradation amelioration actions, however, may represent only one investment choice available to individual land managers to improve farm productivity. Thus, even though a cost-benefit study may show positive returns to an amelioration project against the without-project benchmark, there may be other projects available to the farming community that afford even higher gains. In choosing between alternative projects, investors would be expected to assess the relative gains available from individual projects in the context of budget constraints that they may face. The focus of cost-benefit studies considered in this appendix is on the expected returns from amelioration projects

This appendix first discusses the concept of the production equivalent of degradation and reports selected studies based on this concept (section E.2). Section E.3 discusses some general issues concerning cost-benefit analysis, and considers a selection of cost-benefit studies of degradation amelioration possibilities. Section E.3 provides a summary of the appendix.

E.2 Static measures of land degradation

Conceptual framework

In order to take a snapshot of degradation and report its severity according to a common unit of measurement that is readily related to other information entering into economic management decisions, the level of degradation can simply be reported as a reduction in the potential agricultural productivity of the land. Such a measure would give degradation an economic meaning that is not directly possible through index measures as presented in Appendix C.

One benchmark against which reduced agricultural productivity could be assessed would be potential production using agricultural land, without degradation, in its current use (or likely use if the land is unused). This concept is useful in translating a measure of the incidence of degradation into a standardised numeraire, that is dollars of production or net revenues. A measure based on this concept with respect to production, could be referred to as the *production equivalent of degradation*. It would be a static measure of the financial value of degradation that could be evaluated by assuming competitive markets, thus:

(i) the output of each agricultural holding or locality subject to degradation is too small to influence the price it receives for its produce. In other words, each locality faces infinite elasticities of demand or input supply;

(ii) the land is assessed to be predominantly used for agriculture, either in the degraded state or after the amelioration of degradation;

(iii) the composition of agricultural output in the absence of degradation can be assessed and the appropriate benchmark price for outputs is the current domestic market price (reflecting the import substitution or export parity price for traded produce or the domestic market price for non-traded produce); and

(iv) in the absence of degradation, the price of agricultural outputs and goods, services and factors used in production represents the opportunity cost to the community. This would imply that there are no price or quantity distortions other than those included in the analysis.

Estimates of the production equivalent of degradation are normally provided with respect to the negative effects of land modification on agricultural production (eg reported production costs/losses or deviations from potential output). In interpreting such measures, it should be recalled that the environment is also modified to improve agricultural productivity, for example, through the clearance of land and native vegetation replacement. These modifications could be deemed as degradation from another perspective, although the cost of such degradation would not be within the scope of conventional production equivalent measures.

Measures of the production equivalent of degradation that are reported, from time to time using the above assumptions (or are loosely based on those assumptions) provide broad indicators of the extent of degradation according to a common numeraire. However, they are not true costs of degradation because the assumptions ignore benefits that have accrued to the community from past agricultural production, and the fact that some types of degradation occur as a result of more productive farming systems. The potential production used as a benchmark also may not be a sustainable or optimal measure when evaluated against economic criteria discussed in Appendix E. The measures therefore do not take into account the key processes and farm decisions that lead to degradation or the land management decisions arising from land degradation. For example, the measures do not take into account:

- the extent to which degradation is compensated by previous income flows from agricultural land use which have provided incentives for degradation. For example, the clearance of land for agriculture, soil structure decline, induced soil acidity and some dryland salinity each represent a form of land degradation that has been used to produce income from past activities;
- the extent to which degradation is uncompensated by previous income flows. This occurs when the form of degradation is invasive and has arisen without the compensating benefits of higher production in the locality experiencing the degradation. For example, invasion by pest animals, plants and insects and some cases of irrigation and dryland salinity and induced river pollution;
- off-site effects or externalities, for example, induced irrigation and dryland salinity or river pollution occurring remotely from the farming activities giving rise to those forms of degradation;
- the relationship between degradation and other factors affecting agricultural productivity such as the use of heavy machinery, supply of water in irrigation areas, cultivation of selected pastures and crops and the tolerance of differing farming systems to different forms of degradation;
- the cost of amelioration or management of the form of degradation; and
- the prospects of substitution between different agricultural land uses employing current technology and the prospects for technological change. For example, the substitution of salt tolerant for salt sensitive crops, the adoption of more water efficient farm management practices in irrigation areas and the research and development of more acid tolerant farm crops.

Results from selected studies

There is a developing history of the estimation and reporting of production equivalents of degradation. The format and coverage of these estimates differ. This section reports the results of a selection of studies.

From time to time national overview estimates of the production equivalent of degradation are reported. For example, in a recent overview publication, the Department of Environment, Sport and Territories estimated that land degradation cost $1.15 billion annually in lost production (DEST 1995) which is around 5 per cent of the local value of agricultural production of $23.4 billion in 1994–95 (ABS Cat. No. 5206.0). A recent Prime Ministerial statement put the production equivalent of degradation at around 6 per cent of agricultural production or about $1.5 billion.

EPA-New South Wales (1993) has provided estimates of the production equivalent of degradation for some types of degradation. Those estimates, sourced to various research studies, indicate that the production equivalent of the degradation types analysed is around $250 million (Table E.1) or around 5 per cent of the 1992–93 local value of agricultural production in New South Wales. Because the estimate does not cover all forms of degradation it would be an understatement of the total production equivalent.

Although the Victorian State of the Environment Report provided estimates of the extent of each type of land degradation (see Appendix C), it did not extend the analysis to provide a production equivalent of degradation. On the other hand, the Western Australian report on the extent of degradation included some estimates of the annual production costs of degradation (see Table E.2). The estimated production equivalent of degradation is around $609 million or about 16 per cent of the gross value of agricultural production in 1994–95. This available estimate is well above the national average reported above of around 5per cent to 6 per cent.

Table E.1: **Decline in agricultural productivity of primary land use due to land degradation in New South Wales** ($million)

Type of degradation	*Estimated production equivalent*
Dry land salinity	na
Irrigation salinity	na
Soil acidification	100.0
Soil structure loss	144.0
Gully erosion	5.7
Surface scalding	na
Wind erosion	na
Woody shrub invasion	na
Total of available estimates	**249.7**

Source: EPA New South Wales (1993).

Table E.2: **Estimated production equivalent of degradation in Western Australia[a]** ($ million)

Type of degradation	*Estimated annual cost*	*Estimated potential annual cost*
Dryland salinity	62	952
Water logging	90	na
Water erosion	21	na
Wind erosion	21	na
Soil structure decline	70	na
Subsoil compaction	153	na
Water repellence	150	na
Soil acidification	5	na
Vegetation decline } Wind and water erosion in the rangelands }	37	na
Total	**609**	

a Estimates as published in 1991.
Source: Legislative Assembly Western Australia, (1991).

In addition to broad estimates of the production equivalents of degradation, some studies take a more disaggregated approach to the estimation of the degradation indicator. One such study was undertaken by the CSIRO Division of Wildlife and Ecology (see Mallawaarachchi *et al.* 1994 and Mallawaarachchi and Young 1994). That study estimated the net agricultural income decline due to sheet and rill erosion in the Lachlan catchment. The estimated 'loss' can be used as the production equivalent of degradation in the region.

This study illustrates potential use of integrated data bases of land use and degradation for evaluation of the economic effects of land degradation. In the study, the level of degradation in the form of sheet and rill erosion is estimated at each pixel (or sample data point) in a geographic information system (GIS). The level of degradation is then extrapolated to a sampled area around the data point and matched with a production equivalent per unit of degradation. The final estimates are obtained by adding the values to a regional total. The method is very data intensive, depending as it does on an integrated data base, but it has the advantage that the calculation details and assumptions of the final estimates are well defined.

The study estimated that the production equivalent of degradation in the Lachlan Valley would be around $21 million evaluated in 1989–90 prices (see

Table E.3) which was about 6 per cent of the estimated gross value of agricultural output of $358 million.

Table E.3: **Estimated production equivalent of soil loss due to sheet and rill erosion in Lachlan Valley (New South Wales),[a] 1989–90**

Land use	*$/ha*	*Region $ million*
Grazing	3.95	15.4
Cereals	2.77	2.7
Other animals	48.37	2.3
Horticulture	135.01	0.7
Total	**4.27**	**21.1**

a Net agricultural income is defined as gross margin from agricultural activity less fixed costs of production. The net income lost is the value of the annual reduction in income due to soil erosion. The lost income relates to the reduction in the value of production foregone due to degradation, that is, the production equivalent of degradation.
Source: Mallawaarachchi *et al*. (1994).

Conclusion to consideration of studies of the static cost of degradation

The above examples indicate that a body of research concerning the production equivalent of degradation is accumulating and that those estimates can provide national totals. The estimates, however, are made at different times, using different methods and detailed data conventions.

The estimates are useful in cataloguing the presence of degradation but they do not provide an indication of the cost of achieving the nominated benchmark level of production or indeed, the practicability of reaching such a benchmark target at any cost. The following sections examine a selection of cost-benefit studies to indicate the trade-offs that exist between managing farming systems in the presence of degradation and the amelioration of degradation.

E.3 Cost-benefit analysis of land management alternatives

Cost-benefit analysis is a forward looking method of analysing land management or degradation amelioration possibilities. It can be used to evaluate a single project and to evaluate the relative net benefits of various farm and land management alternatives. It provides a means of disentangling the relative merits of different projects. Cost-benefit analysis is concerned in one form with commercial profitability and in another with the worth of a project to society, on the assumption that commercial profitability is not always a good indicator of social worth. The first form of cost-benefit analysis is typically referred to as financial analysis with the second as economic analysis.

Financial analysis emphasises market prices and the financial viability of a project to its implementor (eg an individual farm). In financial analysis, an individual enterprise would normally be concerned with maximising after tax income in the context of current market prices, taxation arrangements and tariffs; and only limited objectives relating to the conduct of the individual project, or program of closely related projects would be considered.

Economic analysis emphasises the opportunity cost of resources used and the economic viability of a project from the point of view of the community. In economic analysis, governments would be more concerned to ensure that programs are contributing to community welfare. Such analyses would therefore attempt to remove the effect of market distortions from prices and take into account externalities associated with land use as a social cost.

Both financial and economic analyses are concerned with the incremental output and costs of a project and the evaluation of a stream of net benefits on the basis of their net present value.

The main differences between financial analysis and economic analysis concern the way in which costs and benefits are defined, the prices used to value costs and benefits, and the selection of discount rates (see Box E.1). In contrast to costs and benefits in financial analysis, economic costs and benefits are not narrowly defined in terms of individual farmers cash flows, but rather are defined in terms of the effect of the project on the community as a whole.

Box E.1: **Differences between financial and economic analysis**

Characteristics	*Financial analysis*	*Economic analysis*
Purpose	Indication of incentive to adopt	Indication of whether investment is socially justified
Accounting stance	Project implementor	Society
Discount rate	Marginal cost of borrowing funds in financial markets	Social discount rate
Treatment of transfer payments	Included in analysis	Not relevant to analysis
Costs and prices	Market prices of inputs and outputs	Shadow prices and the opportunity cost of inputs
Benefits	Additional revenue from the project	Additional income to the economy as a whole
Treatment of externalities	Not included in analysis	Included in analysis

Source: James (1994).

Studies of the amelioration of land degradation tend towards financial analyses to the extent that they generally value outputs and inputs at domestic market prices. This pricing convention reflects the fact that the projects considered are generally concerned with testing the viability of an amelioration objective given current market prices. Market prices are influenced by government interventions such as domestic market price support schemes for outputs and tariffs on inputs. Where such interventions exist, market prices would differ from the shadow price of outputs or the opportunity cost, which should be estimated free of the effects of government interventions.

On the other hand, the studies tend towards an economic analysis to the extent that the costs and benefits are examined from a locality or regional point of view, with a mixture of on-farm and off-farm works required for implementation. The economic reporting of projects is accompanied by the exclusion of transfer payments, including taxation, from the analysis and the adoption in some cases, but not all, of social discount rates which are based on the general government long-term bond rate. By taking into account the effects of externalities, a number of studies maintain their economic analysis focus.

The mix of on-farm and community works required to implement amelioration programs and the exclusion of transfer payments from economic analysis, means that incentives faced by individual farmers to undertake socially worthwhile degradation amelioration expenditures are not elaborated.

All studies that were consulted adopt the legitimate analytical convention of real discount rates (ie all financial flows and discount rates are defined to exclude the effects of price changes). While adjusting for inflation can be sufficient to account for the effects of price changes, if there are relative price changes (ie terms of trade for the sector) inflation adjustments alone would not be sufficient to obtain costs and benefits in ‘real’ prices. If the analyst has good reason to believe that the value of output will decline (or increase) over time compared to the value of other goods and services, the change in relative values should be incorporated in the stream of real net benefits. In the studies consulted, the farmers’ terms of trade is generally assumed to be constant. In fact, there has been a long history of decline in the agricultural terms of trade (ABARE 1994). According to the principles of cost benefit analysis, an expected continuation of the declining agricultural terms of trade would lower the attractiveness of farming, including amelioration efforts, relative to other land uses.

Because the focus of the studies consulted is on degradation management and amelioration projects, other agricultural investment opportunities are not ranked for consideration in the overall task of agricultural land management. If the implementation of independent projects is not limited by any budget constraint, projects that yield a positive net present value should be adopted. However, in reality, individual projects may compete for the same land resource on a farm or within a region, or there may be budget constraints. Where such conflicts arise the decision rules for project evaluation need to be extended (Perkins 1994). Projects that compete for the same land resource are mutually exclusive in the sense that both could not proceed simultaneously. For example, a project to use a block for irrigation farming would be mutually exclusive to an alternative project to use the same block for dry land farming. For such projects, community welfare (in economic analysis) would be maximised by selecting the project with the highest net present value after account is taken of on-farm and off-farm benefits and costs. The individual farmer would maximise farm income by selecting the project with the highest net present value of on-farm benefits.

Where there is a single period budget constraint, there will be an incentive to select projects that yield the greatest net receipts per unit of investment in that period. Such projects would not necessarily have the highest net present value but would recover the investment in the shortest possible period. Alternatively, the budget constraint may not be limited to a single period, but rather relate to the longer term. Where there is a longer-term budget constraint, the target internal rate of return (or discount rate) should be raised to the point where the projects adopted just exhaust the available supply of funds.

In reality, public and private budget constraints on agricultural investment will apply. In addition, once ranked according to the above criteria, amelioration projects may not always be the most advantageous for the farming sector or the community, either in the longer or shorter term.

Costs and benefits of amelioration of irrigation salinity

Murray Basin

The Murray Basin is part of the Murray-Darling Basin in south-eastern Australia and covers approximately one-seventh of the land area of Australia. The River Murray drains central and northern Victoria, parts of southern New South Wales and South Australia. The Darling and Murrumbidgee rivers flow into the Murray. The Darling drains the northern and western region of New South Wales and southern Queensland; the Murrumbidgee drains central and southern New South Wales.

Problems of salinity in the Murray are due to significant natural saline flows into the river and the fact that it forms the only outlet to the sea for saline groundwater in the Basin. The River Murray salinity problem is intensified by groundwater discharge due to rainfall, clearing of vegetation and irrigation.

As part of a program to introduce integrated (or total) catchment management in the Murray-Darling Basin, a Working Group was established to prepare a Salinity and Drainage Strategy (MDBMC 1987). The supporting analysis included, amongst other things, a cost-benefit analysis of ameliorating river salinity over the next 30 years. Public salt interception schemes were discounted at a real rate of 5 per cent and private land management schemes were discounted at the higher private real rate of 10 per cent.

In the analysis, river salinity was treated as a symptom of land degradation as well as being the result of natural saline conditions in the Basin with both land degradation and naturally occurring salinity imposing costs on the community. Using river salinity as a reference, the main focus of the study was on schemes that would reduce river salinity. The benchmark for assessing costs and benefits of amelioration was the expected production losses as waterlogging became more widespread and watertables rose under current management practices over the next 30 years. Estimates of the production equivalent of degradation due to water logging and salinisation amounted to over 10 per cent of the value of production in 1985–86 rising to around 16 per cent in 2015 (see Table E.4).

Table E.4: **Estimated agricultural production equivalent of degradation in Murray Basin due to waterlogging and salinisation,** ($ million, 1985–86 values)

		Production equivalent of degradation	
Region	*Value of agricultural production*	*1985-86*	*2015*
Victoria			
Kerang	80	24	24
Shepparton	220	13	21
Total	**300**	**37**	**45**
New South Wales			
Wakool	36	8	16
Deniliquin	70	11	16
Murrumbidgee	167	8	16
Lachlan	5	1	2
Total	**278**	**28**	**50**
Total	**578**	**65**	**95**

Source: Murray-Darling Basin Ministerial Council (1987).

A range of options to reduce salinity were considered in this study. Some were not pursued because preliminary assessments indicated that benefits would not outweigh cost (eg as was the case for a pipeline to the sea, subsurface drainage near Kerang, comprehensive surface drainage in Berriquin/Denimein, and the reversion of irrigation farming land to dryland farming). A shortlist of salt interception schemes and land management schemes was analysed.

Analysis of the short-listed schemes indicated that over a thirty year period most schemes would provide both reduced river salinity and positive net benefits to the community (see Table E.5). However, there were some short listed schemes in the Berriquin, Wakool, Shepparton and Campaspe regions which would involve surface and subsurface drainage, improved irrigation management and refurbishment of infrastructure that would increase productivity but also add to river salinity (and off-farm costs). On the other hand, interception schemes in Sunrasia and Lindsey River localities and land management schemes in New South Wales and Victorian Sunrasia localities would reduce river salinity and provide positive off-site benefits. These benefits when combined with on-farm benefits would outweigh costs to provide positive net benefits for the schemes.

Table E.5: **Estimated costs and benefits of selected irrigation salinity control and land management schemes in the Murray Basin[abc],** (1985–86 prices)

		Amelioration costs			*Benefits*			
Scheme	*in river salinity*	*Capital*	*maintenance costs*	*Total*	*Local*	*River*	*Total*	*Net benefits*
EC	Morgan	$m	$m	$m	$m	$m	$m	$m
Salt interception schemes								
Mildura/Merbein/Buronga	-6	0	0	1	0	6	6	6
Chowilla	-11	4	1	5	0	11	11	6
Mallee Cliffs	-8	3	2	4	0	8	8	4
Woolpunda	-40	11	13	24	0	31	31	7
Waikerie	-16	7	5	12	0	13	13	1
Sunraysia	-4	5	2	8	0	4	4	-4
Lindsay River	-7	7	1	8	0	6	6	-2
Land management schemes								
Wakool	11	53	9	62	74	-5	69	6
Berriquin A	4	43	10	53	112	-4	108	54
NSW Sunraysia	-2	18	6	24	15	1	16	-8
Shepparton	14	50	13	63	147	-7	140	77
Campaspe	1	1	1	2	8	-1	7	5
Victorian Sunrasia	-2	62	39	101	91	1	92	-9
Barr Creek	-7	28	0	29	43	7	49	21
SA Riverland	-21	47	34	81	169	13	183	102
Summary costs and benefits								
To maximise NPV	-78	248	88	336	552	74	626	290
To minimise river salinity	-122	192	103	296	318	102	420	124

a The benefits are expressed in 1985–86 dollars; the present value of benefits and costs are based on a project life of 30 years; public salt interception schemes were discounted at a real rate of 5 per cent and private land management schemes were discounted at the higher private real rate of 10 per cent.
b EC (electrical conductivity) is a measure of the conduction of electricity through water or a water extract of soil. It is used to determine the soluble salts in the extract and hence soil salinity. The unit of conductivity is the siemen, and soil conductivity is expressed in millisiemens per centimetre at 25 degrees Celsius. Morgan is a measuring point on the River Murray inside the South Australian border.
c Operating and maintenance costs exclude the estimated costs of salt inflows, where these are expected to be reduced by the amelioration effort.
Source: Murray-Darling Basin Ministerial Council (1987).

The study shows that obtaining the maximum reduction in river salinity and the maximum profit from land use cannot always be pursued concurrently, even when account is taken of the off-farm financial benefits of reduced stream salinity. For example, choosing schemes to maximise salinity reductions would lower salinity by 122 ECs at Morgan and increase profits by $124 million (see Table E.5). However, selecting schemes to maximise profits would only reduce river salinity by 78 ECs while increasing profits by $290 million — more than double the best salinity reduction case. In the minimum salinity case, $102 million or 24 per cent of benefits could come from off-site effects while for the profit maximising case, $74 million or 10 per cent of benefits could come from off-site effects.

The estimated average level of salinity at Morgan (pre Menindee flow regulation) was 618 ECs (MDBMC 1987). The maximum salt reduction schemes would deliver a 20 per cent reduction on this total while the profit maximisation schemes would lead to a 12 per cent reduction in salinity.

Costs and benefits of amelioration of dryland salinity

Dryland Campaspe Catchment, Victoria

The Campaspe Catchment is located in North Central Victoria and covers about 454 800 hectares of which about two thirds is managed for agriculture. The area is bounded by the Great Dividing Range to the south and the Campaspe Irrigation District near Rochester to the north. The main land uses are grazing and cropping.

Problem salinity has led to increasing costs mainly through land salting and contributions to the salt load in local rivers leading to the River Murray. The relationship between farming systems, recharge and groundwater discharge was examined for the Campaspe Dryland Community Working Group on Salinity (Oram and Dumsday 1994).

Oram and Dumsday used a simulation model of groundwater recharge under alternative farm systems to evaluate the impact of land use on soil salting, salinisation of streams and rivers in the catchment, and the contribution of salt flows from the catchment to salinity levels in the River Murray. The information was combined with a cost-benefit analysis to estimate the benefits from the control of salinity, and the move from current agricultural land uses to alternative agricultural land uses. The analysis was undertaken for a 50-year period. The discount rate adopted was a real rate of 4 per cent for off-farm benefits and 8 per cent for on-farm returns. These rates were applied to the appropriate components of all projects.

Table E.6: **Comparison of land use and recharge strategies in the Campaspe Catchment[a]**

				Off-farm returns (b)				
Study area (c)	*Farming system (d)*	*Annual recharge*	*On-farm returns*	*Benefits (water yield)*	*Costs (salinity)*	*Net benefits*	*Economic benefits (e)*	*Marginal benefit from base case*
		mm	$/ha	$/ha	$/ha	$/ha	$/ha	$/ha
SA6: CSR	Base system	38	64	0.19	0.21	-0.02	64	0.00
	WLC	**34**	**89**	**0.14**	**0.15**	**-0.01**	**89**	**25.01**
	WLO3A	23	84	0.09	0.10	-0.01	84	20.01
	WLO10P	7	76	0.03	0.03	0.00	76	12.02
	PERE	0	63	0.00	0.00	0.00	63	-0.98
SA6: HLRFP	Base system	30	71	2.23	3.11	-0.88	70	0.00
	WLC	**25**	**176**	**1.36**	**2.21**	**-0.85**	**175**	**111.17**
	PERE	0	64	0.00	0.00	0.00	64	0.02
SA8: CSR	Base system	38	64	2.87	3.15	-0.28	64	0.00
	WLC	**34**	**89**	**2.10**	**2.28**	**-0.18**	**89**	**24.84**
	WLO3A	23	84	1.35	1.48	-0.13	84	19.89
	WLO10P	7	76	0.38	0.41	-0.03	76	11.99
	PERE	0	63	0.00	0.00	0.00	63	-0.98
SA8: HLRFP	Base system	30	71	17.37	65.67	-48.30	23	0.00
	WLC	**25**	**176**	**10.63**	**38.14**	**-27.51**	**148**	**84.51**
	WLO10P	7	92	2.87	3.15	-0.28	92	27.74
	PERE	0	64	0.00	0.00	0.00	64	0.02

a The on-farm (private returns) are based on an equivalent annuity over a 50 year period discounted at 8 per cent in real terms. Off-farm (economic) returns were also discounted over a 50 year period, at a real interest rate of 4 per cent.
b Off-farm benefits relate to the yield of water not absorbed in the catchment. Costs relate to the off-site income lost due to salinisation caused by farming in the Campaspe Catchment.
c The study areas include: SA6:CSR—Sub-area 6–Cropped Sedimentary Rises (area 3 028 hectares); SA6:HLRFP—Sub-area 6–High Level Flood Plain (area 11 903 hectares); SA8:CSR—Sub-area 8–Cropped Sedimentary Rises (area 2 499 hectares); SA8:HLRFP—Sub-area 8–High Level Flood Plain (area 6 884 hectares)
d Farming systems: Base case–FWWO3A: long fallow, wheat, wheat/oats, three year annual pasture; WLC: wheat, lupins, canola; WLO3A: wheat, lupins, oats, three year perennial pasture; WLO10P: canola, wheat, lupins, oats, 10 year perennial pasture; and PERE: perennial pasture.
e Farm benefits plus (less) estimated off-site benefits (costs).
Source: Oram and Dumsday (1994).

The study found that there would be on-farm financial benefits from moving from the current base agricultural cropping/grazing system (defined as long fallow/wheat/wheat/oats/three-year pasture) to a system of wheat/lupins/canola (see Table E.6) with the level of financial advantage differing between localities within the region. However, the revised cropping rotation generally would provide only marginal reductions in recharge compared to the base system. The introduction of perennial pasture would provide greater reductions in groundwater recharge, but it was estimated that the additional economic gains from off-site improvement in the form of reduced salinity would not offset the financial cost to farmers of reduced groundwater availability (with the effect that the net off-site benefit is zero).

The study examined 12 farming systems including those reported in Table E.6. Alternatives were rejected if they increased recharge and hence could not be recommended as a salinity control strategy, or they decreased recharge but other management systems achieved the same reduction at a lower cost. The high off-site costs of salinity in sub-area 8: HLRFP occur because of local ground water characteristics and proximity to the northern irrigation areas. The estimated off-site costs for this area are higher than the cropped water table rises which have the highest recharge rates of the group examined.

Overall, the estimates indicate that the alternative yielding the most favourable agricultural industry outcome does not necessarily correspond to the case of zero salt emissions. It also emphasises the importance of on-site benefits relative to off-site costs. As the analysis excludes agricultural practices that increase the level of dry land salinity, it has also possibly precluded options that yield higher economic returns with higher levels of dryland salinity.

Neridup Catchment, Western Australia

The Neridup Catchment is located North East of Esperence, with an average rainfall of about 500 mm (Campbell 1994). The total area of cleared arable land is 25 000 hectares containing approximately 25 farms. The land is mainly used for grazing (wool and beef) and cereal cropping (wheat, barley, oats and lupins). Induced salinity is estimated to cover 2 750 hectares (11 per cent) of the region with the biogeographical potential to reach 6 250 hectares (25 per cent) of the region. Problem salinity is expanding at 87 hectares per year under current management, implying that the salinisation potential would be reached over 40 years. In addition, farm productivity would be reduced through wind erosion and water logging as dryland salinity advances.

A cost-benefit analysis of amelioration possibilities in the region estimated that there would be benefits to farmers from the control of the spread of salinity achieved through increasing the area of trees and fodder shrubs and the building of salt drains (see Table E.7). The benefits would be realised through higher stocking rates and increases in crop yields. However, targeting a particular level of salinity spread may not be profitable. For example, on available estimates, it would not be financially feasible to reduce the spread of salinity to zero within a 20 year time horizon because expected revenue gains would not offset costs, evaluated at a real social discount rate of 5 per cent (see Table E.8).

Ultimately, the rate of spread of salinity could reach zero either once the maximum level of salinity is reached (ie approximately 6 250 hectares), or when it becomes financially feasible to adopt management practices that reduce the spread of salinity to zero before that maximum area is reached. Such alternatives are not identified in the study.

Table E.7: **Management strategies assumed to reduce dry land salinity in the Neridup catchment**

Rate of spread	*Area of potential saltland*	*Area of trees planted*	*Area of fodder shrubs planted*	*Area of drains estab.*	*Stocking rate*	*Increase in crop yield*
ha/yr	ha	ha	planted ha	ha	DSE/ha	per cent
Current	6 250	25	210	4	5	0
88	6 250	0	0	0	5	0
80	5 990	105	500	10	501	1
70	5 675	257	1 000	20	5.2	2
60	5 350	455	1 500	30	5.4	4
50	5 000	736	1 925	40	5.6	6
40	4 675	1 093	1 925	40	6	10
30	4 350	1 605	1 925	40	6	10
20	4 025	2 403	1 925	40	6	10
10	3 700	3 816	1 925	40	6	10
0	3 375	7 004	1 925	40	6	10

Source: Campbell (1994).

The study also found that further reductions in salinity would be financially feasible if a commercial return could be obtained from eucalypt oil and wood by-products that could be harvested as the tree area was increased. Nevertheless, even with secondary income from these sources, the best returns would not be obtained from reducing the rate of spread of salinity to zero (see Table E.8).

Table E.8: Comparison of strategies for non-commercial trees and Mallee Eucalypts in controlling dry land salinity in the Neridup catchment[a]

	Catchment wide		*Per hectare*			
			Non-comm. trees		*Commercial trees*	
Rate of spread	*NPV for non-commercial trees*	*NPV with addition of commercial Malley eucalypts*	*Over area of arible land (b)*	*Marginal benefit over base case*	*Over area of arible land (b)*	*Marginal benefit over base case*
ha/yr	$m	$m	$/ha	$/ha	$/ha	$/ha
88	2.02	2.02	81	0	81	0
80	2.54	2.65	102	21	106	25
70	3.12	3.37	125	44	135	54
60	3.52	3.97	141	60	159	78
50	**3.92**	4.65	**157**	76	186	105
40	3.86	**4.92**	154	74	**197**	116
30	3.30	4.86	132	51	195	114
20	2.37	4.73	95	14	189	109
10	0.66	4.44	27	-54	177	97
0	-3.29	3.66	-132	-212	147	66

Point of maximum financial benefit shown in bold.

a Net present values estimated on the basis of a real rate of return of 5 per cent. Source analysis provides sensitivity analyses for discount rates in the range 0 per cent and 7 per cent. The preferred rate of return corresponds to the real rate of return on government bonds and is accepted in the study as the risk free social discount rate.

b An area of arable land in catchment of approximately 25 000 hectares is adopted as the denominator in this calculation. The area of potential saltland is 6 250 hectares.

Source: Campbell (1994).

Costs and benefits of amelioration of acidity

Areas subject to soil acidity are widespread in eastern, southern and south western Australia. In a regional approach to the study of the effects of soil acidification, the AACM (1995) study of the social and economic effects examined eight priority regions. These regions were selected because they were likely to suffer regular crop or pasture losses from induced acidity. They are vulnerable to acidification because they commonly receive sufficient rainfall for significant nitrate leaching to occur and include soils that are poorly buffered and have a substantial history of agricultural use.

One method of ameliorating induced soil acidity is through the application of lime. The balance between use and replenishment of soil alkalies can therefore be illustrated by estimating lime applications required to balance excess acids and replace alkalinity removed from the soil in farm production against actual lime use. Overall, it is estimated that the current level of lime applications in Australian agriculture of about 0.5 million tonnes (1989–90) is about one quarter of the lime required to maintain prevailing acidity levels, with benchmark maintenance applications comprising :

- 0.75 million tonnes per year to maintain the current pH in 7.4 million hectares thought to be very acid or extremely acid in cropping areas; and
- 1.5 million tonnes per year to maintain the pH in 7.7 million hectares of mildly acidic soils which are at risk from acidification (AACM 1995).

In addition, around 2.3 million tonnes of lime would be required to treat the suspected 1.5 million hectares of extremely acid soil ($pH_{Ca}<4.5$) with an ameliorative dressing of 1.5 tonnes per hectare.

Despite these physical accounting balances and the fact that lime applications would raise soil pH and increase production, a cost-benefit analysis of liming in a number of acid sensitive regions and farming systems shows that such strategies are not necessarily profitable (see Table E.9).

Table E.9: **Financial analysis of liming by acid sensitive region and farming system**

Region no.	*Description*	*Farming system*	*Gross margin*	*Average liming costs*	*IRR*	*NPV*	*Breakeven yield response*
			$/ha	$/ha/pa	per cent	$/ha	per cent
1	North West Western Australia	Wheat and lupins	140.0	2.0	50	73.3	0.8
		Wheat	130.6	2.0	86	81.4	0.8
		Lupins	131.9	2.0	na	61.5	0.8
		Sheep	52.3	2.0	7	-6.4	1.8
	East Central Western Australia	Wheat and lupins	25.3	4.0	1	-11.1	3.2
		Wheat	49.5	4.0	15	9.5	2.7
		Lupins	3.8	4.0	na	-35.7	3.7
		Sheep	44.6	4.0	5	-12.3	5.2
	South Coastal Western Australia	Sheep	74.7	5.0	10	10.9	na
		Beef	65.5	5.0	10	10.1	na
2	South Australian Near North	Wheat	253.0	9.0	13	11.5	2.2
		Canola	260.4	9.0	50	136.2	1.9
3	Central Victoria and South East South Australia	Sheep	182.3	6.0	42	114.6	2.2
		Beef	169.6	6.0	38	102.5	na
4	New South Wales and Victorian Riverina	Wheat	255.4	18.2	43	151.8	3.9
5	New South Wales Western Slopes	Wheat	252.6	18.2	53	206.5	3.8
		Canola	280.8	18.2	54	203.7	3.5
6	Eastern Queensland and New South Wales	Milk	629.7	57.5	73	765.7	3.8
		Beans	2603.2	57.5	416	4794.7	0.5
7	New South Wales and Queensland Tablelands	Peanuts	275.4	32.5	43	222.9	5.3
		Maize	195.0	32.5	34	165.0	7.7
		Peanuts and maize	283.8	32.5	40	201.8	6.3
8	Northern Queensland	Milk	551.1	57.2	119	1113.4	3.2
		Sugar	1353.5	33.3	198	2671.1	1.3

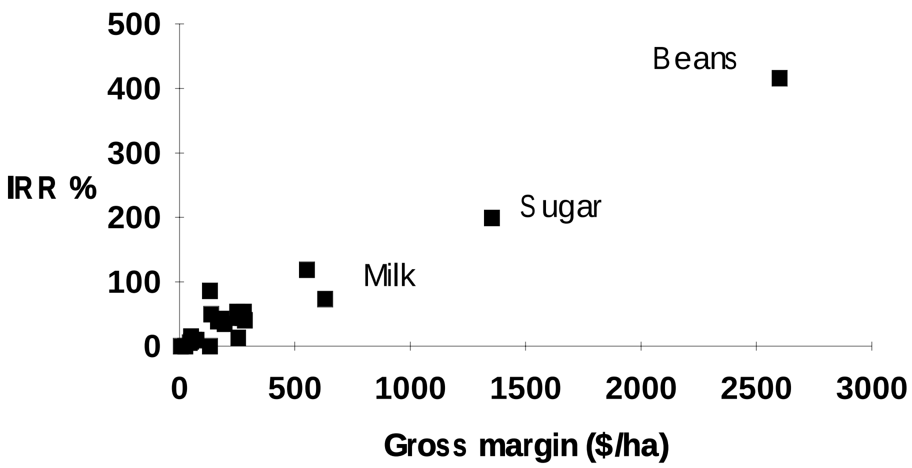
For footnotes, see next page.

a The base case for the financial analysis of each farming system was the respective system without liming. A real discount rate of 10 per cent was used and the analysis was conducted over a 15-year period to demonstrate the longer-term benefits of lime application.
b Liming costs include the cost of the lime, transport of the lime to the farm site and spreading.
c Gross margin per hectare in this analysis is defined as farm cash operating surplus being average yield per hectare less expenses on seed and seed treatment, chemicals, fuel and machinery, repairs and maintenance, labour, interest paid and insurance, and the costs of animal health, fodder, and stock purchases.
d The internal rate of return is the discount rate that returns a net present value of zero.
e The breakeven yield response to lime is the NPV increase in yield required to cover the NPV of the cost of lime and its application.
Source: AACM (1995).

The study shows that the higher returns from liming tend to be associated with farming systems with the higher gross margins per hectare (see Figure E.2). Not surprisingly, the AACM study of farm enterprise practices found that liming was a feature for those activities which are highly acidifying and for which high value farming systems were acid sensitive (eg dairying, horticulture, and canola and lucerne crops). For other farming enterprises, the dominant strategy is to use liming selectively to raise soil pH levels once induced acidification is affecting productivity or reducing farm capabilities, to grow high value crops. Strategies other than liming for dealing with acidifying soils include:

- dependence on acid tolerant species and cultivars (particularly in pasture enterprises);
- inputs of phosphorus (P), other nutrients and trace elements such as molybdenum (Mo) to maintain the productivity of acidifying soils;
- use of dolomite rather than lime to avoid a manganese deficiency in dairy cattle possibly caused by lime use;
- nitrogen management to reduce acidification rates and promote maximum plant use and minimum excess nitrate production; or
- do no additional work as there are better alternative farm or off-farm investments.

Figure E.2: **Internal rate of return (IRR) and gross margin per hectare for liming programs for alternative land uses**[a]



a The internal rates of return from liming are plotted for each farming system shown in Table E.9. The points for the higher yielding (ie to liming) activities of beans, sugar and milk are identified.
Source: Table F5.9.

This analysis does not compare returns from various farm strategies. It also points out that liming does not always have favourable results. For example, liming and gypsum use has been implicated in depressed lupin yield in high rainfall areas of Western Australia.

The net benefits of liming have been re-estimated to illustrate the effects of changing terms of trade on the returns from one specific degradation amelioration strategy. With a continuation of the declining terms of trade (at an average annual rate of 2.6 percent per annum based on the experience over the period 1951–52 to 1992–93), the net present value from a program of liming would be reduced from $206.5 per hectare for a wheat farming system in the Western Slopes of New South Wales (see Table E.9) to $114 per hectare. On the other hand, any improvement in farm terms of trade would have the opposite effect and increase farm net revenues thus making liming more attractive.

Overall, while the cost-benefit information indicates that liming (or other acid reducing treatments) can raise farm gross returns, it does not indicate that strategies based on reducing acidity levels would always be the most profitable or highest priority, for individual farm enterprises.

E.4 Summing up

Taken alone, static measures of land degradation, such as those provided by the production equivalent of degradation, can be used to indicate the economic effects of degradation. They can even be used to indicate a loss to the agricultural industry and the economy as a whole from degradation. However, such measures need to be interpreted with care as they ignore the income that has been generated in the past through the use of the land and the trade offs facing individual farmers and the community in the management of land.

Secondly, land degradation and its amelioration deals with only one aspect of overall land management decisions. Therefore, while recent cost-benefit studies show that net benefits can be obtained from degradation management and amelioration, they do not comment on how those projects might compare with other investment programs also affecting the land. The analyses show that environmental objectives form one element in land management. They also show that nominating environmental objectives, as a method of ranking projects, would not necessarily provide the highest returns to the community in terms of income. The selection of projects to achieve some environmental benefits would therefore need to depend on community judgements that go beyond the information contained in cost-benefits analyses or the commercial imperatives facing individual farmers.

APPENDIX F
ESTIMATES OF THE EFFECTS OF LAND DEGRADATION IN NEW SOUTH WALES

F.1 Introduction

In this appendix, an econometric model has been used to analyse the effects of degradation on agriculture in New South Wales. Currently, there is no other state-wide study analysing economic and land degradation data with which to compare the Commission's estimates. In the absence of a history of state-wide or national estimation of the effects of degradation on production and profits, the magnitude and even the sign of the estimates reported in this appendix should be regarded as tentative. The modelling framework and results are presented in order to encourage discussion and further analysis.[1]

The model uses cross-section data for 148 Statistical Local Areas (SLAs) in New South Wales grouped into broad biogeographic regions (Appendix B). The data for each SLA cover indexes of production and costs for the 1992–93 agricultural year. These indexes were estimated from 1991–92 and 1992–93 source information drawn from ABS and ABARE series (see Annex F2). Land degradation information was drawn from the 1987–1988 New South Wales Soil Conservation Service state-wide survey of land degradation (see Appendix C).

The cross-sectional analysis captures differences in the responsiveness of SLAs to relative output price and input cost changes given the constraints on change imposed by natural biogeographical endowments and prevailing levels of land degradation. In this sense, even though the model is a snapshot of New South Wales agriculture, it provides a medium- to longer-run perspective on the effects of degradation.

Section F.2 reports the revenue and cost shares, price index and farm profit information underlying the econometric model estimation. Section F.3 provides an overview of the model. This section is supported by a more detailed statement of the model and its data sources in Annexes F1 and F2. Section F.4 provides the estimated responsiveness of agricultural outputs and inputs to

1 For those interested in re-estimating the model or undertaking further reviews of the data and methodologies, the estimation data base and input files to the SHAZAM econometric package are available from the Commission on request.

relative price changes. These estimates are used to make a limited comparison between results of the Commission's model and other studies of Australian/ New South Wales agriculture within a similar econometric framework. Section F.5 draws land degradation and production information together to provide an analysis of the snapshot effects of land degradation on farm outputs and profitability in New South Wales. Section F.6 provides a summary of findings.

F.2 Agricultural output and input shares and price indexes

The agricultural output, input and price index data base, together with information on land degradation provide the basis of the Commission's model estimation. Details of the sources used to compute the modelling data base are provided in Annex F.2. This section provides a state-wide summary of the information.

On the output side, production from New South Wales agriculture was summarised by two commodity groups, namely, crops and crop products (henceforth referred to as crops) and animals and animal products (henceforth referred to as animal products). The first group includes grains, fodder, oil seed, vegetable, and fruit products, while the second group includes livestock, wool, milk, eggs and honey products. Over the period studied, animal products contributed more than half of the local value of production of New South Wales farming industry (see Table F.1). This contribution rose fractionally from 1991–92 to 1992–93 due to an increase in animal product prices relative to crop prices (see Table F.2).

On the input side, farm inputs were initially divided into four groups, namely hired labour, fertiliser, water and other materials and services. Total returns to farm management, capital and land (henceforth referred to as farm surplus or profit) was then calculated as a residual by deducting the cost of purchased inputs from the value of farm outputs. The items fertiliser and water use were separated in the analysis because of their association with intensive land use and their potential to increase the level of degradation. When combined they account for less than 6 per cent of total costs (see Table F.1), with that share falling between 1991–92 and 1992–93 due to declining input volumes (see Table F.3). The remaining intermediate input item — other materials and services — includes farm expenses such as marketing costs, fuel and chemicals and farm services (such as contractor, accounting and legal services). Despite a small increase in average prices paid for items in this group (see Table F.2), its share in total costs declined over the two-year period due to a decline in input volumes (see Table F.3).

Table F.1: **Estimated output and input shares in New South Wales agriculture, 1991–92, 1992–93**
(per cent)

	Output shares		*Input shares*				
Year	*Crops*[a]	*Animal products*[b]	*Hired Labour*	*Fertiliser*	*Water*	*Other materials and services*	*Surplus*
1991–92	40.8	59.2	9.9	4.8	1.2	64.6	19.3
1992–93	39.5	60.5	9.6	4.3	1.1	63.6	21.4

a ‘Crops’ include grains, fodder, oil seed, vegetable and fruit products.
b ‘Animals products’ includes livestock, wool, milk, eggs and honey products .
Source: Commission model data base.

Table F.2: **Estimated implicit price indexes of outputs and inputs for New South Wales agriculture, 1990–91 to 1992–93**
(Base 1991–92=100)

	Outputs			*Inputs*			
Year	*Crops*[a]	*Animal products*[b]	*Total*	*Hired Labour*	*Fertiliser*	*Water*	*Other materials and services*
1990–91	104.0	105.2	104.7	n.a.	n.a.	n.a.	n.a.
1991–92	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1992–93	99.5	99.9	99.7	104.4	98.4	106.2	100.6

a, b See Table F.1.
Source: Commission model data base.

Table F.3: **Estimated indexes of output and input volumes for New South Wales agriculture, 1991–92, 1992–93**
(Base 1991–92=100)

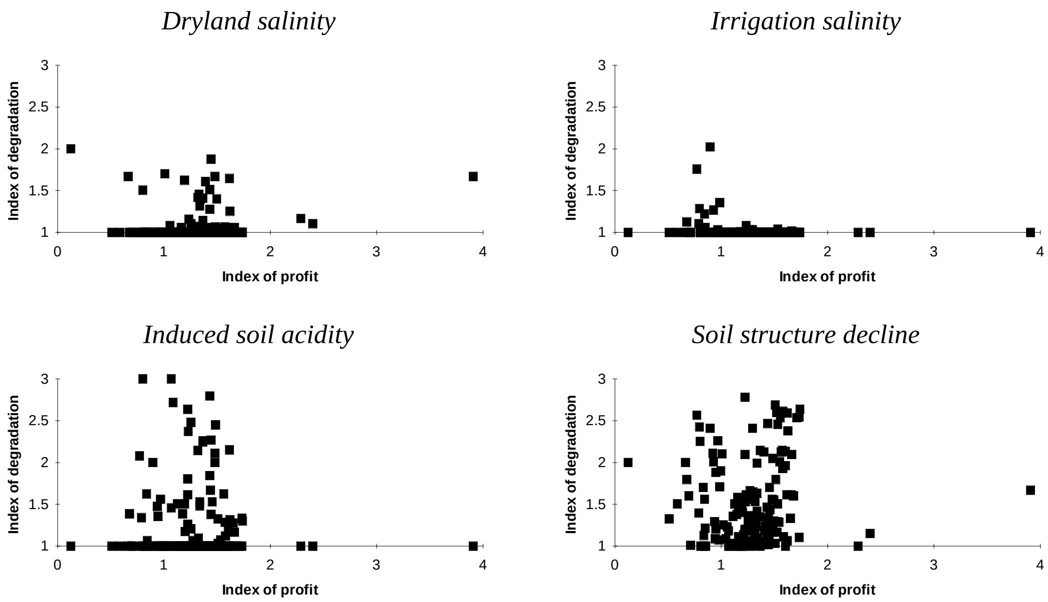
	Outputs			*Inputs*				
Year	*Crops*[a]	*Animal products*[b]	*Total*	*Hired Labour*	*Fertiliser*	*Water*	*Materials and services*	Total
1991–92	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1992–93	97.1	98.2	97.8	91.1	89.3	88.4	95.9	94.9

a, b: See Table F.1.
Source: Commission model data base.

After account is taken of the lower cost of hired labour and intermediate inputs (see Table F.1), the share of farm surplus increased two percentage points from 19.3 per cent to 21.4 per cent of farm revenue.

To bring land degradation into an economic framework, an index of degradation for dryland salinity, irrigation salinity, induced soil acidity and soil structure decline has been calculated for each SLA (see Appendix C). A comparison with that index and the index of farm profit shows that profit varies substantially between SLAs for any given level of degradation (Figure F.1).

Figure F.1: **Relationship between the level of degradation and an index of farm profit,[ab] 1992–93**
(Base 1991–92=1)



a In each chart, individual SLAs are ranked by the SLA index of farm profit. Each SLA therefore has the same rank in each chart.
b A degradation index value of 1 indicates negligible degradation of the type listed in an SLA. Severe or very severe degradation in an SLA is indicated by a maximum index value of 3. For a description of the formation of degradation index values, see Appendix C.
Source: Commission model data base.

Either there is no relationship between degradation and farm profits or a more complex analysis is necessary to reveal a relationship between degradation and profit. Such an analysis would need to adopt an economic-environmental framework which considers the effects of degradation on the output and input decisions of farmers as well as the joint effects of different types of degradation occurring in the same SLA and biogeographic region in which the SLA is located.

An econometric model of New South Wales agriculture has been adopted in order to investigate the relationship between degradation and profits for New South Wales.

F.3 Model outline

The econometric model is based on the profit-maximising behaviour of individual farmers. The modelling approach is developed from established procedures for variable profit function analysis. Annex F.1 sets out a detailed specification of the model adopted.

The model maintains the hypothesis that farmers choose both variable input and output mixes to maximise current profits given a set of input and output prices, land degradation and other fixed factors. The assumption that farmers are price takers is appropriate because the farm sector produces standard commodities that are typically traded on world markets and is characterised by many producers each supplying a small part of total domestic output.

Structure of the model

The model evaluates the responses of farmers to changing conditions on the basis of a cross section of New South Wales agricultural industry data disaggregated into 148 SLAs. The model incorporates two commodity output categories:

- crops and other plant products (crops); and
- animals and animal products (animal products);

while variable inputs are divided into four categories:

- 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;

with the effects of degradation being analysed with reference to:

- dryland salinity;
- irrigation salinity;
- soil structure decline; and
- induced soil acidity.

These types of degradation are a subset of the list of degradation types discussed in Appendix A. Of the other types, sheet and rill and wind erosion were excluded from the econometric analysis because the relevant degradation indexes are highly correlated with the degradation index for soil structure decline which is included.

In order to account for biogeographical differences affecting the nature of farm activity between SLAs, the following six New South Wales regional variables were included in the model:

- North Coast;
- Central and South coast;
- Tablelands;
- Central areas;
- Central-west areas; and
- Western areas.

In addition, the effects of irrigation farming were captured through an irrigation regional variable. The biogeographical regional groupings are defined in terms of component SLAs as set out in Appendix B. Irrigation areas are all those SLAs for which the area of agricultural land irrigated exceeds 10 per cent of agricultural land holdings in that SLA.

The econometrically estimated model was found to have a high degree of explanatory power. Some details about the statistical significance of the model, its estimates and the test results as well as some theoretical properties of the model are reported in Box F.1. While, with some qualification, the tests provide encouragement for the use of the model, ultimately, it must be evaluated on the basis of the economic meaningfulness of its estimates and insights that it can add to the discussion of land degradation and Australian agricultural industry.

Box F.1: Some technical issues in the econometric estimation of the model

The econometrically estimated model was found to have a high degree of explanatory power as tested using the likelihood ratio statistic. With 109 degrees of freedom (corresponding to the number of explanatory variables in the model), the ratio test indicated that variability in New South Wales agriculture over the sample period is explained by the model at the 1 per cent level of significance (calculated value 325 against a 1 per cent critical value of 145). Nearly thirty 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.

There is a set of four restrictions of homogeneity, monotonicity, symmetry and convexity, that are required to maintain the theoretical properties of the model. The property of homogeneity is built into the model, and does not need to be tested as part of model assessment procedures. The property of monotonicity requires that the estimated quantities of output supply and profit be positive and the estimated quantities of input demand be negative for all data points. The estimated model satisfies this property except for one data point which predicts a negative output supply for one commodity. The property of convexity requires that the Hessian matrix of the model's second-order partial derivatives with respect to prices be positive semi-definite, which in turn requires that the characteristic roots of the matrix be positive. All but one of the characteristic roots were found positive. The property of symmetry was tested and it was rejected. However, to preserve some of the theoretical properties of the model and to conform with standard procedures for estimating this type of model, symmetry was imposed in the estimation.

Diagnostic tests on individual equations indicate that there may be heteroskedasticity and functional form problems associated with the animal supply and labour demand equations. Heteroskedasticity does not affect the unbiasedness of the estimates, although its presence in these two equations may indicate a possible incompatibility between data and model formulation. However, the four other equations satisfied the heteroskedasticity and functional form tests. Since none of the equations in the model are ad-hoc but rather derived from a system approach, any arbitrary change of the functional form of a single equation would violate the economic theory behind the model. Because of the complexities involved in the systems approach, it is unlikely that experiments with various other functional forms of the profit function from which the estimated equations are derived, would improve the results.

As a whole, because of the high level of formal explanatory power, and after taking into account the results of formal model testing, the model represents a useful starting point for the evaluation of the state-wide effects of agricultural land degradation.

Economic environment of the model

The constraints on the level of land degradation, the area of farm land and farm labour in each SLA give the model analysis of production decisions a short-run focus.

In addition, there is substantial variability in the level of degradation between SLAs (see Figure F.1). This variability has enabled the assumption of fixed degradation to be relaxed to give a medium- to longer-run perspective on the effects of land degradation. The cross-section modelling approach supports the analysis of this added perspective by evaluating the variability of the level of land degradation, production and profits between SLAs. The medium- to longer-run property of the data is used in this study to analyse the effects of a change in degradation for New South Wales agriculture.

Profit maximising (or loss minimising) farmers would be expected to trade off higher degradation and profit in the current period, against conservation of the land in the current period for production and profit in the future. The outcome of the trade off made by the farmer is embodied in the measure of farm profit, defined in the model as gross revenue less variable input costs of production. Therefore, the measure of profit reflects both current income and the opportunity cost of future resource use. In this sense, decisions made in the current period involve a consideration of possible future income flows and the outcome of decisions is captured in the model.

F.4 Responsiveness of agricultural outputs and inputs to relative price changes

The responsiveness of agricultural inputs and outputs to relative price changes is measured by own and cross-price elasticities (see Table F.4). The elasticities are computed at the sample mean, and represent the state-average for New South Wales. The model estimates elasticities for five items: crops, animal products, labour, fertiliser, and water. The elasticities of the numeraire variable other materials and services are not directly estimated, but derived residually from other parameters (see Annex F.1).

The economic environment relevant for the estimation of price elasticities in the model has a short-run focus. That is the elasticities are estimated with the area of agricultural land, farm management labour and land degradation assumed fixed.

Own price effects

The own-price elasticities appear on the diagonal of Table F.4 and report the estimated percentage change in the volume of output (input) for a one percent change in the price of that output (input) with all other output and input prices held constant. For example, a 1 per cent increase in the price of crops would increase crop output by 0.8 per cent. On the other hand, a 1 per cent increase in the price of fertiliser would lead to 3.3 per cent reduction in fertiliser use. Importantly each of the own-price elasticities are of the expected sign, so that an increase in output prices is estimated to lead to an increase in its supply and an increase in input prices is estimated to lead to a reduction in the use of that input.

Table F.4: **Estimated own and cross-price elasticities in New South Wales agriculture**

	Elasticity with respect to the price of					
Output or input	*Crops*	*Animal products*	*Labour*	*Fertiliser*	*Water*	*Other materials and services*
Crops	**0.793**	0.589	-0.615	-0.265	-0.304	-0.198
Animal products	0.823	**1.123**	-1.137	-0.037	0.316	-0.964
Labour	0.824	1.312	**-2.458**	-1.563	-0.905	2.789
Fertiliser	0.388	0.037	-1.709	**-3.265**	-1.751	6.300
Water	0.370	-0.275	-0.820	-1.453	**-2.343**	4.521
Other materials and services	0.265	0.916	2.763	5.708	4.938	**-14.590**

Source: Commission model estimates.

The estimated own-price elasticity of crop output is somewhat lower than the own-price elasticity for animal products. This suggests that there may be greater limits on the expansion of crop production in New South Wales than is the case with animal production. Such limits could be due to factors such as the availability of suitably located land and the incidence of land degradation within a region in the short run.

Cross-price effects

The cross-price elasticities appear in the off-diagonal entries and capture the interaction of the supply (demand) of one output (input) with respect to a change in the price of another output (or input).

On the output side, the analysis finds a complementary relationship between animal products and crops. Thus, a one per cent increase in animal product prices is estimated to lead to an increase in New South Wales animal product output of 1.12 per cent and a complementary increase in crop output of 0.59 per cent. There are a number of possible explanations for this finding.

In the first instance, animal and crop production are intrinsically complementary in agriculture due to rotation systems of farming. In addition, the complementarity between crops and animal products can be associated with input-output relationships that exist between these two products. Inspection of Australian input-output tables indicates that about 10 per cent of crop production goes as an input to the animal product industries either directly as hay and fodder or indirectly through stock feed products (ABS Cat. No. 5209.0). As the expected price of animal products rises and farmers respond by increased production, crops production also needs to expand to meet the increased feed demand of the animal sector. The extent to which national average links portrayed in Australian input-output tables are accurate descriptions of regional relationships will depend on the agricultural industry structure of the region. The current analysis of New South Wales, as a whole, suggests that inter-industry flows evident at the national level prevail at the state level. A subregion study may not find the same inter-industry links.

On the input side, the analysis also finds substitution and complementary relationships exist among inputs used in the New South Wales agriculture sector. For example, fertiliser and labour appear to be complementary to one another as indicated by a negative cross-price elasticity value of -1.71. This indicates that with a 1 per cent decrease in the price of labour fertiliser demand would increase by 1.71 per cent, as labour demand also increases. On the other hand, other materials and services is found to be a substitute for labour, fertiliser and water. This relationship is indicated by positive signs for the cross-price elasticities appearing in the other materials and service row and column of Table F.4. For example, a 1 per cent decrease in the price of labour is estimated to reduce the demand for other materials and services by 2.8 per cent, as labour demand increases.

Comparison with other studies

A number of other econometric studies of agriculture in Australia have been undertaken using similar methodologies. While these studies are not strictly comparable to this current study due to scope or timing differences, the models provide useful benchmarks against which to consider the results of this study.

The other studies considered relate variously to agriculture in Australia as a whole or to selected activities in a particular agricultural zone or region (eg the wheat-sheep zone). They are based on time series data taken over various periods or pooled time-series cross-section data collected over the states for a number of years. The current study is for New South Wales as a whole and is based on cross-section data taken for 1992–93.

At a general level, researchers have suggested that the responses estimated from time-series data typically suffer from downward bias relative to cross-section studies (Peterson 1979, Hertel 1990). One suggested explanation for this bias is attributed to the transitory nature of the price movements which exaggerate price variability in the time-series data relative to the underlying trends in production volumes. Cross-section studies are based on the variability of responses between sample units (in the case of the current study SLAs) and therefore abstract from the influence of time trends. Cross-section studies are thus not subject to the same understatement of responses in output and input volumes relative to observed price changes.

The Commission estimates of own-price elasticities for inputs such as labour, fertiliser and other materials and service, were, in fact, found to be higher than the available, mainly time series based, estimates for similarly defined items (see Table F.5). Nevertheless, Commission's estimate of own-price elasticity for other materials and services of -14.6, although of the expected sign, appears very high when compared with other available elasticity estimates. As this item is the numeraire variable in the model, and its own and cross-price elasticity values are not estimated directly but computed as residuals (see Annex F.1), the statistical significance of the coefficients behind the estimates could not be ascertained. The estimate is therefore presented for further consideration.

The own-price elasticities of crop and animal output, however, lie within the range established by other studies.

Regarding cross-price elasticities, the complementary relationships between crops and animal products and between fertiliser and other materials and services, found in the current study, were also found in other studies of Australian agriculture (eg Lawrence and Zeitsch 1989a, 1989b).

Table F.5: **Selected econometric estimates of own-price elasticities for Australian agriculture[a]**

Study	*Wool/ Sheep[a]*	*Wheat/ Crops[a]*	*Cattle/ Other[a]*	*Fertiliser*	*Labour*	*Other materials & services*
McKay, Lawrence and Vlastuin (1980)	..	..	..	..	-0.67	-0.98

Wicks and Dillon (1978)	0.25	1.10	0.69	..	..	..
Vincent, Dixon and Powell (1980)[b]	0.25	..	0.48	..	..	..
Adams (1987)	0.46	..	0.70	..	..	..
McKay, Lawrence and Vlastuin (1983)	0.72	0.50	0.12	..	-0.47	-0.10
Dewbre, Shaw and Corra (1985)	0.39	0.92	0.34	..	..	..
Wall and Fisher (1987)[c]						
Regions in NSW only	0.00 to 0.68	0.60 to 0.63	0.16 to 0.24	..	..	..
Regions in other states	0.00 to 1.89	0.87 to 4.79	0.01 to 1.25	..	..	..
Lawrence and Zeitsch (1989a)	..	0.19	..	-1.26	-0.78	-0.33
Lawrence and Zeitsch (1989b)	..	..	..	..	-0.68	-0.53
IC (1995)d	**1.23**	**0.80**	**..**	**-3.26**	**-2.45**	**-14.59**

a Items from source studies are selected to coincide as closely as possible with the items listed in the table column headings.
b Covers the wheat/sheep zone only.
c Covers the sheep industry only.
d New South Wales agriculture.
Sources: As listed in the table.

F.5 Land degradation, output responsiveness and profitability

The model of New South Wales agriculture has been used to examine the responsiveness of outputs, inputs and profits to different levels of land degradation. The results presented are comparative static in nature in the sense that they describe the initial and new situations, but not the growth path between the two points. By comparing the initial equilibrium with a new equilibrium in which the constraint of the level of degradation is relaxed, the analysis provides a medium to longer-run focus.

This section examines the results obtained from this analysis (the mathematical underpinnings of the analysis are given in Annex F1).

Output and input effects

The analysis finds that under the current farm management and technology regime, agricultural production and input effects of additional land degradation vary depending on the type of degradation. For some types of degradation such as irrigation and dryland salinity, overall production is estimated to increase with a move to farming activities that increase the level of these forms of degradation (Table F.6). However for soil structure decline and induced soil acidity, a negative response is observed.

Table F.6: **Estimated elasticities of production and input use with respect to changes in the level of land degradation in New South Wales agriculture**[a]

Output or input	*Dryland salinity*	*Irrigation salinity*	*Soil structure decline*	*Induced soil acidity*
Crops	0.087	0.103	-0.013	-0.164
Animal products	0.091	0.225	-0.007	-0.029
Hired labour	0.265	0.215	0.137	-0.162
Fertiliser	0.052	-0.022	0.190	-0.067
Water	0.114	0.045	0.013	-0.076

a The estimated elasticities refer to the percentage change in outputs or inputs for a 1 per cent change in degradation.
Source: Commission model estimates.

One possible reason for the different effects of additional degradation is suggested by the different nature of dryland and irrigation salinity compared to induced acidity and soil structure decline. In the case of dryland and irrigation salinity, the nature of degradation is such that salinity is visible only at some localised spots rather than in the entire area (Box F.2). Because of the localised nature of visible severe degradation, a farmer could gain more from the increase in productivity in the cleared or irrigated land than productivity lost from those isolated points which develop problem salinity.

On the other hand, induced soil acidity and soil structure decline tends to characterise whole farming areas. In this situation, losses in productivity also tend to be widespread affecting whole farming areas rather than individual points on an otherwise productive farm landscape. Thus the gains from farming activities which initiated these forms of degradation, are outweighed by the losses resulting from reduced productivity.

Box F.2: **Assessment of degradation**

Dryland and irrigation salinity were assessed within a 100 ha circle centred on a sample point. With evidence of these forms of land degradation found within the circle, the sample point was coded as having that form of degradation. The highest severity value observed was recorded.

The severity of induced soil acidity and soil structure decline was assigned with respect to a four hectare quadrant around each sample point. The most severe severity class observed was recorded.

In the Soil Conservation Service-NSW analysis of its survey data, total areas affected by induced soil acidity and soil structure decline were estimated by assuming that the degradation noted for the sample point was representative of the surrounding area, and aggregating the area estimates across sample points using GIS techniques. However, for dryland and irrigation salinity, such aggregate area measures of degradation were not made because land degradation at a specific location does not represent the severity of degradation in the area surrounding the survey point.

The essential difference between the two groups of degradation is that the estimates of the severity of dryland and irrigation salinity should not be viewed as representative of a locality or region while estimates of the severity of induced soil acidity and soil structure decline can be viewed in that way.

The forms of land degradation and the estimates of the indexes of degradation severity are discussed in Appendices A and C.

The model estimates also suggest that changing degradation would lead to a substitution between farm inputs as outputs change. For example, the expansion of activities associated with dryland and irrigation salinity appears from the estimates to favour proportionately more hired labour relative to fertiliser and water inputs. The estimated substitution away from fertiliser and water was more pronounced in the case of additional irrigation salinity compared to dryland salinity. For both types of salinity in New South Wales agriculture, the input changes were orientated to maximising profit from estimated output increases.

The estimated input responses for induced soil acidity and soil structure decline illustrate different approaches to minimising profit declines from reduced output. In the case of induced acidity, the estimates suggest that less use of hired labour, fertiliser and water would occur as farmers attempt to minimise losses by reducing the use of these inputs. On the other hand, with soil structure decline, inputs of the selected items were estimated to increase with additional degradation. This would be consistent with farm strategies involving the substitution of intermediate inputs for land fertility as a means of countering the negative effects of the lost fertility of the soil.

Effects on farm profits

As degradation affects both input and output mixes, the effect of increased degradation on farm profits is ambiguous. In the current analysis, farm profits are found to be increased by the adoption of farming activities that also increase dryland and irrigation salinity while the reverse applies to induced soil acidity and soil structure decline (Table F.7).

Table F.7: **Estimated change in profit due to an increase in the level of land degradation**

Form of degradation	*Elasticities of profit (per cent)*
Dryland salinity	1.22
Irrigation salinity	0.44
Soil structure decline	-0.29
Induced soil acidity	-0.13

a The estimated elasticities refer to a percentage change in farm surplus (or profit) for a 1 per cent change in land degradation.
Source: Commission model estimates.

The estimated elasticity values reported refer to a percentage change in state-wide farm surplus (or profit) for a one per cent change in the level of degradation. In 1992–93, the state-average farm surplus was estimated, from the Commission data base, to be $19 per hectare, with substantial regional variations around the average. Applying these elasticities to this state-wide average suggests that activities that have accompanying higher levels of salinity degradation would raise the per hectare farm profit by $0.24 for dryland and $0.08 for irrigation salinity. The changes represent 1 per cent and 0.4 per cent, respectively, of state farm surplus. On the other hand, degradation associated with soil structure decline and induced soil acidity would lower average farm profit by $0.06 and $0.03 per hectare, respectively, which represent 0.03 per cent and 0.02 per cent, respectively, of state average surplus.

The above financial measures of the state-wide financial effects of degradation are very small when compared to the average profit per hectare. Given that land degradation is a slow and gradual process, it could take a number of years before the cumulative negative effects of degradation become of sufficient importance to enter into the farmer's land management decision making process.

Dynamic considerations

Because the analysis is based on a snapshot of New South Wales agriculture, estimates represent the likely effects of once and for all, marginal changes in land degradation. Thus, the model estimates do not infer the cumulative effects of successive increases in degradation that would occur in the continuum of land use. For example, the extension of farming activities that involve dryland and irrigation salinity could improve New South Wales farm output and profitability as indicated by the model estimates even at the expense of some more degradation. Progressively more and more land would be sacrificed to degradation, under prevailing technologies. Ultimately, the cumulative effect of dryland and irrigation salinity could become negative. This possibility is illustrated in the model estimates of the negative effects of additional induced soil acidity and soil structure decline. They illustrate that at some point degradation can become so severe or so widespread that further increases reduce production and profit.

These analyses are concerned with the effects of degradation and the substitution between activities, given current technologies. They do not take into account the dynamic effects of technological change and other sources of productivity improvement. To be effective, technological changes would involve a shift to new farming activities that raise the productivity of the land. Such productivity changes could, in principle, be associated with higher or lower levels of degradation. A change that could involve more degradation could be one that discounts the importance of the immediate condition of the land (eg., poultry farming, piggeries and cattle feedlots). Alternatively, the technological change could favour reductions in degradation to improve crop and pasture growth (eg introduction of minimum tillage techniques and/or salt and acid resistant plant species).

F.7 Summing up

An integrated profit function model has been used to analyse production, inputs and land degradation in New South Wales agriculture. The estimated price elasticities capturing the link between output, inputs and price changes were found to be of the expected sign. In addition, a substantial proportion of the parameter estimates were also statistically significant according to conventional tests of significance. The estimates obtained were found to be around a range of values suggested by other studies of Australian agriculture. If anything the current analysis suggests that the input mix for agriculture may be somewhat more flexible to relative price changes than previously estimated.

On the basis of this general assessment of the model, it was extended to provide some insights into degradation issues in a state-wide framework.

The general findings of the study indicate that at the current level of development of the agricultural industry there are positive incentives for farmers who are operating with evident salinity not to move away from those farming systems. However, for farmers who are operating with severely acid soil or deteriorated structure in soil, the incentives would favour a shift to alternative, more profitable, farming activities. Similarly, in the case of salinity, there are incentives for other farmers to move towards those farming activities that coexist with higher levels of degradation. For the other two forms of degradation the incentives would appear to discourage a move to activities that encourage additional induced acidity or soil structure decline.

The model results indicate that land management decisions, as they are applied to degradation, influence farm production and profits. Depending on farm technologies, allowing some additional on-farm degradation may increase profits, or it may lead to reduced returns.

Annex F1: Econometric model of agriculture and the effects of land degradation

Basic theoretical model

Given a set of product and input prices and a number of fixed factors of production such as family labour, area of agricultural land holdings, land characteristics, capital stock, weather, etc., farmers make decisions about output and input-mix. 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 problem 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,

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

and

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

Equation (*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.

Model specification and functional form

A wide range of functional forms is available to model production decisions involved in equations (*2*) to (*4*). The most commonly used are Cobb-Douglas or CES. While a Cobb-Douglas function restricts partial elasticities of substitution between all products to be equal to one, the CES form restricts them to be equal, but not necessarily to one. Among the more flexible functional forms, those commonly used include: generalised Leontief, symmetric generalised McFadden, normalised quadratic, and transcendental logarithmic. These flexible functional forms are nonlinear in the variables and they are termed flexible because they are second order, or Taylor series, approximations to any underlying actual production functions, and they do not impose as many restrictions on the production technology as functional forms such as Cobb-Douglas, CES or CRESH/CRETH.

These flexible functional forms have been developed for a variety of applications of applied production theory, and there is not one particular function that can be expected to suit all purposes. However, one common limiting factor present in most of these models in the past has been their failure to satisfy some curvature condition such as global convexity. The underlying economic theory behind deriving production technology from profit function is applied duality.[2] Global convexity of the profit function (that is, decreasing returns to scale in production) is a necessary condition for the duality to hold between profit and production functions. If the condition of convexity does not hold for a model, which is more often the case, it can be imposed by following one of the methods suggested by Wiley, Schmidt and Bramble (1973), Lau (1978) and Jorgensen and Fraumeni (1981). However, Diewert and Wales (1987) have shown that when convexity is imposed on a translog function, it collapses to a Cobb-Douglas form and loses its flexibility. In fact, among the set of flexible functional forms, the normalised quadratic function developed by Lau (1976) and the symmetric generalised McFadden function, developed by Diewert and Wales (1987) are the only functional forms on which global convexity can be imposed while retaining their flexibility. The normalised quadratic profit function also has the advantage of being self-dual, that is, the production function underlying a normalised quadratic profit function is also a quadratic function. This property is also shared by some other functional forms, such as Cobb-Douglas or CES, but they imply more rigid production structure.

Examples of studies using a normalised quadratic profit function to estimate the input demand and output supply elasticities are Shumway, Saez and Gottret (1988), Moschini (1988), Coxhead (1988), Maligaya and White (1989), Nehring (1991), Salma (1992), and Polson and Shumway (1992). An example of the application of normalised quadratic functional form for Australian agriculture is Wall and Fisher (1987, 1990) for its sheep industry study. The Symmetric Generalised MacFadden function, a function similar to normalised quadratic, was applied by Lawrence (1990) and Lawrence and Zeitsch (1989a, 1989b) to study Australian agriculture.

The normalised quadratic functional form is adopted in this study to estimate the profit, input demand and output supply functions in New South Wales agriculture. The empirical model uses information on agricultural outputs, commodity inputs, farmers and farm managers, land and land degradation. The variable profit function in (*2*) in normalised quadratic functional form in this multi-output multi-input case is given by:

2 In essence duality theory states that under certain regularity conditions, the profit function and the production function contain the same information about production technology. A dual approach, which uses a profit function rather than a production function, provides more flexibility and econometrically it is a rigorous approach to the derivation of estimates of technology parameters.

$$\Pi^{\circ} = \alpha_0 + \sum_{i=1}^{n-1} \alpha_i \frac{P_i}{P_n} + \sum_{r=1}^{s} \beta_r Z_r + \frac{1}{2} \sum_{i=1}^{n-1} \sum_{j=1}^{n-1} \alpha_{ij} \frac{P_i}{P_n} \frac{P_j}{P_n} + \frac{1}{2} \sum_{r=1}^{s} \sum_{v=1}^{s} \beta_{rv} Z_r Z_v + \sum_{i=1}^{n-1} \sum_{r=1}^{s} \lambda_{ir} \frac{P_i}{P_n} Z_r \qquad (5)$$

where *i*, *j*=1,...,*n* is for farm outputs and inputs, *r*, *v*=1,...,*s* for fixed factors of production and land degradation. For notational convenience, input and output prices are combined into a single price vector defined as $P =$ [redacted] $_1, \ldots, P_g, P_{g+1}, \; P_j$, where the range *1 to g* covers outputs and the range *g+1* to *j* covers inputs. Π° is nominal profit (Π^*) divided by the price of n, the numeraire variable. As the prices of outputs and inputs are similarly normalised, they are nominal prices of outputs and variable inputs divided by the nominal price of the numeraire.

The output supply and (negative) variable input demand equations are obtained from the estimation model (*5*) by taking first derivatives with respect to normalised output prices and normalised variable input prices, respectively. The equations are linear in normalised prices of outputs, and variable inputs, and the exogenous Z variables:

$$\frac{\partial \Pi^{\circ}}{\partial (P_i / P_n)} = Y_i = \alpha_i + \sum_{j=1}^{n-1} \alpha_{ij} \frac{P_j}{P_n} + \sum_{r=1}^{s} \lambda_{ir} Z_r \qquad i=1,...g, \qquad (6)$$

$$\frac{\partial \Pi^{\circ}}{\partial (P_j / P_n)} = -X_j = \alpha_j + \sum_{i=1}^{n-1} \alpha_{ji} \frac{P_i}{P_n} + \sum_{r=1}^{s} \lambda_{jr} Z_r \qquad j=g+1,...n-1 \qquad (7)$$

Equation (*6*) is a set of output supply equations for each type of output. Equation (*7*) is the negative of the variable input demand equations. The equations yield the intercepts α_i and α_j, and the behavioural parameters α_{ij} and λ_{ir}. Parameter α_{ij} indicates changes in output supply or input demand with respect to changes in relative prices. Parameter λ_{ir} estimates changes in outputs or inputs due to changes in fixed factors and land degradation. The parameter β_{rv} in equation (*5*) which does not appear in (*6*) and (*7*), indicates the effects of interaction between fixed factors and land degradation.

For completeness, the numeraire input demand equation can be derived as follows:

$$-X_n = \Pi^{\circ} - \sum_{i=1}^{n-1} X_i P_i / P_n = \alpha_0 + \sum_{r=1}^{s} \beta_r Z_r - \frac{1}{2} \sum_{i=1}^{n-1} \sum_{j=1}^{n-1} \alpha_{ij} \frac{P_i}{P_n} \frac{P_j}{P_n} + \frac{1}{2} \sum_{r=1}^{s} \sum_{v=1}^{s} \beta_{rv} Z_r Z_v \qquad (8)$$

From the symmetry property of the profit function, it follows that $\alpha_{ij} = \alpha_{ji}$ and $\beta_{rv} = \beta_{vr}$ across equations (*5*) to (*8*). Thus equation (*5*) contains all the information given in equation

(*8*). Hence, the basic empirical model to estimate production decisions includes equations (*5*) to (*7*) in a simultaneous estimation system. The symmetry conditions are imposed during the estimation process. The properties of monotonicity and convexity are tested after the model is estimated.

Model estimation

The basic empirical model of production decisions outlined in equations (*5*) to (*7*) form the final model to be estimated. The model covers all agriculture in New South Wales. The various products are aggregated into two major groups: one including all crops and plant products, and the other, all animal and animal products. Four major variable inputs are identified: hired labour, fertiliser, water, and other materials and services. The two fixed factors included in the model are the area of agricultural land holdings and farmer and farm manager labour. To consider the effects of selected forms of land degradation such as dryland salinity, irrigation salinity, soil structure decline and induced soil acidity, four indexes of land degradation are included as exogenous variables in the model. In addition, to capture regional differences in land use and farm income patterns, a biogeographical classification code with seven regional dummies is considered. Thus, referring to equations (5) to (7), the subscripts i and j, r and v stand respectively as follows: i and j refers to crops, animal products, labour, fertiliser, and water; while r and v refers to land, dryland salinity, irrigation salinity, soil structure decline, induced soil acidity, family labour, and seven regional dummy variables. The full model comprising one profit function and two output supply and three input demand equations outlined in equations (5) to (7) has 337 coefficients. However, because of the symmetry restrictions, the number of estimates is reduced significantly. The number gets reduced even further when interaction terms between regional dummies, farmers and farm mangers, and degradation, and between regional dummies and price terms are omitted. The total number of coefficients estimated in the final model was 115.

Estimation of equations (*5*) to (*7*) involves a system of seemingly unrelated regressions where contemporaneous correlation among the equations is likely. This is because parameters are shared across equations and production decisions for one output are likely to be related to decisions about others as it involves land reallocation. Use of Ordinary Least Squares in this situation would cause inefficiency as the error correlation would be ignored. Efficient estimation is accomplished using Zellner’s (1962) estimation technique for seemingly unrelated regressions using generalised least squares. The SUR estimation technique in SHAZAM (White 1978) was used for this purpose.

Derivation of elasticities

As noted, equations (*5*) to (*7*) provide a behavioural model revealing farmers’ responses to changes in the relevant variables across SLAs. The importance of these equations for this study is that they can be differentiated in order to analyse the effects of changes in relative prices of inputs and outputs, of production, of land characteristics etc, including the loss or gain from a marginal increase in degradation.

Own- and cross-price elasticities

The first set of key items that can be derived from the model are: own- and cross-price elasticities of input demand and product supply, derived using the value of each α_{ij} from the basic model.

The own- and cross-price elasticities of *i*th output/input to changes in price of the *j*th item can be defined as:

$$\varepsilon_{ij} = \left(\frac{\partial Y_i}{\partial \frac{P_j}{P_n}} \right) \left(\frac{P_j / P_n}{Y_i} \right)$$

$$= \alpha_{ij} * \frac{P_j / P_n}{Y_i}$$

For completeness, the elasticity of the numeraire input with respect to *i*th item is derived from equation (*8*) as:

$$\varepsilon_{ni} = \left(\partial X_n / \partial \frac{P_i}{P_n} \right) \left(\frac{P_i / P_n}{X_n} \right)$$

$$= \left(\sum_{j=1}^{n-1} \alpha_{ij} * P_j / P_n \right) \left(\frac{P_i / P_n}{X_n} \right)$$

$$= X_i * \left(\sum_{j=1}^{n-1} \varepsilon_{ij} \right) \left(\frac{P_i / P_n}{X_n} \right) \qquad (9)$$

The linear homogenous property of the profit function in (*5*) means that:[3]

$$\sum_{j}^{n-1} \varepsilon_{ij} = -\varepsilon_{in}$$

Therefore,

$$\varepsilon_{ni} = - X_i * \varepsilon_{in} * \frac{P_i / P_n}{X_n}$$

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[3] One of the properties of the profit function is that it is linear homogenous in prices, which implies that the sum of price elasticities appearing in each equation in (*6*) and (*7*) is zero. This property is imposed by the normalisation process.

$$\text{or } \varepsilon_{ni} = -\varepsilon_{in} * \frac{X_i * P_i / P_n}{X_n} \quad \text{and} \quad \varepsilon_{nn} = -\sum_{j=1}^{n-1} \varepsilon_{nj} \qquad (10)$$

Effects on inputs and outputs of a marginal change in land degradation

The second set of key items derived from the model estimates provides elasticities of output and input with respect to land degradation. Similar to the above definition of elasticities, prices are now replaced by level of land degradation.

The elasticities of output supply with respect to a marginal change in land degradation is derived by partial differentiation of (*5*) with respect to the index of land degradation. Thus, the expression $\frac{\partial Y_i}{\partial Z_q} = \lambda_{iq}$, where q is the land degradation index, represents the marginal response of the *i*th output when qth form of land degradation is changed.

The estimated opportunity cost of land degradation

Other than elasticities, the model can be used to provide an estimate of profit/loss resulting from a marginal increase in land degradation. From microeconomic theory it follows that, partial derivative of (*2*) with respect to the *Z* variables will give shadow prices of these variables, so that:

$$\partial \Pi^* (P, R; Z) / \partial Z_q = \omega_q = Z_q (P, R, Z) \qquad (11)$$

If, for example, Z_q is the stock of qth form of land degradation, and if the overall sign of ω_q is negative, expression (*11*) 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 (*11*) will suggest a magnitude of that gain.

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

$$\partial \Pi^\circ (P; Z) / \partial Z_q = \omega_q = \beta_q + \sum_{r=1}^{s} \beta_{rq} Z_r + \sum_{i=1}^{n-1} \lambda_{iq} \frac{P_i}{P_n} \qquad (12)$$

Using the parameters recovered from the model, the estimated loss/gain from an extra unit increase in the stock of land degradation can be derived.

Model results

The model was estimated using the SUR estimation method in SHAZAM. The estimated parameters with their t-ratios are presented below in tables Annex Table F1 and Annex Table F2.

Annex Table F.1: **Estimated output supply and input demand equations**

	Coefficients																	
	Constants	*Price terms*					*Fixed factor terms*		*Land degradation terms*				*Regional dummy variables*					
Equations	α_i	α_{i1}	α_{i2}	α_{i3}	α_{i4}	α_{i5}	λ_{i1}	λ_{i2}	λ_{i3}	λ_{i4}	λ_{i5}	λ_{i6}	λ_{i7}	λ_{i8}	λ_{i9}	λ_{i10}	λ_{i11}	λ_{i12}
Supply of Crops	0.59 (0.43)	0.95 (2.29)	0.78 (4.61)	-0.75 (-4.02)	-0.34 (-3.74)	-0.37 (-3.08)	0.24 (0.32)	-0.00 (-0.02)	0.13 (0.13)	0.10 (0.22)	-0.01 (-0.05)	-0.17 (-0.97)	0.15 (0.55)	0.07 (0.25)	0.09 (0.41)	0.33 (1.30)	-0.21 (-0.47)	-0.32 (-0.55)
Supply of Animal products	-0.76 (-0.69)	0.78 (4.61)	1.31 (1.97)	-1.33 (-1.92)	-0.04 (-0.11)	0.31 (0.70)	0.57 (2.12)	-0.00 (-1.41)	0.22 (0.65)	0.09 (0.52)	-0.01 (-0.08)	-0.02 (-0.36)	0.51 (0.39)	-0.03 (-0.20)	-0.01 (-0.05)	0.05 (0.50)	0.17 (0.90)	0.13 (0.58)
Demand for Labour	-2.74 (-1.63)	-0.75 (-4.02)	-1.33 (-1.92)	2.28 (2.02)	1.52 (2.77)	0.83 (1.23)	-0.67 (-2.28)	0.00 (2.14)	-0.20 (-0.55)	-0.24 (-1.34)	-0.09 (-0.96)	0.10 (1.47)	0.17 (1.21)	0.15 (1.11)	0.16 (1.54)	-0.06 (-0.50)	0.07 (0.37)	0.08 (0.33)
Demand for Fertiliser	-6.37 (-6.43)	-0.34 (-3.74)	-0.04 (-0.11)	1.52 (2.77)	3.07 (6.59)	1.56 (3.19)	-0.46 (-3.33)	0.00 (1.86)	0.02 (0.11)	-0.04 (-0.54)	-0.12 (-2.73)	0.05 (1.50)	0.17 (2.60)	0.19 (2.94)	0.24 (4.79)	0.03 (0.60)	0.30 (3.14)	0.23 (2.04)
Demand for Water	-5.49 (-4.25)	-0.37 (-3.08)	0.31 (0.70)	0.84 (1.23)	1.56 (3.19)	2.38 (3.27)	-0.32 (-1.72)	0.00 (0.29)	-0.05 (-0.20)	-0.11 (-0.99)	-0.01 (-0.15)	0.06 (1.45)	0.01 (0.06)	0.77 (0.90)	0.08 (1.24)	-0.02 (-0.39)	0.37 (2.93)	0.08 (0.57)

0.00 Less than |0.005|.

a figures in parentheses are t-ratios.

Source: Commission estimates.

Annex Table F.2: **Estimated profit equation**

Coefficients

	Constant	Fixed factor terms												Linear price terms				
Eq^n	α_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}	β_{11}	β_{12}	α_1	α_2	α_3	α_4	α_5
Profit	28.79 (1.04)	-7.36 (-0.40)	-0.003 (-1.77)	-8.74 (-0.42)	-28.20 (-1.03)	2.46 (1.06)	0.44 (0.22)	0.92 (0.53)	0.75 (0.38)	0.46 (0.48)	0.92 (1.24)	3.94 (0.88)	-0.84 (-0.10)	0.59 (0.43)	-0.76 (-0.69)	-2.74 (-1.63)	-6.37 (-6.43)	-5.49 (-4.25)

Coefficients

Quadratic price terms

α_{11}	α_{22}	α_{33}	α_{44}	α_{55}	α_{12}	α_{13}	α_{14}	α_{15}	α_{23}	α_{24}	α_{25}	α_{34}	α_{35}	α_{45}
0.95 (2.29)	1.31 (1.97)	2.28 (2.02)	3.07 (6.59)	2.38 (3.27)	0.78 (4.61)	-0.75 (-4.02)	-0.34 (-3.74)	-0.37 (-3.08)	-1.33 (-1.92)	-0.04 (-0.11)	0.31 (0.70)	1.52 (2.77)	0.84 (1.23)	1.56 (3.19)

Coefficients

Interaction terms between fixed variables

β_{11}	β_{12}	β_{13}	β_{14}	β_{15}	β_{16}	β_{17}	β_{18}	β_{19}	β_{210}	β_{111}	β_{112}	β_{22}	β_{23}	β_{24}	β_{25}	β_{33}	β_{34}
-7.86 (-2.73)	-0.82 (-0.62)	18.22 (1.01)	-1.92 (-1.92)	1.08 (1.98)	0.00 (1.45)	-0.78 (-0.43)	-0.77 (-0.39)	-0.40 (-0.41)	-1.01 (-1.37)	-4.21 (-0.89)	0.88 (0.10)	-1.46 (-1.51)	12.56 (0.61)	-0.71 (-1.54)	0.13 (0.51)	0.69 (0.23)	0.01 (0.04)

Coefficients

Interaction terms between price and fixed variables

β_{35}	β_{44}	β_{45}	β_{55}	λ_{11}	λ_{12}	λ_{13}	λ_{14}	λ_{15}	λ_{16}	λ_{21}	λ_{22}	λ_{23}	λ_{24}	λ_{25}	λ_{26}	λ_{31}	λ_{32}
-1.86 (-1.06)	0.15 (0.74)	0.04 (0.28)	0.11 (0.50)	0.24 (0.32)	0.10 (0.23)	0.13 (0.13)	-0.01 (-0.05)	-0.17 (-0.97)	-0.00 (-0.02)	0.57 (2.12)	0.08 (0.52)	0.22 (0.65)	-0.00 (-0.05)	-0.02 (-0.36)	-0.00 (-1.41)	-0.67 (-2.28)	-0.24 (-1.34)

Coefficients

Interaction terms between price and fixed variables

λ_{33}	λ_{34}	λ_{35}	λ_{36}	λ_{41}	λ_{42}	λ_{43}	λ_{44}	λ_{45}	λ_{46}	λ_{51}	λ_{52}	λ_{53}	λ_{54}	λ_{55}	λ_{56}
-0.21 (-0.55)	-0.09 (-0.96)	0.10 (1.47)	0.00 (2.14)	-0.46 (-3.33)	-0.04 (-0.54)	0.02 (0.11)	-0.12 (-2.73)	0.05 (1.50)	0.00 (1.86)	-0.32 (-1.71)	-0.11 (-0.99)	-0.05 (-0.20)	-0.01 (-0.15)	0.06 (1.45)	0.00 (0.29)

0.00 Less than |0.005|.

a figures in parentheses are t-ratios

Source: Commission estimates.

Annex F2: Sources of data for the integrated econometric modelling data base

Information necessary to undertake a broad economic analysis of agriculture and land degradation is not available from a single source. Nevertheless, there is a range of sources that individually have components of the information necessary to undertake the analysis. Information has been brought together from these various data bases to form the analytical data base used in this study.

The main series used in the analysis were obtained from ABS, ABARE and SCS-New South Wales sources. For the current pilot study, the data assembled relate to the agricultural industry in New South Wales. As not all data from these sources are available for the reference years of the study, that is 1991–92 and 1992–93, the reference year for data used and any adjustments to place it on a 1991–93 basis are described. With the exception of information about the level of land degradation, the data sources discussed below could also be used to construct a similar data base for other years and for the agricultural sector in other states.

Economic data

Local value of commodities produced is the value of commodities at the place of production. It is estimated by deducting ex-farm marketing costs from the gross value of commodities produced. Data on gross value of production classified by SLA were obtained from the ABS Agricultural Census. These values were generally converted to the required local value basis using state-wide local value to gross value ratios obtained from ABS value of commodities produced series (ABS Cat. No. 7503). For the commodities: barley, oats, wool, sheep and beef cattle, local values were estimated on a regional basis using unit value information from ABARE farm finance surveys and the volume of production from the ABS Agricultural Census.

Volume indexes of commodities produced were estimated by revaluing current price commodity production series (at local values) derived from ABS production data by ABARE commodity price indexes. The series were revalued to constant 1991–92 dollars. In a second stage, individual commodity flows were aggregated to the broad commodity groups used in the analysis, namely, crops and plant products and animals and animal products. The information was used to estimate aggregate indexes of commodities produced. An index with 1991–92=100 was then estimated from the series of values.

Price indexes of commodities produced were estimated for each SLA by reweighting the ABARE indexes of prices received by farmers in New South Wales by the level of production of each commodity in 1991-92. The price index used is therefore a fixed weighted (or Laspeyres) price index. The base period of the price index is 1991–92=100. In the analysis, output prices are lagged one period to indicate that farmers' land management decisions for the year are based on prices received in the previous year. This approach conforms to the approach adopted in comparable studies (see Section F.3).

The area of agricultural land holdings and the area of irrigated land was obtained for each SLA from the annual Agricultural Census conducted by the ABS.

The number of farmers and farm managers were obtained by SLA from the 1991 Population Census conducted by the ABS.

Industry costs were estimated for each SLA using a three stage process. First, industry cost structures were obtained from Agricultural Finance Survey data published by the ABS (Cat. No. 7507.0) and farm financial information obtained from ABARE farm surveys (ABARE various). In many cases, relevant industry data were available for the study reference years of 1991-92 and 1992-93. These data were used directly in the analysis. In some cases, relevant input cost data were only available for other years. These data were adjusted to a 1991–92 or 1992–93 basis, as appropriate, using an index of prices paid by New South Wales farmers obtained from ABARE (1995b). For some items, such as water, there was no price data available at the time of estimation. A general price index was used to calculate water costs. In the second stage, each agricultural commodity produced in each SLA was matched to an industry cost structure and an implicit cost structure for the production of that commodity in the SLA was estimated. Thirdly, the costs for the SLA were obtained by aggregating the costs pertaining to commodities produced. Finally, the costs for each SLA were summarised into the groups: labour costs, fertiliser costs, water costs (including water rates), and other materials and service inputs. Once the estimation process was complete, indexes of current price inputs were estimated, with the base year being 1991–92=100.

The number of persons employed as hired labour were estimated by dividing wages and salaries paid by farm industries by a farm labour wage rate.

Implicit indexes of the volume of intermediate inputs to the production of agricultural commodities were estimated by revaluing input costs to 1989–90 prices using ABARE indexes of prices paid by farmers in NSW (ABARE, 1995b). The estimated constant 1989–90 price inputs were linked to SLA and then aggregated to summary commodity using the procedure applied to current price inputs (see above). Indexes of intermediate inputs to production were then estimated for each SLA, with the base year being 1991–92=100.

Indexes of prices paid for inputs by SLA were estimated by dividing the index of current price inputs by the index of constant price inputs with 1991–92=100.

Farm operating surplus (the model estimate of profit) is estimated for each SLA by deducting labour income and intermediate input costs from an estimate of income from farm production.

Land degradation and other environmental data

An index of land degradation by type of degradation was estimated for each SLA from approximately 13000 grid points assessed in the Land Degradation Survey, NSW 1987–1988.

The grid point data were provided on disk by the SCS-New South Wales and linked to SLAs using GIS techniques by the National Resource Information Centre (NRIC), Bureau of Resource Sciences. An assessment of land degradation in New South Wales using data from this survey is provided in Appendix C. Because degradation advances slowly, the 1987–1988 data were used as a proxy for the level of degradation prevailing in the 1991 to 1993 period.

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