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National Land & Water Resources Audit

Signposts for Australian Agriculture

The Australian grains industry

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The Australian grains industry

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GRAINS COUNCIL OF AUSTRALIA

RESEARCH WITHOUT BOUNDS
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Foreword

Agriculture is under pressure to demonstrate its performance credentials — in particular, its environmental credentials — and to inform the community about its management practices. The agricultural sector recognises that failure to respond to this pressure may constrain future access to natural resources and markets and increase the risk of regulation of agricultural practices.

Since 1997, the National Land & Water Resources Audit has played an important role in the national coordination, collation and reporting of data and information. Under Signposts, government, industry and research bodies have collaborated in providing strategic direction and in exchanging data and information.

Signposts provides access to social, economic and environmental data specific to an industry and geographical area to inform policy development, strategic decision making and future research priorities. The Signposts reporting framework has been designed to align with other government reporting initiatives, including the evaluation framework for natural resource management programs such as Caring for our Country and Landcare.

The partnership built under Signposts needs to continue, to ensure an ongoing legacy of cross-agency collaboration in reporting.

Geoff Gorrie

Chair

National Land & Water Resources Audit Advisory Council and Signposts Reference Group

Acronyms and abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
AGO	Australian Greenhouse Office
ASCC	Australian Safety and Compensation Council
ASFPD	Australian Sustainable Farming Practices Database
ASRIS	Australian Soil Resources Information System
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEWHA	Department of the Environment, Water, Heritage and the Arts
EMS	environmental management system
ESD	ecologically sustainable development
GCA	Grains Council of Australia
GHG	greenhouse gas
GRDC	Grains Research and Development Corporation
ISO	International Organization for Standardization
M&E	monitoring and evaluation
NAP	National Action Plan for Salinity and Water Quality
NFF	National Farmers' Federation
NLWRA	The National Land & Water Resources Audit ('the Audit')
NOHSC	National Occupational Health & Safety Commission
NRM	natural resource management
R&D	research and development
WUE	water use efficiency

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Summary

> **Signposts for Australian Agriculture (Signposts)**
>
> Industries are increasingly being required to account for their economic, social and environmental contribution.
>
> Such accountability is driven by community expectations for socially and environmentally responsible business, market preferences for products and services produced in a sustainable and healthy way, and international and domestic regulations requiring compliance with social and environmental best practice.
>
> Signposts is an initiative of the Australian Government that will provide industry and government with information to respond to community and market expectations and demands arising in Australia and internationally. Signposts currently relies on data derived primarily from the National Land & Water Resources Audit and hence depends on the continuation of this program.
>
> The Signposts framework has been designed to answer the question: 'How do Australian agricultural industries contribute to ecologically sustainable development (ESD)?'
>
> Through this question, Signposts provides a platform for compiling data and communicating information that can be used to:
>
> - build an industry's credentials in markets and the community for highly valued economic, environmental and social performance
> - address community perceptions of the industry's management and activities
> - identify priority issues and areas for planning and action.

This report is about the contribution of the grains industry to ecologically sustainable development (ESD). It is largely based on data compiled through the web-based Signposts industry profile of Australian grains.[1]

In some cases, the Signposts data are supplemented by other government and industry sources, where these provide a more complete and up-to-date description of the report's topics. The availability and quality of data vary, and the ability to monitor trends in ESD objectives will depend on continuity and improvements in data collection and reporting for key indicators.

This report has been prepared with the cooperation of the Grains Research and Development Corporation (GRDC) and the Grains Council of Australia. It relates to grains production to the farm gate.

The report is aimed at both government and industry. From a public policy perspective, government is interested in and monitors the economic, social and environmental performance of the industry. It values the contribution of the grains industry to national and regional economies, and to the nutrition and health of Australians; it also values the active participation of producers in natural resource management and environmental conservation.

This report aims to reach some conclusions about how the industry is performing, based on Signposts' ESD indicators. Conclusions in this summary are supported in the report; the data and reports on which these conclusions are based are cited in the body of the report.

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[1] See http://signposts4ag.com:80/signposts-grains

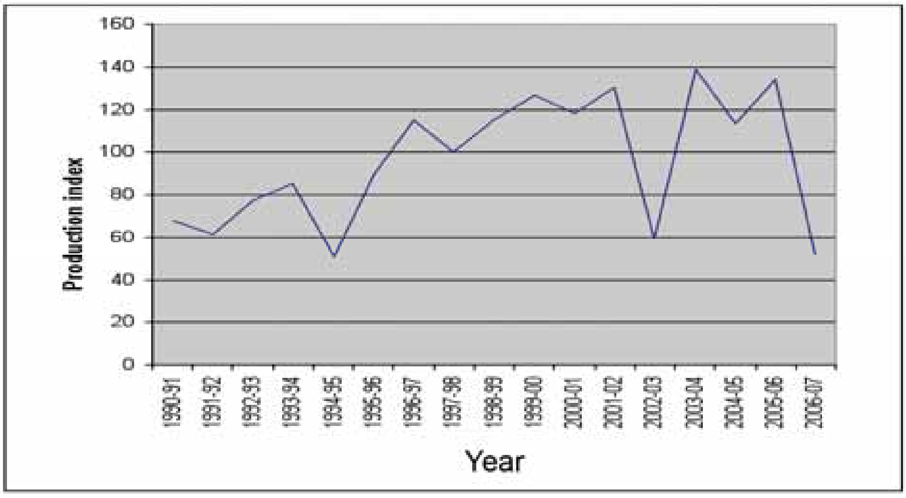
Key learnings from the Australian grains industry

Grain cropping occupies an area of about 21 million hectares in the inland, eastern, southeastern and southwestern parts of Australia. Grains are often grown in conjunction with livestock, principally sheep in the southern and western regions, and cattle in the northern region. The principal winter crops are wheat, barley, oats, canola and lupins (mostly in Western Australia and southern New South Wales). Other significant crops include field peas, chickpeas, triticale and faba beans. The main summer crop is grain sorghum. Up to 25 different grain crops (not including rice) are grown in Australia in any one year.

At different levels, the grains industry contributes to all three aspects — economic, environmental and social — of the Signposts framework.

Economic contribution

Figure i Farm production index for grains and oilseeds, 1990–91 to 2006–07



Source: ABARE (2007a)

Gross value of grains production

The productive capacity of the grains industry — in terms of both volume and value — is greater today than at any other time in its history. This is a remarkable achievement in the face of the declining number of farmers, the more frequent and worsening impact of drought, and natural resource issues such as salinity and acidity. However, when considered in real terms (that is, adjusted for inflation), the productive capacity of the industry has often struggled to maintain stable levels, let alone show real growth, in the face of declining terms of trade.

There is some indication that increased international demand for grain (due partly to use of grains for biofuels and difficult seasons in some overseas and local production areas) is causing real prices to rise. This may be a significant factor in growing real productive output in future.

The industry's achievement is largely due to a combination of increased production area, new crops, technological advances, management improvements and greater economies of scale. It is the result of the industry's investment in research and development, capital intensification, and education and training.

Private investments and developments have been made in technologies such as machinery, herbicides, fertiliser use and plant breeding. Together with industry investments, these initiatives have contributed to a more sophisticated, productive and efficient industry.

Grain exports

The Australian grains industry relies on exports for profitability and growth. It is an effective exporter from a relatively small production base in world terms.

> From 1999–2000 to 2006–07, Australia produced 3.5% of the world wheat supply, but achieved overseas sales of almost 14% of world exports in volume terms. For coarse grains, the corresponding figures are 1% of world production and almost 5% of world exports**.**

The industry has performed exceptionally well because it has developed competitive advantages through the quality of its products and through its marketing services. A key challenge in servicing existing customers while developing and growing new markets lies in minimising fluctuations in production due to climate variability and severe drought. The grains industry's Single Vision strategy seeks to generate future exports by diversifying into new markets, with higher margins flowing to producers, and to create new market opportunities ahead of competitors.

Net worth per farm

The net worth or wealth of the Australian grains industry — as measured by the value of farm capital and equity per farm — is increasing. Rising net worth reflects increasing industry capacity to generate future income and attract further investment in the industry.

Key factors in increasing wealth per farm are increasing farm size, economies of scale, greater profitability per farm and rising land values. These have greatly increased rates of return to individual farms, especially when capital appreciation is included.

Industry productivity

Increases in industry productivity of 2.7% per annum since the late 1970s have been critical to the profitability and sustainability of Australian grain production in the face of declining terms of trade.

The pursuit of productivity increases through new markets, new grain enterprises, technological advances, management improvements and farm aggregation is likely to bring changes in the structure of the industry.

This may result in fewer specialist grain producers and mixed livestock–grain farms, and more stockfeed producers and farms with special-use grain processing capacities.

Environmental contribution

In agriculture, the natural assets of primary interest are the atmosphere, climate, soil, water, sunlight and plants. These elements are interlinked. In combination with on-farm management, they determine the capacity of farms to produce food, fibre, biofuel and ecosystem services such as biodiversity conservation.

Natural capacity to produce food and biofuel

> **Proactive management of environmental concerns**
>
> Nitrogen: Individual farm soil testing ensures effective, timely and environmentally sustainable application.
>
> Phosphorus: Australia has generally low levels of soil phosphorus, and farmers manage this by soil testing and applying fertilisers that match plant demand.
>
> Salinity: Major on-farm rehabilitation and prevention activities to combat soil salinity are under way.
>
> Acidity: On-farm application of lime raises the soil pH, improves yields and alleviates long-term soil degradation and permanent loss of fertility.

Soil nitrogen

The critical factor in plant growth is the amount of nitrate available to the plant when required, which depends on factors including soil microbial activity. Sufficient soil nitrogen (available as nitrate), together with soil phosphorus, is necessary to achieve optimum yields and the protein content of grains required by markets. Soils in Australia's grain-growing areas are often low in available nitrate.

Overall, 56% of cropped land in the GRDC agroecological zones have a nitrogen concentration greater than 0.2%, which is considered to be moderate to high as a measure of the nitrogen status of soils. In Western Australia, less than 10% of cropped land in the Mallee zone and only 3% in the Sandplain zone have a soil nitrogen concentration above 0.2%.

Low levels of naturally available soil nitrogen are not always a major limiting factor in grain productivity on farms since farmers can use several measures to provide nitrogen. These include the application of nitrogenous fertilisers; and growing nitrogen-fixing plants, including pulse crops or annual or perennial leguminous pastures, in rotation with crops. The use of minimum tillage and stubble retention can also assist.

Use of nitrogenous fertiliser has increased 2.5-fold over the past 10 years and has been a factor in increased production. With rising fertiliser prices, nitrogen application adds to the cost of production, driving strategies to increase the efficiency of the use of this nutrient.

The increase in application of nitrogen in fertilisers, coupled with the use of leguminous crops and pastures, has also increased the environmental risk of soil acidification and nutrient runoff or leaching (especially in lighter textured soils), which may pollute streams and groundwater. However, the majority of grain farmers now undertake soil testing, nutrient budgeting and crop monitoring to ensure that the amounts and timing of nitrogen application match crop requirements, taking seasonal conditions into account.

Vehicle tracks through a wheat field (photo by Arthur Mostead 2005)

Soil phosphorus

Like soil nitrogen, soil phosphorus is also vital to crop yields and quality across much of the grain belt. Australian soils are generally low in naturally available phosphorus (as phosphate), and phosphate-based fertilisers are commonly used to maintain the productive capacity of the soil.

A key feature of Australian cropping soils is that only a small proportion (1–4%) of total soil phosphorus is accessible to plants; its availability is also related to soil pH.

Overall, the proportion of the GRDC agroecological zones with cropped land having a phosphorus concentration greater than 0.02% (which is considered to be medium to high as a measure of the phosphorus content of grain farming soils) is only 37%. Although some soils in the northern region can have relatively high levels of available soil phosphorus, most soils in the southern and western regions are low in available phosphorus.

Providing adequate soil phosphorus affects the cost of production, as well as the sustainability of grain production. Environmental concerns centre around excessive buildup of phosphate in water bodies due to surface runoff, although phosphate is less soluble than nitrate and is generally transported with soil if it erodes from the farm.

Farmers generally manage their phosphorus usage by soil testing and budgeting this nutrient to match the likely crop needs. Even in areas where natural soil phosphorus is deemed adequate, a common practice is for farmers to apply 'maintenance' levels of phosphate to ensure soil levels remain relatively static.

Rain and soil water management

In many dryland farming systems, water is scarce and could become scarcer in future if predictions of climate change eventuate. Making the best use of water stored in the soil, as well as that falling as rainfall, in order to maximise grain yields is important. Water use impacts on other factors of interest to Signposts, notably soil salinity, erosion, nutrient issues and other related factors.

The concept of water use efficiency (WUE) has been used in the grains industry as a measure of crop productivity, but it can also have connotations for water use.

The definition of dryland WUE is the actual yield per hectare as a proportion of the yield that could be obtained under environmental conditions adjusted for rainfall — that is, if the stored water and rainfall were optimally used (Beeston et al 2005).

In some soils where watertables are reasonably high, and where annual cropping systems dominate without perennial species in rotations, accessions to the watertable can increase. This can cause waterlogging that is detrimental to crop growth and yields, and/or detrimental effects on the environment through deep drainage and a higher chance of development of salinity.

Crop failure and low yields occur from time to time in Australia due to a lack of rainfall or soil moisture.

Waterlogging also occurs sporadically due to extreme rainfall events, or regularly in higher rainfall areas. Soils growing crops with high runoff have lower yields than soils with low runoff.

Waterlogging and induced salinity from groundwater accessions (deep drainage) are also a function of insufficient moisture storage and use, in and above the root zone of the crops. Waterlogging in Western Australia has been shown to affect yields by as much as 40% in about half of all seasons. Waterlogging often occurs in duplex soils that are often sodic as well and have low subsoil permeability. Perched watertables can be deleterious to soil biota and soil structure and create additional loss of water, which can have environmental impacts.

Less than desirable water availability and use can lead to lower yields. In some situations, a high level of water availability and use may mean the difference between obtaining a harvestable yield or not.

Environmental impacts of annual cropping systems can include increased runoff into waterways, so increasing sediment; nutrient and chemical export to waterways; rising watertables, which increase the salinity experienced by some native vegetation and waterways (so affecting aquatic biodiversity); and reduced runoff, which reduces the amount of water in waterways that may be available for extractive uses, environmental flows and maintaining riparian and aquatic biodiversity.

Current WUEs for grain producers in agroecological zones are shown in Table i. All efficiencies are significantly below 1, and the northern zones have significantly lower WUEs than southern and western systems.

Table i Current water use efficiencies for grain producers in agroecological zones

Agroecological zone	Area of grain crop, 2001 (million ha)	Average water use efficiency
NSW Central	1.460	0.73
NSW Northeast–Qld Southeast	2.388	0.45
NSW Northwest–Qld Southwest	1.240	0.40
NSW/Vic Slopes	1.867	0.59
Qld Central	0.590	0.39
SA Midnorth–Lower,Yorke, Eyre	1.841	0.60
SA/Vic Bordertown–Wimmera	1.602	0.60
SA/Vic Mallee	2.613	0.58
Vic High Rainfall	0.196	0.58
WA Central	3.611	0.54
WA Eastern	1.172	0.53
WA Mallee and Sandplain	0.792	0.55
WA Northern	1.730	0.50
Total	**21.102**	–
Simple average	–	0.53

NSW = New South Wales; Qld = Queensland; SA = South Australia; Vic = Victoria; WA = Western Australia
Source: Beeston et al (2005)

Additional data on WUE are presented later in this report, noting the difficulty in presenting such measures at the level of agroecological zone, especially in the northern region where fallow is a very common practice for soil moisture accumulation.

The potential impacts of not improving dryland water use are that yields will continue to be suboptimal, and loss of water from runoff and deep drainage will continue to have environmental impacts.

There is a need to improve the infiltration, storage and availability of soil moisture to crop roots, and to improve grain yield per unit of water, in order to reduce the incidence of crop failure and any contraction of the area in which cropping is feasible.

Measures for increasing the WUE of crops include:

- improved cropping systems based on controlled traffic, zero tillage, stubble retention and cover cropping
- development of crop varieties that use limited water more efficiently (that is, have a higher physiological efficiency)
- improved drainage and cultural practices such as raised beds to avoid waterlogging.

These measures will help to keep cropping farmers viable under conditions of lower and more variable rainfall. Hence they will assist in maintaining the social fabric in rural areas. At the same time, they will reduce runoff and drainage of subsoil and deep soil, so reducing erosion and export of sediment, nutrients and chemicals to waterways where they can damage biodiversity and reduce water quality.

Monitoring WUE is a key aspect that may become a useful indicator for the Signposts framework.

Soil erosion

Soil erosion from water and wind has been of concern in Australia for many years. Erosion was initially exacerbated by farming practices that relied on soil cultivation. More recently, cropping systems and practices orientated towards protecting the land resource have increased crop yields and reduced soil erosion. However, cropping soils are still subject to both water and wind erosion. Water erosion is more relevant in the northern cropping regions, and wind erosion in the southern and western regions.

Signposts would find value in measuring soil erosion and developing indicators for this issue.

Increasing stubble cover and reducing tillage are the main opportunities for controlling soil erosion. In the higher rainfall areas of the northern region, erosion rates can be as high as 30–60 tonnes per hectare where stubble cover is removed by cultivation. In comparison, soil loss is less than 5 tonnes per hectare where zero tillage is used.

Wind erosion is more relevant in the southern and western regions because wind speeds can be higher and soils lighter than in the north. Wind erosion is also effectively reduced by standing stubble and minimising tillage. Erosion risk can increase by a factor of up to eight as cover reduces from 50% to 20%.

Cropping practices can contribute mainly to water-driven sheet and rill erosion. For this type of erosion, only about 8% of the soil moved in Australia actually reaches waterways. Stream bank and gully erosion, which is not particularly influenced by cropping systems per se, contributes to the soil reaching waterways. Much of the sediment supplied to waterways is actually exported from those waterways, the remainder being deposited in the waterway, in water storages or on floodplains (NLWRA 2001). This sediment has a major environmental impact.

Other impacts from the movement of water off cropping farms include the movement of phosphorus (attached to sediment) and nitrogen. In addition, chemical residues from pesticides may be exported to waterways.

Wind erosion can be particularly severe during periods of low rainfall and where groundcover is less than 50% in the summer/autumn period until the onset of winter rains. Stubble retention and minimal tillage systems reduce the risk of wind erosion considerably.

Grain crops in the northern region constitute the major source of water-driven erosion of cropping lands in Australia. Grain crops in southern Australia are less vulnerable to water erosion because rainfall is generally low during periods of the least vegetative cover.

Vulnerable soils on grain-producing farms can exacerbate the impact of dust storms, particularly in the drier grain areas.

Soil erosion of grain-producing land has decreased with the increasing adoption of a range of practices to better maintain cover. There will continue to be some soil loss from cropping lands in future, but this may not significantly influence the sustainability of crop production. However, soil loss will contribute to impacts on water quality and sediment deposition off-farm. The environmental impacts will be influenced by climate change. The most serious changes associated with erosion will result from the more severe rainfall events that are predicted, whereas predicted decreases in wind speed may reduce wind erosion events. Managing soil cover for more extreme rainfall events is likely to reduce soil loss.

Potential benefits from improved management of soil structure, compaction and erosion will have a major impact on both the economics and sustainability of farming. Higher productivity of grain production systems can lead to more stable rural communities and can protect the soil resource for future use.

Reducing soil erosion on cropping land can improve off-farm water quality. This is particularly so in northern areas where soil erosion is a major cause of higher turbidity and nutrient levels in runoff waters. Some reduction in dust for rural communities may also be realised through maintaining groundcover. Measures undertaken to reduce erosion, such as rotations, maintaining fertility, reducing tillage and maintaining groundcover, can all increase organic matter, or at least reduce the rate of decline of organic matter. This will have a positive effect on greenhouse gases by storing more carbon on farms.

Soil salinity

Dryland salinity occurs when soils are degraded by rising saline groundwater in the root zone of plants or discharging to the surface. High soil salinity severely affects grain yields and can lead to a complete loss of productive capacity.

Soil salt is widely distributed across Australian landscapes, with high concentrations naturally occurring in many of the semiarid regions where grain is grown. Australia's natural salinity has been exacerbated by extensive land clearing, which has caused watertables to rise and has mobilised the salt content of topsoils.

However, for all GRDC zones, 94% of cropped land is not assessed as high salinity risk, according to data from the National Land & Water Resources Audit collected in 2000. The greatest risk of an impact of dryland salinity on grains production is in Western Australia.

Although most of the cropped area is not of a high salinity risk, dryland salinity has been identified as one of Australia's main natural resource and environmental issues. Australian farmers, governments and natural resource management organisations have funded major rehabilitation and prevention activities at the farm, catchment and regional scales to combat the problem.

Increasing the 'perenniality' of the landscape is one strategy for managing dryland salinity. This involves encouraging farmers to include more perennial plants in their farmland. One strategy of note is the inclusion of lucerne in the rotation, in a phased fashion. Lucerne is a perennial pasture species, which provides valuable grazing in many mixed farming areas. The deep-rooted nature of this plant can greatly assist with drying down the soil profile, lowering the watertable and taking saline water to deeper levels, more akin to the natural state. A phase of lucerne in rotation with annual crops can be an effective strategy to manage dryland salinity risk in some regions. As a legume, lucerne also contributes soil nitrate for use in subsequent cropping phases, and provides opportunities for weed control that are unavailable in many crop situations.

View of an oat field (photo by Richard Humphrys 2008)

Soil acidity

Soil acidification can be a naturally occurring process that may be accelerated by farming systems. It is an issue for the grains industry because soil acidity affects the availability of nutrients to plants and leads to increased availability of some elements (eg aluminium) in the soil to levels where they may impede normal plant growth.

Acidity is measured in topsoil by soil testing for pH, usually with a testing method that uses calcium chloride. Soils with a pH less than 7 are acidic, with levels below 5.5 considered sufficiently acidic to impede some plants' growth. A pH of 7 is neutral, and each unit below this is 10 times more acidic. Soils with pH values above 7 become progressively more alkaline. Topsoil pH above 5.5 is considered a desirable level for most crops.

Soil acidity is often a function of the farming system. The use of annual legume pastures and nitrogenous fertilisers can lead to leaching of nitrate from topsoil to levels deeper in the profile, leaving higher concentrations of hydrogen ions — and hence acidity — in the topsoil.

Soil acidity is an issue in almost half of the grain cropping area. It is of greatest significance in the western region and the southeast of the southern region, where the proportion of land with 'suitable' pH is below 30%.

Soil acidification is largely an on-farm issue that impacts on the economic contribution of the grains industry. It can be managed by the application of lime (finely ground calcium carbonate), which raises the soil pH and improves yields but adds to production costs. However, severe soil acidity (a pH of less than 4.5) that is not treated can lead to long-term soil degradation such as erosion and permanent loss of fertility. It can also contribute to increased nitrate pollution of groundwater and reduced water quality.

Farmers are learning to use lime and test for nitrate levels and so manage soil acidity as part of the production cycle. Increased yields and savings in fertiliser costs can be benefits of immediate value.

Natural capacity to provide ecosystem services

There are many aspects to the capacity of an industry to provide ecosystem services, an emerging area requiring further research and knowledge development. The most compelling current issues in the minds of both consumers and the general community are the contribution of industries to the conservation of biodiversity and greenhouse gas emissions (or, conversely, carbon sequestration).

Biodiversity conservation

This relates to the capacity of land held by the industry to conserve or regenerate native biodiversity. It is an issue of national and state consideration and is reflected in national and industry strategies, and through laws that control land clearing.

Native vegetation coverage and quality is an indicator of biodiversity conservation. The summary measure is the proportion of land that is generally intact and having regenerative capacity. The data show that 25% of the area 'outside protected areas' and within GRDC agroecological zones is native vegetation in good condition. GRDC zones in New South Wales and Queensland have large areas with native vegetation, although much of this is in modified rather than residual condition.

> Farmers have responded to the challenge of biodiversity conservation by taking areas out of production and revegetating them, fencing remnant and revegetated areas to exclude stock and feral animals, and planting windbreaks to protect crops and provide shelter for native fauna.

Carbon sequestration

Australia's cropping soils are generally low in organic carbon, which is frequently at levels less than 1% in the top 10 cm. A background paper for the Grains Council of Australia considered that farmers involved in producing grain are generally net emitters of greenhouse gases through the use of fossil fuels, soil cultivation and nitrogenous fertiliser. However, it is also noted that tillage has decreased dramatically in the past 20 years with the adoption of no-till practices and the retention of crop stubbles. This has led to a reduction in fuel use of 50% on farms since 1990; as a result, there has been a reduction in emissions of around 0.5 million tonnes of carbon dioxide per year, compared with 1990 levels, for the whole industry.

The National Farmers' Federation, in its submission to the Garnaut report on climate change policy, notes that agriculture is responsible for around 17% of Australia's total carbon emissions, but this does not take into account the carbon being sequestered in farm soils, crops and trees. The submission states that primary industry greenhouse gas emissions have been cut by 40% over the past 15 years.

Agriculture is responsible for around 17% of Australia's total carbon emissions, but this does not take into account the potential for carbon to be sequestered in farm soils, crops and trees. Further research is in progress.

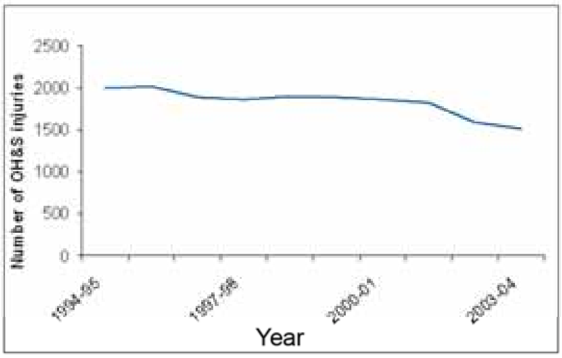
Social contribution

The grains industry can make a social contribution in two ways:

- through changes in the value of its own human and social assets
- by changing the value of human and social assets held by others.

Physical health

Figure ii Agricultural occupational injuries over the past decade



OH&S = occupational health and safety
Source: ABARE (2007a)

The most direct impact of the industry on the physical health of individuals is through injuries on farms.

The desired outcome is that the negative impacts of the industry on the health of individuals involved in it are reduced. Analysis shows that occupational injuries are at their lowest level to date. Over the previous decade there has been a trend of declining occupational injuries in the industry.

Anecdotal evidence suggests that, especially in times of drought, coupled with low commodity prices, levels of depression among farmers and their families have risen.

Employment

Ideally, the industry would like to maintain or increase employment opportunities in local and regional communities.

The most obvious indicator of the industry's employment contribution is the number of people employed in grain-related farming as a proportion of the total people employed in agriculture. It is Australia's largest agricultural industry in this respect. Data from the 2001 Agricultural Census show that this is the case in almost all of the GRDC agroecological zones. This indicates that, in grain-growing areas, the majority of people employed in agricultural activities are employed in the grains industry. For Western Australia, all people employed in agriculture in those zones are employed in the grains industry.

However, given the increasing size of farms, and machinery, the increase in 'efficiency' (that is, the amount of land able to be farmed by a 'labour unit') can lead to fewer people needing to be employed to farm the same area, and this is a downward force in employment in the grains industry.

Introduction

Signpost reports

This Signposts report on the grains industry is one of six initial reports on the contribution of Australia's major agricultural industries to ecologically sustainable development (ESD).

What is ESD?

The Australian *National Strategy for Ecologically Sustainable Development* (Council of Australian Governments 1992) defines ESD as:

> 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.

In the Signposts framework, ESD is interpreted as an overall increase in the value of the nation's capital assets (ie in its produced capital, human capital, social capital and natural capital) that is available to increase the wellbeing of the Australian population. Similarly, at an industry level, ESD is interpreted as an increase in the value of the industry's capital that is available to produce income and environmental and social benefits both to the industry's stakeholders and to broader society.

Partnership with industry

This report has been prepared in collaboration with the Grains Research and Development Corporation (GRDC) and the Grains Council of Australia (GCA). The GRDC is an Australian government statutory corporation. It operates as a research investment body on behalf of, and in partnership with, growers, who pay a levy on grain production that is matched by the government. The GRDC is recognised internationally as one of the world's leading grains research organisations, responsible for planning, investing in and overseeing research and development; and delivering improvements in production, sustainability and profitability across the Australian grains industry.

This report is based on data compiled through the web-based Signposts industry profile of Australian grains.[2] It provides the best available data from the Signposts industry profile, supplemented by other government and industry sources where these provide a more complete and up-to-date description of the issue being examined.

The report recognises that, at this stage in the development of Signposts, many of the components and subcomponents have not been populated with the required data. Data imperfections are a fact of life in most industry reporting, but Signposts provides a platform that allows information to be updated, refined and extended over time to reflect industry and government priorities.

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[2] See http://signposts4ag.com:80/signposts-grains

The economic contribution

The economic contribution of the grains industry to Australia can be measured from many perspectives. Signposts centres around four key perspectives:

- the contribution of the industry to national income through grains production, which is supplied to domestic and international markets
- the contribution of the industry to exports, since the growth in the industry's income and Australia's national income relies heavily on exports
- the value of the industry's assets that currently yield income or have the potential to yield future income
- the industry's total factor productivity, which indicates its actual performance and potential to contribute to growth in production, income and profits.

This report is about grain production and the on-farm sector of the industry. However, this sector is only one part of a wider 'grains' economy. The output of grain farms provides the raw materials for other sectors of the economy, including ingredients for food, beverages and pharmaceuticals; feed grains for other agricultural industries; and, increasingly, raw materials for biofuel production. The farm sector produces goods that are supplied through the value chain, creating income for other industries through to the sale of intermediate or finished goods to processors and consumers.

In addition to being part of a value chain, grains production has led to the creation of an extensive service sector that provides inputs, advice, transport, storage, selling, marketing, brokering, financial, information, research, consulting, education and training services.

The on-farm sector also contributes to the wider economy through the effects of incomes earned from grain growing being spent in other sectors of the economy. This is a very important contribution to many rural communities that lie within grain-growing areas.

Gross value of grains production

This Signposts report relates to the grains industry that comprises the 25 leviable crops within the GRDC's research portfolio. The crops span temperate and tropical cereals, oilseeds and pulses. They are:

- wheat
- coarse grains: barley, oats, sorghum, maize, triticale, millets/panicums, cereal rye and canary seed
- pulses: lupins, field peas, chickpeas, faba beans, vetch, peanuts, mung beans, navy beans, pigeon peas, cowpeas and lentils
- oilseeds: canola, sunflower, soybean, safflower and linseed.

Wheat, oats, barley, canola and lupins are the principal winter-grown grains. Sorghum is the principal summer-grown grain.

Around 32 000 growers run farm businesses that produce these leviable crops, cropping around 20 million hectares of land in the grain belt of Australia (ABS 2008). It is difficult to generalise about the number of grain producers and the areas cropped, since these can change from year to year in response to the relative prices of grain and livestock and seasonal conditions.

There are three general types of enterprises:

- specialist grain producers (around 39% of grain producers)
- mixed livestock and grain enterprises (38%)
- other farms where grains are produced on an opportunistic basis or as part of a cropping system where another crop is the main enterprise (around 23%).

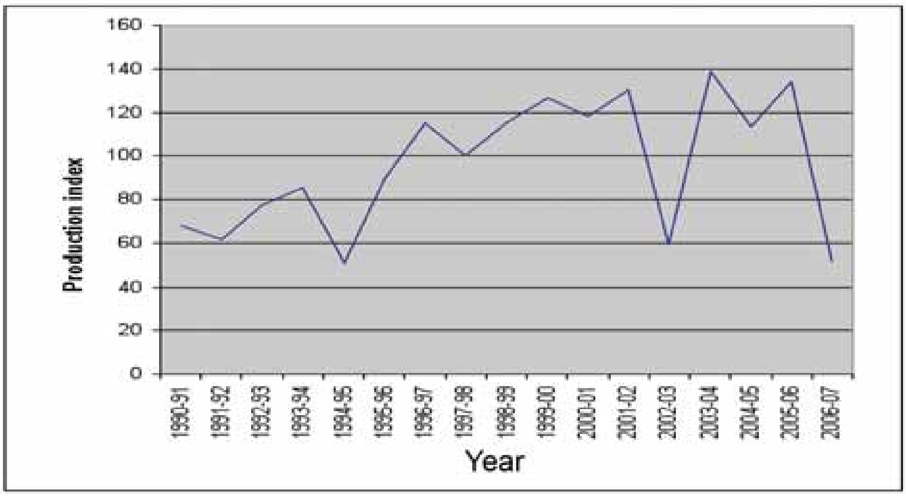
The sheer number of grain-growing businesses and their wide distribution in eastern, southern and Western Australia means that the grains industry is a significant contributor to regional economies and towns.

At the national level, the desired outcome for an industry is that its net contribution to the economy is positive and increasing over time. In the absence of net value of production statistics (ie aggregate farm business gross revenue generated from the production of agricultural goods minus production costs), farm production indexes and the gross value of production for the grains and oilseeds industry (from the Australian Bureau of Agricultural and Resource Economics — ABARE) are indicators of the industry's productive capacity.

Grain growing is Australia's largest agricultural industry. Grain production is largely an enterprise of dryland farming. Production is, therefore, highly variable over time due to Australia's climate.

ABARE's production index for grains and oilseeds shows the extent of the variation during the 1990s and the beginning of the current century. Figure 1, however, demonstrates that the volume of production has been significantly higher since the turn of the century than during the 1990s, particularly if the drought-affected crops in 1994–95, 2002–03 and 2006–07 are excluded.

Figure 1 Farm production index for grains and oilseeds, 1990–91 to 2006–07



Source: ABARE (2007a)

Table 1 shows that the area grown to all types of grain in this decade has been substantially above the average area for the 1970s, 1980s and 1990s.

Table 1 Area grown to crops, 1970s to 2006–07 (thousands of hectares)

Crop	Av 1970s	Av 1980s	Av 1990s	2000 –01	2001 –02	2002 –03	2003 –04	2004 –05	2005 –06	2006 –07
Wheat	8 734	10 924	9 608	12 141	11 529	11 170	13 067	13 399	12 543	11 798
Coarse grains	4 047	4 750	4 816	5 326	5 806	5 900	6 815	6 715	6 573	5 619
Pulses[a]	–	–	–	2 287	2 086	2 034	1 700	1 764	1 588	1 461
Grain sorghum	–	–	–	758	823	667	734	755	766	613
Oilseeds[b]	397	533	–	1 459	1 332	1 298	1 211	1 377	971 (canola)	1 052
Total[c]	**–**	**–**	**–**	**20 658**	**19 971**	**19 241**	**21 446**	**22 300**	**20 652**	**19 524**

– = not available; Av = average
a Lupins, field peas, faba beans, mung beans, navy beans, vetch and lentils
b Canola, cottonseed, linseed, peanuts, safflower seed, soybeans and sunflower seed
c Includes all crops, including those not listed above
Source: ABARE (2007a)

From 2000–01 to 2006–07, the grains industry produced a yearly average of 35.5 million tonnes from 21.8 million hectares planted (Table 2). In 2005–06, production was 41 million tonnes from 20.34 million hectares.

Table 2 Summary of Australian statistics for grain production, 2006–07 and 7-year average

Crop	Area: 2006–07 ('000 ha)	Area: 7-year average ('000 ha)	Volume: 2006–07 (kt)	Volume: 7-year average (kt)
Wheat	11 138	12 141	9 819	19 966
Coarse grains	5 619	6 113	5 854	11 245
Pulses[a]	1 461	1 846	770	1 945
Oilseeds[b]	1 181	1 674	1 026	2 312
Total	**19 399**	**21 774**	**17 469**	**35 468**

ha = hectare; kt = kilotonne
a Lupins, field peas, faba beans, mung beans, navy beans, vetch and lentils
b Canola, cottonseed, linseed, peanuts, safflower seed, soybeans and sunflower seed
Source: ABARE (2007a)

The 7-year average for the gross value of production for grains and oilseeds was $8.1 billion (Table 3).

Table 3 Gross value of production for grains and oilseeds, 2000–01 to 2006–07

Year	GVP ($ million)
2000–01	8 701
2001–02	10 875
2002–03	5 440
2003–04	9 837
2004–05	7 364
2005–06	8 917
2006–07	5 307
7-year average	**8 063**

GVP = gross value of production
Source: ABARE (2007a)

Grains exports

Australia's domestic market consumes around 40% of grain production. The industry largely depends on income derived from sales outside Australia for its future growth and contribution to the nation's economy. The desired outcome for the industry is that export income is significantly increasing over time. Table 4 shows the value of exports of grains and oilseeds from 1999–2000 to 2006–07.

Table 4 Value of exports of grains and oilseeds, 1999–2000 to 2006–07 ($ million)

Crop	1999–2000	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06	2006–07
Wheat (incl flour)	3481	4197	4612	3109	3475	3488	3296	2765
Barley (incl malt)	822	1101	1278	955	1239	1275	1108	833
Oats	27	22	37	44	38	36	47	20
Sorghum	4	59	109	17	61	96	33	13
Lupins	235	166	109	57	148	89	99	36
Peas[a]	90	112	157	43	56	33	43	80
Chickpeas	101	113	167	52	71	65	106	168
Canola	639	544	572	289	453	397	331	108
Other oilseeds[b]	29	28	20	21	26	33	21	22
Total	**5428**	**6342**	**7061**	**4587**	**5567**	**5512**	**5084**	**4045**

a Field peas and cowpeas
b Soybeans, linseed, sunflower seed, safflower seed and peanuts
Source: ABARE (2007a)

In world terms, Australia is a highly effective exporter from a small production base. For example, during the eight years from 1999–00 to 2006–07, Australia produced around 3.5% of the world's wheat, but achieved overseas sales of 13.7% (by volume) of world exports. For coarse grains, Australia produced 1% of world production, but achieved sales of 4.6% of world exports.

Australia has been an effective exporter due to its ability to win markets through the quality of its products and its marketing and supply chain capacities, including the institutions that have driven these aspects of sales and delivery.

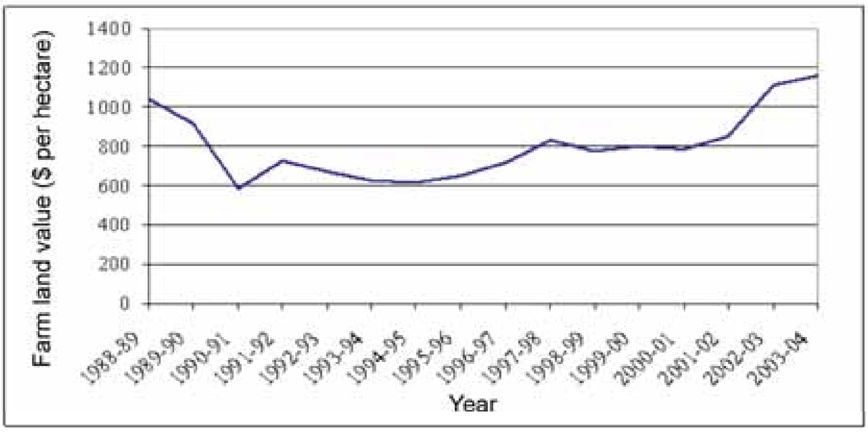
Towards a Single Vision for the Australian Grains Industry 2005–2025 (GRDC and GCA 2004) has an objective to ‘grow the value of the industry by diversifying into new markets with higher margins for producers’. A core element in the Single Vision strategy is ‘developing an industry that is a world leader in adopting technology and capturing emerging markets ahead of competitors’.

Net worth per farm

Ideally, industry wealth is measured as net worth (ie the total value of the industry’s assets minus the value of its liabilities). The desired economic position of an industry is that its net worth is positive and increasing over time. Rising net worth reflects increasing capacity of the industry to generate income in the future, and the attraction of further investment in the industry.

Signposts uses land value (dollars per hectare) as an indicator of net worth, since land is often the major single asset of grain growers. Other indicators are the value of farm capital and farm equity (the value of ‘owned’ capital, less farm business debt) per farm as measured in ABARE farm surveys. Figure 2 shows that land values have increased significantly since 2001–02. The impact of rising land values for farms growing wheat and other crops can be seen in ABARE farm survey results for 2000–01 to 2006–07 (Table 5).

Figure 2 Farm land value for farms growing wheat and other crops (excludes mixed farms)



Source: ABARE (2007a)

Table 5 ABARE farm survey results for farms growing wheat and other crops[a] (average per farm)

	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06 (preliminary)	6-year average
Farm capital ($ million)	1.5	1.8	2.4	2.9	3.3	3.6	2.6
Net capital additions ($ million)	0.045	0.066	0.068	0.082	0.074	0.089	0.07
Equity ($ million)	1.2	1.6	2.1	2.4	2.6	3.0	2.2
Rate of return (%) (excl capital)	3.4	7.5	1.5	3.7	2.2	3.2	3.6
Rate of return (%) (incl capital appreciation)	7.1	11.3	6.8	12.9	8.0	5.5	8.6

a Wheat and other crops industry (ANZSIC class 0121): farms engaged mainly in growing cereal grains, coarse grains, oilseeds and/or pulses

Source: ABARE, Australian Farm Survey Results, 2000–01 to 2006–07 (http://www.abareconomics.com/interactive/farmsurveys_07)

Table 5 shows a significantly higher rate of return to farm capital for all years when capital appreciation — due largely to rising land value — is included. Over the period 2000–01 to 2005–06, the rate of return per farm excluding capital averaged 3.6% per year, whereas the rate of return including capital appreciation averaged 8.6% per year.

Over the period 2000–01 to 2005–06, the rate of return per farm excluding capital averaged 3.6% per year, whereas the rate of return including capital appreciation averaged 8.6% per year.

Net worth can also be measured by the equity position per farm (farm capital minus farm debt) of grain farms. As shown in Table 5, assets as measured by farm capital have more than doubled from $1.5 million per farm in 2000–01 to $3.6 million in 2005–06 (preliminary). Annual net additions to capital increased over the period, along with a substantial increase in equity from $1.2 million to $3.0 million (preliminary).

Industry productivity

Australia's grain farmers have continually been able to produce more grain with less inputs or resources. ABARE (2007b) reports that prices received for agricultural commodities have failed to keep pace with the prices paid for agricultural inputs over the past three decades — a declining 'terms of trade'. Increasing productivity has been necessary to offset declining terms of trade and to maintain viability.

The concept of total factor productivity is a measure of on-farm productivity that compares output with the combined use of all resources. Total factor productivity, which is expressed as an index, is frequently used as an indicator of industry performance since it measures the effects on output of factors such as technological advances, improvements in management and exploitation of economies of scale.

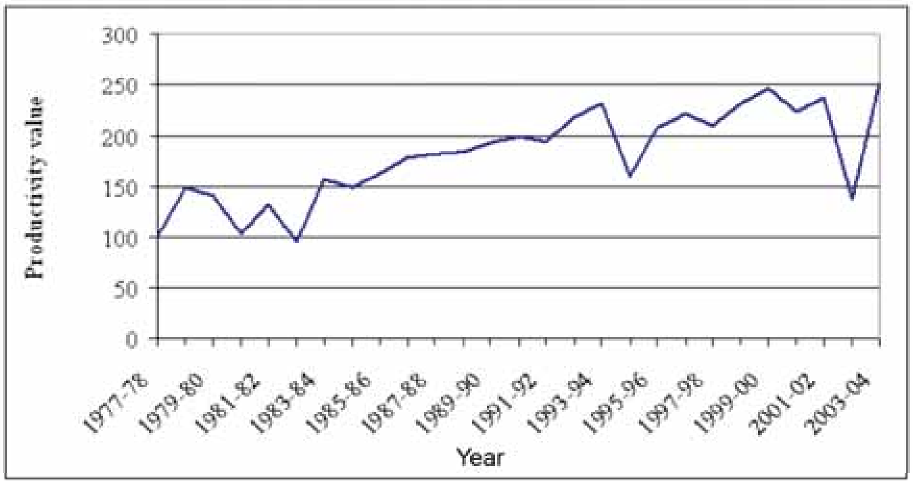
Total factor productivity for broadacre farms whose main source of income is grain increased on average by 2.7% annually between 1977–78 and 2005–06 (ABARE 2007a). Cropping farms performed better than mixed livestock–cropping operations as a group, as shown in Table 6.

Table 6 Average annual productivity growth in the cropping and mixed livestock–cropping industry, 1977–78 to 2005–06

Productivity	Crops (%)	Livestock–crops (%)
Total factor productivity:	2.7	1.9
Outputs	3.8	0.4
Inputs	1.1	–1.4
Factor productivity:		
Labour	3.9	2.9
Capital	4.1	3.0
Purchased inputs	0.7	0.4
Land	2.6	1.7
Prices:		
Terms of trade	–1.7	–1.9
Price received (outputs)	2.3	2.6
Price paid (inputs)	4.0	4.4

Source: ABARE and GRDC (2007)

Figure 3 Productivity of Australian wheat and other crop-growing farms



Source: ABARE (2007b)

Total factor productivity has been increasing on average in all grain producing regions over recent decades (Table 7), although Figure 3 clearly shows the impact of drought on output, such as in 1994–95 and 2002–03.

Table 7 Productivity growth in the cropping and mixed livestock–crops industries, by GRDC region, 1988–89 to 2003–04

TFP	GRDC grain region north	GRDC grain region south	GRDC grain region west	All regions
Average annual growth rate	0.8	2.2	1.8	1.9
Average annual growth rate (excluding moisture availability)	1.3	2.8	2.7	2.6

GRDC = Grains Research and Development Corporation; TFP = total factor productivity
Source: ABARE and GRDC (2007)

The pursuit of increased productivity and profitability will drive farm aggregation. The industry foresees that farm aggregation will continue, given the large number of small and medium-sized farms available for aggregation, although it does not expect grower numbers to fall below 30 000 by 2025 (GRDC and GCA 2004). The shift in the structure of the industry predicted by 2025 is for 27% of grain farms to be specialist producers (down from 39% in 2004), 21% to be mixed farmers (down from 38% in 2004) and 52% to be users or producers of grain for stockfeed and/or special-use grain processing (up from 23% in 2004).

The changes in industry structure are expected to be driven by the establishment of new grain industry enterprises in the northern regions of Australia and new grain markets supporting growth in other grain regions of Australia. As well, there may be opportunities for some first-stage processing to occur in Australia, and for some specialised grain industries to emerge in certain locations.

The suggested reasoning for changes in industry structure (GRDC and GCA 2004) also includes changes in the locations best suited for growing grain, possibly in response to changing or more variable climate; more grain will be grown in more reliable or traditionally higher rainfall areas in the future.

A 2025 snapshot:

- 27% of grain farms to be specialist producers (↓ 39%)
- 21% to be mixed farms (↓ 38%)
- 52% to be users or producers of grain for stockfeed or special-use grain processing (↑ 23%)

The environmental contribution

Signposts addresses the environmental contribution or impact of agricultural industries in terms of natural assets and systems.

In agriculture, the natural assets of primary interest are the atmosphere, climate, land, water and vegetation. Obviously, these elements are highly interlinked. In combination, they determine the capacity of farms to produce food, fibre, fuel and ecosystem services such as biodiversity conservation and carbon sequestration.

Grain production takes place on farms that are mostly a mix of enterprises. The most common mix is one that includes some form of livestock production, usually sheep or cattle. Hence, most grain farms also have areas of pastures, mostly grown in rotation with crops.

Pastures can bring benefits to the biophysical nature of the farm as well as for the cropping phase, in providing opportunities for soil cover, weed or disease management, addition of organic matter to soil, and some inputs of soil nitrogen where the pastures are legume dominant.

Mixed-enterprise farms can also mitigate some economic or production risks to farmers, by providing a more diverse source of production and income.

From a physical and biological viewpoint, many see the mix of pastures, animals and crops as acceptable.

The area of crop in relation to the total farm area is called cropping intensity. This is not necessarily a measure or indicator of soil or farm ‘health’, but it does allow the industry to track the relative levels of crops and other vegetation being managed on farms, and to see how farmers respond to changes in commodity prices, seasonal conditions and risk. Some data derived from Australian Bureau of Statistics (ABS) censuses are presented in Table 8.

Centre pivot near Yea, Victoria (photo by Land & Water Australia 2006)

Table 8 Crop intensity by agroecological zone

Agroecological zone	Average farm size (ha)		Average area of crop/farm (ha)		% crop	
	2000–01	2005–06	2000–01	2005–06	2000–01	2005–06
NSW Central	2712	2447	564	586	20.8	24.0
NSW Northeast–Qld Southeast	1137	1042	459	502	40.4	48.2
NSW Northwest–Qld Southwest	9082	7821	892	911	9.8	11.6
NSW/Vic Slopes	734	695	324	338	44.1	48.6
Qld Central	5478	5009	1003	718	18.3	14.3
SA Midnorth–Lower, Yorke, Eyre	6921	5987	484	520	7.0	8.7
SA/Vic Bordertown–Wimmera	652	649	326	351	50.0	54.1
SA/Vic Mallee	888	924	724	902	81.5	97.6
Tas Grain	690	628	73	81	10.6	13.0
Vic High Rainfall	305	274	140	163	45.9	59.5
WA Central	2639	1928	912	920	34.6	47.7
WA Eastern	4558	5073	1958	2219	42.9	43.7
WA Mallee and Sandplain	3341	2547	1043	1327	31.2	52.1
WA Northern	7527	6181	1800	1860	23.9	30.1

NSW = New South Wales; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia
Source: ASFPD (2008), derived from ABS data 2001, 2006

Atmosphere

Air quality, climate and greenhouse gas emissions are important considerations in agriculture. Fortunately, Australian agriculture is generally practised in areas of excellent air quality (or low air pollution), and this represents a competitive advantage in the 'clean and green' qualities of Australian food. Greenhouse gas emissions, principally carbon dioxide from human activity, have become a major global issue affecting climate, with impacts on temperature and rainfall, which are important to grain-producing areas.

Climate

Prevailing atmospheric conditions determine climate, along with location and topography. The elements of climate that are critically important in agriculture are temperature, rainfall, wind speed and relative humidity, and their combinations within seasonal conditions associated with the production cycle of crops.

Australian grain growing is located in areas with a suitable combination of temperatures, rainfall and soil factors for the particular crop. The most significant issue for the grains industry relating to temperature is the impact of frost at crucial times — for example, coinciding with the flowering stage of crops. Frost can be infrequent and unpredictable in grain-growing areas, and increased climate variability may bring mixed results. Although the generally increased temperatures expected with climate change are expected to reduce frost frequency and intensity, allowing grain farmers to plant earlier when circumstances permit, increased climate variability may mean that frosts occur with unusual timings and levels, making frost more devastating than at present.

Rainfall is by far the most significant climatic factor in Australian grain production. Most grain is produced under non irrigated conditions and relies on sufficient rainfall during the growth period, with generally reduced rain during the ripening stage of the plant's lifecycle. Australian grain crops are grown in areas of highly variable rainfall, and drought conditions significantly reduce grain production. Figure 1 shows the effect of severe droughts in 1994–95, 2002–03 and 2006–07 on grain production. A major concern is the possibility that climate change will increase the frequency and severity of droughts, and that this may result in some current grain-growing areas becoming unviable.

Land

Australia has extensive areas of cleared land with suitable topography for broadacre grain production. The key land issue for grain production is the characteristics of soils, including their fertility, water-holding capacity, texture, structure, depth and other factors relating to the type of crop that is grown in a specific location.

Soil suitable for crop production is the result of the combined effects of three major interacting components. These are the chemical, physical and biological characteristics of the soil. Australian soils in grain-growing areas are generally shallow and infertile in their chemical and biological components, though exceptions do occur. Grain farmers, therefore, often need to ameliorate their soils by applying fertiliser, particularly containing nitrogen and phosphorus. Other ameliorants, including lime, gypsum, or trace elements, are also often of benefit.

Rapidly rising fertiliser prices are causing cost pressures on farm budgets and profitability, although price rises are accepted by grain producers.

The major large-scale soil issues for the grains industry are degradation due to dryland salinity, acidification and sodicity; and soil erosion, which results in loss of productive soil from the system.

Water

Grain production is mainly undertaken in dryland conditions; only sorghum and maize often use irrigation. The main water issues for the industry are rainfall variability and drought. Consideration also needs to be given to the impact of rising watertables on dryland salinity, and loss of nitrogen and phosphorus in water through surface runoff or to groundwater.

The concept of water use efficiency (WUE) has become established as a measure of the effectiveness with which crops are able to access the available (rain) water available from soil. High-yielding crops generally are associated with high WUE, which may have secondary influences on water relations within the soil, affecting leaching or runoff.

Vegetation

The main vegetation issues, from a production viewpoint, facing the grains industry are the economic, environmental and social costs of weeds.

Secondary considerations include the ability to integrate crop production in the landscape, such that the mix of cropping, pastures, remnant and native vegetation can be balanced and improved over time.

Natural capacity to produce food and biofuels

The main aspects considered in the Signposts framework are soil fertility (nitrogen and phosphorus levels) and degradation (dryland salinity and acidity) issues.

Soil nitrogen

Sufficient soil nitrogen, in combination with phosphorus (the other major nutrient used in Australian cropping), is necessary to achieve optimum yields and the protein content of grains required by markets. The level of naturally occurring nitrogen depends upon the soil history and organic matter content. Areas with a long history of sparse natural vegetation and/or frequent burning generally have low inherent organic matter, and consequently lower nitrogen levels (Standing et al 2006).

Soil nitrogen can be measured in terms of total nitrogen and 'available' nitrogen, or nitrate, the latter being the component of total soil nitrogen that is available for uptake by plants. There are few data on the 'available' nitrogen in Australian cropping soils, and total nitrogen is used as the indicator of the nitrogen 'health' of soil for grain production.

In most soils, more than 95% of the nitrogen is present in an organic form. To become available for plant use, total nitrogen has to convert to nitrate forms as a result of microorganisms decomposing organic matter in soil (Black 1987). This process is influenced by temperature and soil moisture, which drive microorganism activity.

Signposts uses the proportion of land with total soil nitrogen above 0.2% as a measure of a 'suitable' nitrogen status of soils. This level is considered moderate to high in the National Land & Water Resources Audit (NLWRA) (NLWRA 2001a). Overall, the proportion of cropped land in Australia with nitrogen concentration greater than 0.2% is only 56%.

Table 9, which provides information on soil nitrogen by GRDC agroecological zone, shows a considerable variation among the zones. In the Tasmanian and Victorian High Rainfall zones, close to 100% of cropped land has total soil nitrogen greater than 0.2%. For Western Australia, three zones (WA Northern, WA Eastern and WA Mallee and Sandplain) have less than 10% of cropped land with greater than 0.2% total soil nitrogen. These data reflect the natural history of the soils in these zones.

Low soil nitrogen levels are not a major factor in the sustainability of grain farms, since a range of management actions can be taken to add or replenish nitrogen. These include the application of nitrogenous fertilisers, growing nitrogen-fixing plants such as annual or perennial legume pastures or pulse crops in crop rotations, applying livestock manures, and adopting conservation farming practices, such as minimum or no tillage combined with stubble retention.

Nitrogenous fertiliser use has increased 2.5-fold over the past 10 years, which has assisted with significantly increased production. However, this has also increased the environmental risk of soil acidification and nutrient runoff or leaching on lighter soils, which may pollute streams and groundwater.

Soil testing and matching the amount and timing of nitrogen application to the needs of the crop can increase economic effectiveness, while reducing the potential for runoff and leaching losses as well as the risk of losses as nitrous oxide (a very potent greenhouse gas). The 2001–02 Resource Management Survey (ABARE 2002) estimated that 71% of broadacre and dairy industry farms in the wheat/sheep zone conducted soil testing in that year.

Table 9 Area of cropped land with total soil nitrogen > 0.2%

Region	GRDC zones	Total area of cropped land (000's of hectares)	Area of cropped land with total N > 0.2% (000's of hectares)	Proportion of cropped land with total N > 0.2%
Northern	Qld Central	1623	995	0.61
	NSW Northwest–Qld Southwest	1577	808	0.51
	NSW Northeast–Qld Southeast	3810	3508	0.92
Southern	NSW Central	1656	773	0.47
	NSW/Vic Slopes	3139	2837	0.90
	SA/Vic Mallee	3272	1087	0.33
	SA Midnorth–Lower, Yorke, Eyre	2184	1377	0.63
	SA/Vic Bordertown–Wimmera	4116	3554	0.86
	Vic High Rainfall	1254	1246	0.99
	Tas Grain	306	305	1.00
Western	WA Northern	2211	135	0.06
	WA Eastern	1555	95	0.06
	WA Central	5898	2011	0.34
	WA Mallee and Sandplain	1188	38	0.03
All regions	All zones	33 789	18 769	0.56

GRDC = Grains Research and Development Corporation; N = nitrogen; NSW = New South Wales; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia
Source: NLWRA (2001a), Australian Soil Resources Information System

Table 10 shows nitrogen usage on farms based on ABS data from the 2000–01 census. In many cases, nitrogen balance on farms is negative, indicating that significant amounts of nitrogen were supplied to crops from soil mineralisation. This suggests that farmers are taking into account this natural source in their nitrogen fertiliser applications.

Table 10 Nitrogen fertiliser usage on-farm, 2000–01

Agroecological zone	N applied (tonnes)	Area where N applied (ha)	Average rate of N as fertiliser (kg/ha)	N use by crop (tonnes)	N balance (kg/ha)
NSW Central	62 891	1 409 751	44.6	79 191	–16.3
NSW Northeast–Qld Southeast	131 343	1 945 210	67.5	83 865	47.5
NSW Northwest–Qld Southwest	50 952	1 352 605	37.7	41 685	9.3
NSW/Vic Slopes	81 458	1 879 291	43.3	139 274	–57.8
Qld Central	12 415	544 756	22.8	29 436	–17.0
SA Midnorth–Lower, Yorke, Eyre	64 238	1 632 564	39.3	105 144	–40.9
SA/Vic Bordertown–Wimmera	47 873	1 302 257	36.8	79 338	–31.5
SA/Vic Mallee	39 226	2 434 475	16.1	115 457	–76.2
Tas Grain	3 497	17 673	197.9	1 306	2.2
Vic High Rainfall	22 324	218 099	102.4	16 261	6.1
WA Central	116 635	3 120 970	37.4	101 718	14.9
WA Eastern	28 357	1 007 492	28.1	27 542	0.8
WA Mallee and Sandplain	30 001	800 254	37.5	29 180	0.8
WA Northern	59 375	1 257 551	47.2	43 416	16.0

ha = hectare; kg = kilogram; N = nitrogen; NSW = New South Wales; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia
Source: ASFPD (2008)

Soil phosphorus

Phosphorus is another soil macronutrient that is important to crop yields and quality. It is common to add phosphorus to the soil via the application of phosphate-based fertiliser to maintain the productive capacity of the soil. Only a small proportion (1–4%) of total, naturally present soil phosphorus is accessible to plants, and this amount depends on soil pH.

The bulk of soil phosphorus exists in three general groups of compounds: organic phosphorus, calcium-bound inorganic phosphorus, and iron or aluminium-bound inorganic phosphorus. Most of the compounds in these groups have very low solubility and are not readily available for plant uptake.

Plant-available phosphorus in soil is usually present as inorganic phosphate ions ($H(PO_4)_2$ and $H_2(PO_4)_2$) and sometimes as soluble organic phosphorus. The $H(PO_4)_2$ anion dominates in strongly acidic soils, whereas the $H_2(PO_4)_2$ anion dominates in alkaline soils. Both anions are important in near-neutral soils.

Signposts uses the level of phosphorus in the topsoil as an indicator of the available phosphorus (phosphate), and the proportion of land with total soil phosphorus above 0.02% as the summary measure of the phosphorus 'health' of grain-farming soils. The NLWRA (2001) defines 0.02% as a medium to high level of total soil phosphorus. Overall, the proportion of cropped land in Australia with phosphorus levels greater than 0.02% is only 37%.

Table 11, which provides information on soil phosphorus by GRDC agroecological zone, shows a considerable variation among the zones. The Queensland Central, New South Wales Northwest – Queensland Southwest and New South Wales Northeast – Queensland Southeast zones have more than

90% of the cropped area showing total phosphorus above 0.02%, whereas no Western Australian regions have currently cropped land with phosphorus above this level.

Total soil phosphorus measures as used in these data are not very useful for farmers (and crop plants) from a practical viewpoint. Instead, soil tests can determine available phosphorus levels, and these can be used to determine the requirements for fertiliser use.

Table 11 Area of cropped land with total soil phosphorus > 0.02%

Region	GRDC zones	Total area of cropped land (000's of hectares)	Area of cropped land with total P > 0.02% (000's of hectares)	Proportion of cropped land with total P > 0.02%
Northern	Qld Central	1 623	1 565	0.96
	NSW Northwest–Qld Southwest	1 577	1 489	0.94
	NSW Northeast–Qld Southeast	3 810	3 644	0.96
Southern	NSW Central	1 656	655	0.40
	NSW/Vic Slopes	3 139	2 258	0.72
	SA/Vic Mallee	3 272	646	0.20
	SA Midnorth–Lower, Yorke, Eyre	2 184	384	0.18
	SA/Vic Bordertown–Wimmera	4 116	695	0.17
	Vic High Rainfall	1 254	947	0.76
Southern	Tas Grain	306	253	0.83
	WA Northern	2 211	<0.5	0.00
	WA Eastern	1 555	0	0
	WA Central	5 898	52	0.01
	WA Mallee and Sandplain	1 188	0	0
All regions	All GRDC zones	33 789	12 588	0.37

GRDC = Grains Research and Development Corporation; NSW = New South Wales; Qld = Queensland; P = phosphorus; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia
Source: NLWRA (2001a), Australian Soil Resources Information System

Like soil nitrogen, low total soil phosphorus is not a major factor in the sustainability of grain farms, since a range of management actions can be taken to add or replenish phosphorus. These include the major practice of applying phosphorus fertilisers, and recently the supportive actions of adopting conservation practices, such as minimum tillage and stubble retention.

Environmental concerns with phosphorus centre on eutrophication, an increase in the nutrient levels of natural waters that causes accelerated growth of algae or water plants. This may have detrimental effects on native aquatic flora and fauna.

Phosphorus, primarily in the form of phosphate, is not as soluble as nitrate and is primarily transported off site by soil sediment loss in runoff, which can ultimately end up in water bodies. Farmers can manage this risk by soil testing and applying fertilisers that match the expected crop needs, and by placing fertiliser in the seedbed in the root zone of the crop.

Table 12 shows some derived data from the ABS. It shows the phosphorus 'balance' for farms in the agroecological zones, based on the amounts of phosphorus applied and the amounts used by the crops in producing grain. Farmers attempt to apply adequate levels of phosphorus for potential yields, but levels of application are often generous because phosphorus is usually applied at planting, when likely crop yield is difficult to estimate, and phosphorus uptake by plants is inefficient if fertiliser is applied after crop emergence. However, in recent years, the combination of soil testing and knowledge of residual phosphorus from fertiliser use in the previous year has led many farmers to reduce phosphorus fertiliser use, without depleting soil phosphorus levels. The table suggests that amounts of phosphorus not used by the crops are generally low.

Table 12 Phosphorus fertiliser use, 2000–01

Agroecological zone	Area where P applied (ha)	Average use rate (kg/ha)	P balance (kg/ha)
NSW Central	1 751 455	13.5	7.7
NSW Northeast–Qld Southeast	3 435 718	3.7	-0.4
NSW Northwest–Qld Southwest	1 504 386	5.4	2.3
NSW/Vic Slopes	3 337 113	12.3	4.8
Qld Central	609 513	3.2	-2.5
SA Midnorth–Lower, Yorke, Eyre	2 048 268	15.5	8.3
SA/Vic Bordertown–Wimmera	3 142 770	7.3	0.9
SA/Vic Mallee	2 884 817	10.5	5.0
Tas Grain	136 044	11.4	5.6
Vic High Rainfall	1 130 903	8.7	1.1
WA Central	5 637 416	6.7	3.1
WA Eastern	1 195 304	8.7	5.8
WA Mallee and Sandplain	1 511 352	7.6	3.6
WA Northern	1 948 335	8.5	4.9

ha = hectare; kg = kilogram; NSW = New South Wales; Qld = Queensland; P = phosphorus; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia
Source: ASFPD (2008)

Rain and soil water management

In many dryland farming systems, water is scarce, and it could become scarcer in future if predictions of climate change eventuate. Making the best use of water stored in the soil, as well as that falling as rainfall in order to maximise grain yields, is important since it impacts on other factors of interest to Signposts, notably soil salinity, erosion, nutrient issues and other related factors.

The concept of water use efficiency (WUE) has been used in the grains industry as a measure of crop productivity, but can also have connotations for water use in these areas.

The definition of dryland WUE is the actual yield per hectare as a proportion of the yield that could be obtained under environmental conditions adjusted for rainfall — that is, if the stored water and rainfall were optimally used (Beeston et al 2005).

A second dimension of WUE is physiological efficiency. Plants that use water more efficiently fix more carbon from the air for a given amount of water.

In some soils where watertables are reasonably high, and where annual cropping systems dominate without perennial species in rotations, accessions to the watertable can increase. This can cause waterlogging that is detrimental to crop growth and yields, and/or detrimental effects on the environment through deep drainage and a higher chance of development of salinity. The issue therefore is to manage the water balance effectively. Management options may vary by region, soil type and season.

Broad comparisons of WUE between regions can be misleading, given that climate differences are often the key underlying factor. Also relevant in the use of a WUE measure for environmental purposes is the inability of simple measures of WUE to account for runoff and drainage terms in the water balance.

Crop failure and low yields occur from time to time in Australia due to a lack of rainfall or soil moisture. Crop failure in the future may increase due to the effects of climate change, which may include higher temperatures, lower average rainfall and increased droughts.

Conversely, waterlogging occurs sporadically due to extreme rainfall events or regularly in higher rainfall areas. Soils growing crops with high runoff have lower yields than soils with low runoff. Higher levels of cultivation in preparing land for crops can decrease the soil moisture-holding capacity and increase runoff through surface sealing. Use of controlled traffic and permanent wheel tracks, stubble retention and zero tillage can increase water holding. There is also potential for a soil with high organic matter to have a structure that enables the rapid passage of rain and exacerbates drainage.

Waterlogging and induced salinity from groundwater accessions (deep drainage) are also a function of insufficient moisture storage and use, in and above the root zone of the crops. Waterlogging in Western Australia has been shown to affect yields by as much as 40% in about half of all seasons. Waterlogging often occurs in duplex soils that are often sodic as well and have low subsoil permeability. Perched watertables can be deleterious to soil biota and soil structure and create additional loss of water, which can have environmental impacts.

Less than desirable water availability and use can lead to lower yields. In some situations, a high level of water availability and use may mean the difference between obtaining a harvestable yield or not.

Environmental impacts of annual cropping systems can include the following:

- Low levels of water use can result in, or be a result of, increased runoff into waterways, so increasing sediment, nutrient and chemical export to waterways.
- Rising watertables can raise salt levels, increasing the salinity experienced by some native vegetation and waterways, so affecting aquatic biodiversity.
- Conversely, reduced runoff can lower the amount of water in waterways that may be available for extractive uses, environmental flows and maintaining riparian and aquatic biodiversity.

The proportion of grain farms surveyed by ABARE that reported significant degradation from waterlogging, by grain region, is shown in Table 13.

Table 13 Surveyed grain farms that reported waterlogging

Grain region	Farms reporting surface waterlogging (%)
Western	27
Southern	4
Northern	8

Source: ABARE (2002)

The proportion of grain-producing dryland farms that were showing signs of salinity, as of 2002, is shown in Table 14.

Table 14 Farms and areas showing signs of dryland salinity

Industry sector	Farms showing signs of salinity (%)	Area of land showing signs of salinity (ha)
Grain farms	33.5	628 000
Mixed grain and beef/sheep	31.8	375 000

Source: ABS (2002)

The total land area in each region of the National Action Plan for Salinity and Water Quality (NAP) that is showing signs of salinity is shown in Table 15. These NAP regions that are involved in cropping make up a large proportion of the total area of land in Australia showing signs of salinity.

Table 15 Total land area showing signs of salinity

NAP region	Land area showing signs of salinity (ha)	Significant grains NRM region
Avoca–Loddon–Campaspe	8 000	
Avon	450 000	Yes
Border Rivers	–	
Burdekin–Fitzroy	35 000	Yes
Condamine–Balonne–Maranoa	28 000	Yes
Darwin–Katherine	2 000	
Glenelg–Hopkins–Corangamite	30 000	Yes
Goulburn–Broken	4 000	
Lachlan–Murrumbidgee	30 000	Yes
Lockyer–Burnett–Mary	1 000	
Lower Murray	75 000	Yes
Macquarie–Castlereagh	7 000	Yes
Midlands	3 000	
Mt Lofty–Kangaroo Island–Northern Agricultural District	51 000	Yes
Murray	3 000	Yes
Namoi–Gwydir	5 000	Yes
Northern Agricultural District	152 000	Yes
Ord	0	
South Coast	74 000	Yes
South East	51 000	Yes
South West	153 000	Yes
Total	1 171 000	

– = not available; NAP = National Action Plan for Salinity and Water Quality; NRM = natural resource management
Source: ABS (2002)

Water use efficiencies (WUEs) for grain producers in agroecological zones are shown in Table 16. All efficiencies are significantly below 1, and the northern zones have significantly lower WUEs than southern and western systems.

Table 16 Water use efficiencies in agroecological zones, 2001

Agroecological zone	Area of grain crop (million ha)	Average WUE
NSW Central	1.460	0.73
NSW Northeast–Qld Southeast	2.388	0.45
NSW Northwest–Qld Southwest	1.240	0.40
NSW/Vic Slopes	1.867	0.59
Qld Central	0.590	0.39
SA Midnorth–Lower, Yorke, Eyre	1.841	0.60
SA/Vic Bordertown–Wimmera	1.602	0.60
SA/Vic Mallee	2.613	0.58
Vic High Rainfall	0.196	0.58
WA Central	3.611	0.54
WA Eastern	1.172	0.53
WA Mallee and Sandplain	0.792	0.55
WA Northern	1.730	0.50
Total	**21.102**	
Simple average		0.53

NSW = New South Wales; Qld = Queensland; SA = South Australia; Vic = Victoria; WA = Western Australia; WUE = water use efficiency
Source: Beeston et al (2005)

Manipulated data from the ABS for 2000–01 and 2005–06 (Table 17) tend to show similar WUEs. Table 17, which shows these data for wheat, indicate that WUEs have remained similar between the two census years, around 54% of optimum. There are likely errors in the figures, since they are based on means of yields (from ABS) and rainfall (from Bureau of Meteorology stations in the agroecological zones), using the large areas involved in many agroecological zones. They cannot accurately cater for soil-stored water at planting. More accurate analyses of WUE can only be made at paddock level, taking into account stored soil water from fallow or summer weed control.

Ears of wheat (photo by Arthur Mostead 2004)

Table 17 Derived wheat water use efficiencies for agroecological zones for 2000–01 and 2005–06

Agroecological zone	Wheat WUE (kg grain per mm of plant-available water supplied from rain falling in-crop)		% of optimum (at 20 kg grain/mm)	
	2000–01	2005–06	2000–01	2005–06
NSW Central	10.1	11.0	50.5	54.8
NSW Northeast–Qld Southeast	8.2	8.6	40.8	42.8
NSW Northwest–Qld Southwest	8.2	12.6	41.2	63.2
NSW/Vic Slopes	10.4	9.7	52.0	48.3
Qld Central	9.6	9.2	47.8	45.8
SA Midnorth–Lower, Yorke, Eyre	12.4	14.6	62.1	73.2
SA/Vic Bordertown–Wimmera	11.1	11.8	55.7	59.0
SA/Vic Mallee	13.1	11.0	65.3	55.2
Tas Grain	12.0	10.1	59.8	50.7
Vic High Rainfall	9.7	12.4	48.6	61.9
WA Central	8.3	7.4	41.6	37.0
WA Eastern	16.6	12.8	83.1	63.9
WA Mallee and Sandplain	6.9	6.3	34.7	31.4
WA Northern	17.3	11.1	86.4	55.4

NSW = New South Wales; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia; WUE = water use efficiency
Source: ASFPD (2008)

The potential environmental impact of not improving dryland water use is that yields will continue to be suboptimal, and loss of water from runoff and deep drainage will continue to have environmental impacts.

However, these threats are likely to be magnified by climate change:

- Average rainfall is expected to be lower in most grain cropping regions.
- Rainfall intensity is likely to increase, and seasonal rainfall is likely to be more variable.

There is therefore a need to improve soil moisture infiltration, storage and availability to crop roots, and improve grain yield per unit of water, in order to reduce the incidence of crop failure and any contraction of the area of cropping feasibility. At the same time, without as much rainfall as possible being able to enter cropping soils and with reduced cover, the heavier rainfall events that do occur may be associated with increased runoff, with associated higher levels of soil erosion and increased nutrient and sediment exports.

Measures for increasing water use of crops include:

- improved cropping systems based on controlled traffic, zero tillage, stubble retention and cover cropping
- development of crop varieties that use limited water more efficiently (that is, have a higher physiological efficiency)
- improved drainage and cultural practices, such as raised beds to avoid waterlogging.

These measures will help to keep cropping farmers viable under conditions of lower and more variable rainfall. Hence, they will assist in maintaining the social fabric in rural areas. At the same time, they will reduce runoff and drainage of subsoil and deep soil, so reducing erosion and export of sediment, nutrients and chemicals to waterways where they can damage biodiversity and reduce water quality.

Waterlogging is a significant constraint to crop yields in most states except Queensland. There are drainage solutions in many cases. Another solution, which has expanded considerably in recent times, is the use of raised beds and shallow drains for management of surface water for growing crops (eg in western Victoria). Other solutions to waterlogging and groundwater accessions include alley tree farming, replacements of perennial grass species, water harvesting and water reuse.

One practice that has known positive impacts on WUE is the use of no-till and stubble retention systems. The use of this practice is shown in Table 18.

Table 18 Area of no-till, by agroecological zone

Agroecological zone	No-till (% crop area)		Change (% crop area)
	1996	2001	
NSW Central	6.2	14.8	+8.6
NSW Northeast–Qld Southeast	8.4	25.5	+17.1
NSW Northwest–Qld Southwest	7.4	20.0	+12.7
NSW/Vic Slopes	14.1	27.9	+13.9
Qld Central	4.7	32.7	+28.0
SA Midnorth–Lower, Yorke, Eyre	8.5	27.6	+19.9
SA/Vic Bordertown–Wimmera	14.4	23.6	+9.2
SA/Vic Mallee	5.3	13.6	+8.2
Vic High Rainfall	16.7	39.3	+22.6
WA Central	32.5	62.6	+30.1
WA Eastern	31.8	48.2	+16.4
WA Mallee and Sandplain	29.1	66.3	+37.2
WA Northern	36.3	40.4	+4.1

NSW = New South Wales; Qld = Queensland; SA = South Australia; Vic = Victoria; WA = Western Australia
Source: Beeston et al (2005)

Soil erosion

Soil erosion from water and wind has been of concern in Australia for many years. Erosion was initially exacerbated by farming practices that relied on soil cultivation. More recently, cropping systems and practices orientated towards protecting the land resource have increased crop yields and reduced soil erosion. Cropping soils are still subject to both water and wind erosion. Water erosion is more relevant in the northern cropping regions, and wind erosion in the southern and western grain-producing regions.

Increasing stubble cover and reducing tillage are the main opportunities for controlling soil erosion. In the higher rainfall areas of the northern region, erosion rates can be as high as 30–60 tonnes/ha where stubble cover is removed by cultivation. In comparison, soil loss is less than 5 tonnes/ha where zero tillage is used.

Wind erosion is more relevant in the southern and western regions because wind speeds can be higher and soils lighter than in the north. Wind erosion is also effectively reduced by standing stubble and less tillage. Erosion will increase around eight-fold as cover reduces from 50% to 20%.

Soil erosion has a severe and largely irreversible effect on productivity via loss of nutrients, reduced soil structure and soil depth, and eventually loss of land. Of most importance to grain profitability is the impact of productivity loss, as shown in Table 19.

Table 19 Soil erosion and productivity loss

Estimated productivity loss after 20 years of conventional farming practice (and percentage of farming land affected)				
Erosion type	**Northern region**	**Southern region**	**Western region**	**Comments**
Soil erosion — water	15% (60%)	4% (15%)	3% (20%)	Water erosion increases markedly with rainfall intensity moving north, and on sloping soils
Trend	significant with slope	slow decline	slow decline	
Soil erosion — wind	5% (5%)	6% (35%)	10% (50%)	Wind erosion is more significant in south and on light-textured soils
Trend	slow decline	slow decline	slow decline	

Source: These figures are estimates from a research project that focused on sustainable farming systems around Australia (Wylie 2007).

Cropping practices can contribute mainly to water-driven sheet and rill erosion. For this type of erosion, only about 8% of soil moved in Australia actually reaches waterways. Stream bank and gully erosion, which is not particularly influenced by cropping systems per se, contributes to the soil reaching waterways. Much of the sediment supplied to waterways is actually exported from those waterways, the remainder being deposited in the waterway, in water storages or on floodplains (NLWRA 2001). This sediment has a major environmental impact.

Other impacts from the movement of water off cropping farms include the movement of phosphorus (attached to sediment) and nitrogen. In addition, chemical residues from pesticides may be exported to waterways. The environmental impacts of nutrients and chemicals exported off farms are discussed in separate information sheets (Chudleigh 2007).

Wind erosion can be particularly severe during periods of low rainfall and where groundcover is below 50% in the summer/autumn period until the onset of winter rains. Stubble retention and minimal tillage systems reduce the risk of wind erosion considerably.

Grain crops in the northern region constitute the major source of water-driven erosion of cropping lands in Australia. Grain crops in southern Australia are less vulnerable to water erosion because rainfall is generally low during periods of the least vegetative cover.

Vulnerable soils on grain-producing farms can exacerbate the impact of dust storms, particularly in the drier grain areas.

A subjective assessment of the grain agroecological zones most at risk from water and wind erosion is given in Table 20.

Table 20 Soil erosion risk for agroecological zones

Agroecological zone	Water erosion risk	Wind erosion risk
Qld Central	High	Low
NSW Northeast–Qld Southeast	High	Low
NSW Northwest–Qld Southwest	High	Medium
NSW/Vic Slopes	Medium	Low
NSW Central	Medium	Medium
SA Midnorth–Lower, Yorke, Eyre	Low	High
SA/Vic Bordertown–Wimmera	Low	Low
SA/Vic Mallee	Low	Medium
Tas Grain	Low	Low
Vic High Rainfall	Medium	Low
WA Central	Low	Medium
WA Eastern	Low	Medium
WA Mallee and Sandplain	Low	Medium
WA Northern	Low	Medium

NSW = New South Wales; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia
Source: Subjective assessment based on NLWRA (2001) and McTainsh et al (2001).

Soil erosion of grain-producing land has decreased with the increasing adoption of a range of practices to better maintain cover.

There will continue to be some soil loss from cropping lands in the future, but this may not unduly influence the sustainability of crop production. However, soil loss will contribute to impacts on water quality and sediment deposition off-farm. The environmental impacts will be influenced by climate change. The most serious changes relating to erosion will result from the more severe rainfall events that are predicted, whereas predicted decreases in wind speed may reduce wind erosion events. Managing soil cover for more extreme rainfall events is likely to reduce soil loss.

Potential benefits from improved management of soil structure, compaction and erosion will have a major impact on both the economics and sustainability of farming. Higher productivity of grain production systems can lead to more stable rural communities and can protect the soil resource for future use.

Reducing soil erosion on cropping land can improve off-farm water quality. This is particularly so in northern areas where soil erosion is a major cause of higher turbidity and nutrient levels in runoff waters. Some reduction in dust for rural communities may also be realised through maintaining groundcover. The measures undertaken to reduce erosion such as rotations, maintaining fertility, less tillage and maintaining groundcover can all increase organic matter, or at least reduce the rate of organic matter decline. This will have a positive effect on greenhouse gases by storing more carbon on farms.

Maintaining stubble cover and reducing tillage operations have increased in most grain-producing systems. Table 21 demonstrates the extent of some improved industry practices associated with soil management.

Table 21 Industry practices associated with structure and soil management

Current practice	Improved practice	Adoption of improved practice		
		North region	South region	West region
Conventional tillage (cultivation)	Minimum tillage Zero tillage	50% 18%	30% 5%	50% 25%
Set rotations — one crop or less per year	Opportunity cropping — more than one crop per year	20% as regular practice 80% occasionally	–	–
No traffic patterns	Tramlines Controlled traffic farming	20% (in addition to controlled traffic farming) 10%	3% 2%	5% 1%
No drainage	Raised bed farming % of area where raised beds may be applicable	<1% 4%	1% 10%	<1% 20%
Continuous cropping	Pasture leys % of area applicable	2% 50%	60% 80%	25% 90%
Monoculture	Crop rotation	High in NE/SE/Central Qld Low in NW/SW	90% in high rainfall zone, 60% in dry areas	100% in high rainfall zone, 90% in dry areas
Cereal crops and cotton	Legume crops	Low % legumes in cotton and dry areas	–	–
	Gypsum treatments	Regarded as too expensive	Sodic soils 30% treated with gypsum	–
No conservation works	Contour banks and other water-control structures	75% adoption where needed	85% adoption where needed	80% adoption where needed
Inadequate fertiliser	Soil fertility maintenance	Most farms below replacement	30%	80%
No wind protection	Tree planting	No data	No data	60% of farmers have *some* trees

– = not available; NE = north-east; NW = north-west; Qld = Queensland; SE = south-east; SW = south-west
Source: Estimates in this table developed by Wylie et al (2001)

More recent data on the extent of use of some of these practices will be available soon from the Grains Industry's Farming Practices Database. Such data may be of use to Signposts, and form useful indicators for use in the framework. Table 22 shows area of stubble retained or burnt on farms for the census year 2000–01; this is a major contributor to management of soil cover and erosion risk.

Table 22 Stubble management on farms

Agroecological zone	Area of stubble retained (ha)	% stubble retained of cropland	Area of stubble burnt (ha)	% stubble burnt of cropland
NSW Central	658 819	40%	356 217	22
NSW Northeast–Qld Southeast	1 791 667	65%	199 464	7
NSW Northwest–Qld Southwest	1 055 577	86%	149 135	12
NSW/Vic Slopes	712 215	32%	907 420	41
Qld Central	478 889	75%	14 249	2
SA Midnorth–Lower, Yorke, Eyre	1 033 779	55%	415 546	22
SA/Vic Bordertown–Wimmera	695 836	43%	445 634	27
SA/Vic Mallee	1 066 326	40%	211 211	8
Tas Grain	13 485	49%	5 917	22
Vic High Rainfall	63 652	25%	126 535	50
WA Central	1 770 900	41%	385 036	9
WA Eastern	563 930	48%	196 252	17
WA Mallee and Sandplain	492 627	57%	29 700	3
WA Northern	1 006 569	58%	201 387	12

NSW = New South Wales; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia
Note: Percentages do not always add to 100 due to reporting errors and presence of fallow in many areas.
Source: ASFPD (2008)

Soil salinity

Salts are distributed widely across Australian landscapes, and many areas within grain-growing regions have naturally occurring salt scalds and saline watertables that predate cropping activities. Dryland soil salinity occurs when soils and vegetation are degraded by the rising or discharge of saline groundwater. This commences when the watertable reaches within 2 metres of the ground surface (NRM M&E Framework 2004).

Australia's natural salinity has been exacerbated since European settlement by clearing of large areas and replacement of native vegetation with shallow-rooting crops. These crops do not extract soil water to the depth of the previously existing perennial-based vegetation. This can result in water from rainfall draining through the soil to below the root zone of annual crops and to the watertable. Over some years, this can cause the watertable to rise, bringing salt, which then rises to the land surface. Once watertables are near the surface, salt stored in the soil or groundwater may be concentrated through transpiration by plants and evaporation. If this occurs in the root zone, it can depress land productivity and crop yields, and in more extreme cases preclude the production of grain completely (NLWRA 2001a).

Dryland salinity has been identified as one of Australia's main natural resource and environmental issues. From an environmental viewpoint, salinisation of soil can influence biodiversity on-farm, and salt can be transported to waterways, adversely affecting riparian vegetation, water quality and biodiversity off-farm.

Australian farmers, governments and natural resource management organisations have funded major rehabilitation and prevention activities at the farm, catchment and regional scales to combat the problem. Soil salinity has been identified as an important issue in the Single Vision grains industry strategy under the objective to reduce the impact of soil degradation. The strategy notes the need to speed the 'uptake of alternative or advanced farming systems to combat soil related production and productivity losses' (GRDC and GCA 2004).

The Signposts indicator of soil salinity is the area identified as at 'high salinity risk or hazard'. These areas were determined for the year 2000 using assessments of groundwater levels and trends, groundwater salinity, and salinity outbreaks. Where data were not available, the key drivers of salinity — such as geological features, land use and climate —were used to determine high risk or hazard areas (NLWRA 2001).

It is important to note that the indicator is based on an assessment of risk rather than an actual measurement of soil salinity. In 2000, assessments were also made for the risk of hazard salinity areas in 2020 and 2050 (Australian Dryland Salinity Assessment 2000).

Signposts' summary measure of the state of the industry's soil with respect to dryland salinity is the proportion of cropped land that is not assessed as having a high salinity risk. Salinity in dryland grain cropping is widespread, particularly in the western cropping region.

Many surveys and estimates for salinity have been produced by various agencies over time. However, a consistent measure or set of repeatable indicators seems elusive, preventing reliable assessment of trends in levels of salinity. This is indicated in a number of ways:

- Terms used in statistics on areas of land affected by salinity vary; they include 'at risk', 'showing signs of salinity', 'existing salinity', and 'unsuitable for agricultural production'. The NLWRA (2001) reports the area at risk or affected by salinity as being 5.7 million ha. A report from the Prime Minister's Science, Engineering and Innovation Council estimated an area of salinity-affected land of 2.5 million ha (PMSEIC 1999).
- However, McFarlane et al (2005) reported existing salinity in Western Australia to be about 1 million ha, compared with 4.3 million ha predicted to be at risk in the Audit report.
- A Land Management Survey by the ABS in 2002 (ABS 2002) reported that 1.97 million ha of agricultural land in Australia were identified as showing signs of salinity. An area of 0.82 million ha was affected to the extent that it was unsuitable for agricultural production, with Western Australia having the largest area of salinity.

The extent of salinity on grain-cropping farms from ABS census data (2000–01) is shown in Table 23. For the nonirrigated farms, the proportion of grain producers with salinity is higher than for other industry groups. Also, for nonirrigated farms the area of land in the grains industry makes up a high proportion of all land showing signs of salinity.

Deposit of salt crystals, Victoria (photo by Alison Pouliot 2008)

Table 23 Farms showing signs of salinity by farm type

Industry	Number of farms showing signs of salinity	Total farms showing signs of salinity (%)	Land area showing signs of salinity (ha)
Irrigated			
Grain farms[a]	411	17.9	18 000
Mixed grain farms[a]	364	23.8	25 000
Total irrigated farms	4 049	10.2	138 000
Nonirrigated			
Grain farms	4 692	33.5	628 000
Mixed grain farms	4 578	31.8	375 000
Total nonirrigated farms	15 430	15.4	1 831 000

Source: ABS (2002)
a Presumably includes rice

Table 24 shows the results by GRDC agroecological zone. For all zones, 94% of cropped land is not assessed as a high salinity risk. The table shows that soil salinity poses the greatest risk in Western Australia.

The area of saline land is expected to increase over the next 20–50 years. The National Dryland Salinity Program (NDSP 2004) reports that the five agroecological zones facing large salinity problems over the next 20 years are the WA Sandplain, SA/Vic Bordertown–Wimmera, NSW/Vic Slopes, WA Central and Vic High Rainfall. Most of these are major grain-producing regions.

Estimating the magnitude of this increase is difficult, partly due to the low rainfall in recent years, which has slowed the expansion of salinity, although this has not been uniform. For example, in a survey of primary producer subscribers to SALT Magazine in 2006, 17% reported that the area of salt-affected land had increased over the past 10 years, 35% reported a decrease, and 47% reported that the area had stayed about the same (CRC Salinity 2006).

A significant factor driving the impact of dryland soil salinity in the future will be the influence of climate change on average rainfall in the various cropping areas.

Table 24 Area of land under crops that was assessed as 'high salinity risk or hazard'

GRDC region	GRDC agroecological zone	Area under crops assessed as high salinity risk or hazard ('000 ha)	Area under crops ('000 ha)	Proportion of cropped land not at high salinity risk or hazard
Northern	Qld Central	0	3272	1.00
	NSW Northwest–Qld Southwest	1	1577	1.00
	NSW Northeast–Qld Southeast	20	3810	0.99
Southern	NSW Central	2	1656	1.00
	NSW/Vic Slopes	30	3139	0.99
	SA/Vic Mallee	6	4116	1.00
	SA Midnorth–Lower, Yorke, Eyre	10	1625	1.00
	SA/Vic Bordertown–Wimmera	165	2218	0.96
	Vic High Rainfall	24	1254	0.98
	Tas Grain	5	306	0.98
Western	WA Northern	208	2215	0.91
	WA Eastern	386	1555	0.75
	WA Central	784	5898	0.87
	WA Mallee and Sandplain	292	1664	0.82
All regions	All zones	1933	34 305	0.94

GRDC = Grains Research and Development Corporation; NSW = New South Wales; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia
Source: NLWRA (2001a), Australian Soil Resources Information System

The NAP regions were selected by the Australian Government as having the major soil salinity issues. Twenty-one NAP regions made up 88% of farms reporting signs of dryland salinity, and these NAP regions made up 64% of all land reported as showing signs of salinity (Table 25, ABS 2002).

Table 25 Salinity on farms in NAP regions

NAP region	Non irrigated farms showing signs of salinity (number)	Area of land showing signs of salinity (ha)
Avon	2 279	450 000
South West	1 681	153 000
Mt Lofty–Kangaroo Island –Northern Agricultural District	1 451	51 000
Glenelg–Hopkins–Corangamite	1 378	30 000
South Coast	1 354	74 000
Lachlan–Murrumbidgee	1 124	30 000
Lower Murray	1 119	75 000
Northern Agricultural District	868	152 000
Avoca–Loddon–Campaspe	477	8 000
Macquarie–Castlereagh	435	7 000
Namoi–Gwydir	226	5 000
South East	209	51 000
Midlands	188	3 000
Lockyer–Burnett–Mary	168	1 000
Border Rivers	137	–
Condamine–Balonne–Maranoa	132	28 000
Murray	104	3 000
Burdekin–Fitzroy	96	35 000
Darwin–Katherine	1	2 000
Ord	0	0
Total	**13 658**	**1 171 000**

– = not available; NAP = National Action Plan for Salinity and Water Quality
Source: Adapted from ABS (2002)

High soil salinity severely affects yields of broadacre grain crops and can cause total loss of productive capacity where the groundwater is very close to the surface. Salinised cropping land has resulted in:

- land being taken out of productive use
- restricted choice of crop type that can be grown
- cropping land having to be changed to pasture
- reduced grain crops yields.

Aside from reduced grain productivity, dryland salinity has serious impacts on the farm and surrounding environments. For example, rising watertables cause damage to natural and planted vegetation, riparian zones and wetlands (including those of floodplains), as well as fragmentation of wildlife corridors and general biodiversity loss.

It is suggested that, in Western Australia, at least 1500 plant species will suffer from dryland salinity, with 450 of these possibly becoming extinct. Fauna species are likely be reduced by 30% (NLWRA 2001).

Landscape salinity causes higher maintenance costs for infrastructure such as roads, sewerage pipes and water pipes, bridges, railways, buildings, and parks and gardens. For example, as of 2004, at least 220 rural towns and cities located throughout the Murray-Darling Basin were experiencing an urban salinity problem (Wilson 2003).

Transient salinity can impact on crop yields because water uptake by plants is reduced as the salt concentration of the subsoil water rises.

Estimates of the costs of dryland salinity to Australia vary. The total cost of dryland salinity was reported to be $243 million per year in lost agricultural production alone (Hill 1997). The most authoritative estimate of the annual cost to agriculture (loss of profits) due to salinity in the year 2000 is $187 million, increasing to $287 million in 2020 (NLWRA 2002).

The total cost across the Murray-Darling Basin was estimated as approximately $304.73 million per year, of which only 33% is incurred by dryland agricultural producers (Wilson 2003). This estimate does not include any values for environmental costs on or off farms.

Grain farmers naturally are very concerned about the impact of soil salinity on their profitability and sustainability. The ABS Land Management and Salinity survey (May 2002) showed that 63.5% of the land reported by farmers as showing signs of salinity was unable to be used for production.

The NLWRA (2002) estimated the cost of salinity to the grains industry through a yield gap methodology, which looked at the profits from production with and without soil problems. The yield gap for cereal and coarse grains was estimated at $70.6 million and $2.9 million, respectively, for 2000 (Standing et al 2006).

Australian farmers and catchment management organisations have adopted a range of measures to combat soil salinity. Farm-level changes motivated by soil salinity management will have private benefits beyond the benefits to salinity alone. For example, increasing perennials in the farming system will improve nutrient management, water use, soil health and acidification management, with associated productivity, environmental and natural resource sustainability benefits.

Broad control technologies currently available to address dryland soil salinity include:

- tree/shrub retention and/or planting in recharge areas and between recharge and discharge areas
- perennial pasture improvements, including lucerne, and higher level of integration of cropping systems with livestock
- crop management, including double cropping or opportunity cropping, phase farming and intercropping with lucerne
- structures to divert water from recharge areas, including drains and banks
- establishment and/or use of salt-tolerant pasture plant species and management of land that has already become salinised
- exclusion of stock and/or controlled stocking to promote regeneration
- use of sacrificial areas
- aquifer pumping to lower watertables
- subsurface drainage to lower watertables.

Evidence that Australian farmers are taking action to manage salinity is provided in the ABS Salinity Survey carried out in 2002 across both dryland and irrigated farmers (ABS 2002). ABS states that ‘a key finding was that nearly 30 000 farms have changed land management practice to manage or prevent salinity’. The type and extent of land management practices undertaken wholly or partly for the management or prevention of salinity are shown in Tables 26 (by agroecological zone) and 27 (by state and territory).

Table 26 Mitigating measures taken on-farm for salinity management

Agroecological zone	Area fenced off for protection of saline land (ha)		Area of perennial pasture (ha)	Farmland area under perennial pasture (%)	Area of perenni al pasture sown this year (ha)	Farmland sown to perennial pasture this year (%)
	2000–01	**2005–06**	**2000–01**	**2000–01**	**2000–01**	**2000–01**
NSW Central	2 598	2 352	215 449	1.29	19 464	0.12
NSW Northeast–Qld Southeast	1 153	208	1 035 938	5.71	126 375	0.70
NSW Northwest–Qld Southwest	0	1 605	106 967	0.38	8 394	0.03
NSW/Vic Slopes	1 379	783	1 132 084	11.13	79 105	0.78
Qld Central	0	493	592 706	4.29	47 776	0.35
SA Midnorth–Lower, Yorke, Eyre	2 214	1 114	74 206	0.20	8 297	0.02
SA/Vic Bordertown–Wimmera	1 935	881	1 184 745	19.39	70 872	1.16
SA/Vic Mallee	2 722	877	208 355	2.54	14 468	0.18
Tas Grain	27	10	205 078	29.86	11 448	1.67
Vic High Rainfall	756	420	764 549	31.63	64 763	2.68
WA Central	17 283	4 362	341 337	2.01	27 258	0.16
WA Eastern	1 109	1 393	17 121	0.59	786	0.03
WA Mallee and Sandplain	1 925	1 682	150 032	2.75	20 164	0.37
WA Northern	4 298	1 656	49 176	0.56	3 157	0.04

NSW = New South Wales; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia
Source: ASFPD (2008)

Table 27 Land management practices by state/territory for the management or prevention of salinity

State	Crops, pastures and fodder plants sown for salinity management ('000 ha)	Trees planted for salinity management ('000 ha)	Land fenced from grazing for salinity management ('000 ha)	Earthworks undertaken for salinity management ('000 km)
NSW/ACT	1096	91	17	43
Vic	680	40	40	37
Qld	331	126	27	15
SA	452	14	29	13
WA	633	500	352	98
Tas	7	5	1	3
NT	6	–	–	not known
Total Australia	**3205**	**776**	**466**	**208**

– = insignificant; ACT = Australian Capital Territory; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia
Source: ABS (2002)

The reported reasons for changing practices include farm sustainability (66%), improved environmental protection (56%) and increased productivity (54%). Barriers to change reported included the lack of financial resources (68% reported this as limiting or very limiting) and lack of time (57% reported this as limiting). Some 23% of farmers described information as limiting or very limiting and 25% reported doubts about likely success as limiting or very limiting.

One of the main mitigation strategies farmers can use is to include in the crop rotation a phase of perennial plants, such as lucerne. This pasture plant is well adapted to much of the grain-growing area of Australia, and provides economic benefits to mixed grain and livestock farmers by providing grazing (or hay-making) opportunities for these farmers. The major feature of lucerne when it is used in areas where salinity is a risk is its deep-rooted nature and summer-active growth habit. In some soil types, roots can reach depths similar to that of the native vegetation. A period of a few years of lucerne pasture can dry the soil profile down, allowing groundwater to return to deeper levels in soil, with a resultant reduction in salinity risk. This strategy allows the farm to remain productive and a following cropping phase to be implemented with confidence.

Soil acidity

Soil acidification (the accumulation of acid in the soil over time) is a natural process. It may be accelerated by farming; cropping is generally considered to be more acidifying than growing pastures (National NRM M&E Framework 2004, NLWRA 2001). Soil acidity affects the availability of nutrients and can lead to toxic levels of some elements (eg aluminium) in the soil, which can limit plant growth and resulting grain yields.

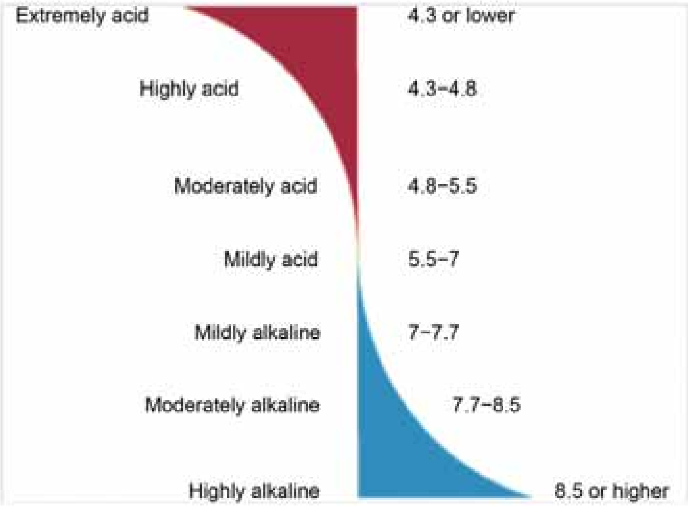
Most serious problems with soil acidity are manifest in permanent pasture areas where average annual rainfall is greater than 500 mm per year. The following factors can contribute to acidification in grain-growing systems:

- Nitrogen management contributes to soil acidification through the general inefficiency of nitrogen use, inappropriate use of fertilisers, and the types of fertilisers applied. For example, ammonium-based fertilisers are more acidifying than urea.
- Accumulation of organic matter in the soil increases soil acidity.
- Leaching of nitrates through the soil profile results in surface and subsoil acidity.

- Cropping practices, such as the use of nitrogen-fixing crops (lucerne, clover), contribute to soil acidity.
- Product removal (harvesting crops) removes alkalinity and results in acidification of soils.

Acidity is measured by topsoil pH. Soils with a lower pH are more acidic (Figure 4). A neutral pH is 7, and each pH unit below 7 is ten times more acidic. Soils with pH values above 7 become progressively more alkaline (NLWRA 2001).

Figure 4 Soil pH range (pH measured in 0.1 M $CaCl_2$)



$CaCl_2$ = calcium chloride; M = molar
Source: NLWRA (2001a), ASRIS dataset Australian Soil Resources Information System

Signposts' summary measure for soil acidity is the proportion of land with topsoil pH above 5.5, which is considered a suitable level of acidity for most crops. Some crops, such as lupins and lucerne, will be adversely affected by soil pH below 5.5, especially if aluminium, as a consequence, is at high levels.

At pH levels below 4.5, the yields of canola, barley and some wheat varieties will be reduced. Canola is particularly sensitive to acidity. Dramatic falls in wheat yields (up to 40%) can occur if pH falls below 4.5. Triticale and rye are considered to be the most acid-tolerant crops (Standing et al 2006). Highly alkaline soils (pH above 8.5) are also considered undesirable for plant growth.

Induced aluminium toxicity associated with acidity occurs in older, weathered soils. Acidity can induce high manganese in younger soils and deficiencies in elements such as molybdenum.

Some of the known and unknown impacts of soil acidification are listed in Table 28.

Table 28 Impacts of soil acidification

Issue	Known impacts	Unknown impacts
Agricultural production	• Reduced agronomic choices • Toxicity of aluminium to plant growth • Reduced plant growth of sensitive species • Increased loss of fine clay fraction	• Movement of nutrients beyond paddock • Ability of organic matter to protect plants from low pH
Terrestrial biodiversity	• Reduced earthworm numbers	• Microbial populations • Soil fauna biodiversity
Aquatic biodiversity	• Reduced rhizobium survival and persistence	• Impacts of acid soils on stream pH • Impact of declining stream pH on aquatic life • Degree of sedimentation caused by declining pH • Impact of soil pH decline on water quality

Source: Slattery and Hollier (2002)

The cost of soil acidification to Australian agriculture was estimated by NLWRA (2002) $1.6 billion per year, with the cost to the cereal industry at $156 million per year and coarse grains at $56.4 million per year (Standing et al 2006).

The environmental impacts of soil acidification in grain-producing areas are mostly indirect and include:

- reduction of water use by plants as acidification reduces root growth and access to nutrients
- increase in erosion, sediment export and turbidity, and nitrate and phosphorus levels in waterways, due to increased runoff, poor plant growth and lack of groundcover
- increased deep drainage, contributing to rising watertables and the exacerbation of dryland salinity.

In 1997, it was estimated that approximately 25% of Australia's grain-growing areas were influenced by soil acidification.

NLWRA (2001) estimated from the Australian Soil Resources Information System (ASRIS) that 38 million ha of agricultural land in Australia suffers from a pH of less than 5.5 in its surface layer and can be considered acidic. Of the 22.2 million ha of cropping soils, 48% (10.7 million ha) had a surface soil pH of less than 5.5, including 1.6 million ha with pH less then 4.8. Also, 23.1 million ha of Australian land had subsoil pH less than 5.5. Many of these acidic soils are located in the tablelands of New South Wales and northeast and central Victoria, where cropping is less common than permanent pasture.

It was estimated in 2001 that soil acidification is an important issue for 40% of the grain-growing area in the western region, 10% of the southern region, and less than 4% of the northern region. The extent of soil acidification in cropping areas was increasing in the western and southern region, and was steady in the northern region.

Table 29 shows the proportion of land with suitable acidity for grains cropping in the GRDC agroecological zones.

Table 29 Area and percentage of land with suitable acidity for grains cropping in GRDC agroecological zones

Regions	GRDC agroecological zones	Cropped land with pH >5.5 ('000 ha)	Total cropped area ('000 ha)	Performance measure (% of cropped land with pH >5.5)
Northern	Qld Central	1 590	1 619	98
	NSW Northeast–Qld Southeast	3 299	3 801	87
	NSW Northwest–Qld Southwest	1 533	1 576	97
Southern	NSW/Vic Slopes	854	3 137	27
	NSW Central	1 328	1 656	80
	SA Midnorth–Lower, Yorke, Eyre	2 181	2 183	100
	SA/Vic Bordertown–Wimmera	3 636	4 113	88
	SA/Vic Mallee	3 270	3 271	100
	Tas Grain	0	304	0
	Vic High Rainfall	380	1 248	30
Western	WA Central	334	5 897	6
	WA Eastern	0	1 557	0
	WA Mallee and Sandplain	303	1 187	25
	WA Northern	61	2 214	3
Total	**All zones**	**18 769**	**33 763**	**53**

GRDC = Grains Research and Development Corporation; NSW = New South Wales; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia
Source: NLWRA (2001a), Australian Soil Resources Information System

The data in Table 29 suggest that soil acidity is an issue in almost half of the grains cropping area. Soil acidity is not a major issue in the northern region and the north and west zones of the southern region, where over 80% of cropped area has a soil pH of more than 5.5. Soil acidity is of greatest significance in the western region and the southeast of the southern region, where the proportion of land with 'suitable' pH is below 30%.

Soil acidification is largely an on-farm issue that impacts on the economic contribution of the grains industry. It can be managed by the application of carbonates, which raise the soil pH and improve yields, but add to production costs. Lime ($Ca(CO)_3$) is the most common, though dolomite is also used in some cases.

Past attempts to address subsoil acidification have met with mixed success. Amelioration techniques suited to surface acidification, such as liming, are not easily transferred to subsoil acidification because of the large quantities of lime and the time (up to 50 years) required for lime applied to the surface to move deeper. Some of the cropping soils in Western Australia are inherently acidic, and management by liming or deep ripping is not currently economically feasible. All that can be done is to use acid-tolerant species and crop varieties and manage inputs according to yield potential.

ABS data from the two recent censuses (2000–01 and 2005–06) provide some useful indicators of the extent to which farmers are using lime on-farm. These data have been manipulated to show use of lime at the agroecological zone level (Tables 30 and 31).

Table 30 Acid soil management — liming (2000–01)

Agroecological zone	Total area where lime applied (ha)	% of the farmland	Average amount of lime applied (tonnes/ha)
NSW Central	26 858	0.16	1.34
NSW Northeast–Qld Southeast	23 706	0.13	1.86
NSW Northwest–Qld Southwest	9 283	0.03	1.64
NSW/Vic Slopes	243 514	2.39	1.72
Qld Central	406	0.00	1.55
SA Midnorth–Lower, Yorke, Eyre	24 621	0.07	2.23
SA/Vic Bordertown–Wimmera	74 088	1.21	1.69
SA/Vic Mallee	10 158	0.12	1.77
Tas Grain	12 685	1.85	2.70
Vic High Rainfall	75 449	3.12	1.90
WA Central	276 221	1.63	0.92
WA Eastern	34 143	1.18	0.71
WA Mallee and Sandplain	44 085	0.81	1.07
WA Northern	86 645	0.98	1.03

NSW = New South Wales; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia
Source: ASFPD (2008)

Table 31 provides further data on the response of industry in terms of the area of liming carried out in each GRDC agroecological zone region.

Table 31 Liming in agroecological zones

Agroecological zone	Area limed (ha)	Lime applied (tonnes of lime equivalent)
NSW Central	22 991	32 241
NSW Northeast–Qld Southeast	25 485	42 956
NSW Northwest–Qld Southwest	9 752	16 561
NSW/Vic Slopes	217 104	360 449
Qld Central	356	440
SA Midnorth–Lower, Yorke, Eyre	20 262	42 420
SA/Vic Bordertown–Wimmera	31 551	46 269
SA/Vic Mallee	6 902	10 841
Vic High Rainfall	65 902	124 441
WA Central	544 610	467 687
WA Eastern	71 918	49 387
WA Mallee and Sandplain	52 368	38 839
WA Northern	179 970	176 101
Total	**1 249 171**	**1 408 632**

NSW = New South Wales; Qld = Queensland; SA = South Australia; Vic = Victoria; WA = Western Australia
Source: Beeston et al (2005)

Adoption of practices such as liming acidified soils has increased over the past 10 years in some areas (in particular, the western region), and higher levels of adoption could be possible in that region as well as in the southern region.

Natural capacity of grain-farming lands to provide ecosystem services

There are many aspects to the capacity of an industry to provide ecosystem services, and this is a developing area that requires further research and knowledge. In some cases, new markets are developing that, over time, may generate income for grain producers. The most compelling issues in the minds of consumers and the general community at present are the contribution of industries to the conservation of biodiversity and greenhouse gas emissions (or, conversely, carbon sequestration).

Biodiversity conservation

Biodiversity conservation relates to the capacity of land held by the industry to conserve or improve native biodiversity. As an issue of national and state consideration, it is reflected in the *National Strategy for the Conservation of Australia's Biological Diversity* (Commonwealth of Australia 1996) and, at state level, through laws and regulations that include controls on land clearing.

The National Strategy has an objective to 'protect and restore native vegetation and terrestrial ecosystems'. An objective that relates directly to agriculture is to 'achieve the conservation of biological diversity through the adoption of ecologically sustainable agricultural and pastoral management practices'.

From the grains industry's perspective, its 'Single Vision' also has a strategy of protecting and nurturing biodiversity.

Signposts uses native vegetation coverage and quality as an indicator of biodiversity conservation. The summary measure is the proportion of land that is generally intact and having regenerative capacity.

The average area of land under grain production (over the five years to June 2006) in Australia is 22 million hectares (ABARE 2006), which makes up 3% of Australia's total land area. By the very nature of grain production, most vegetation on grain farms has been cleared.

The NLWRA reports that approximately 13% of Australia's total land area has been cleared, and that this clearing has been concentrated in areas of fertile soils (generally excluding the arid interior and tropical far north). Where the broad native vegetation fabric is still intact, the condition of the vegetation and biodiversity varies greatly.

Australia has 85 designated bioregions, and extensive clearing of native vegetation has been concentrated in comparatively few of these. The Australian Native Vegetation Assessment (NLWRA 2001) reports that five bioregions have less than 30% of native vegetation remaining. These are:

- Victorian Midlands (Victoria)
- Victorian Volcanic Plains (Victoria and South Australia)
- Naracoorte Coastal Plain (Victoria and South Australia)
- Avon Wheatbelt (Western Australia)
- South East Coastal Plain (Victoria).

With the exception of the South East Coastal Plain, all of these bioregions are in grain-producing areas.

An additional 22 bioregions have between 30% and 70% of native vegetation remaining, and a number of these bioregions are aligned with grain-producing regions. The regions are:

- South Eastern Queensland
- NSW South Western Slopes
- Eyre Yorke Block
- Nandewar
- Swan Coastal Plain
- New England Tableland
- Kanmantoo
- Geraldton Sandplains
- Tasmanian Northern Midlands
- Tasmanian Northern Slopes
- Riverina
- Brigalow Belt North
- Mallee
- Jarrah Forest
- Brigalow Belt South
- South Eastern Highlands
- Murray Darling Depression
- NSW North Coast
- Esperance Plains
- Darling Riverine Plains
- Sydney Basin
- Central Mackay Coast

Clearing has caused significant habitat loss and increased fragmentation of remnant areas, which are detrimental to species survival in the long term. For example, Table 32 presents information on numbers of threatened bird species in key grain-growing regions.

Table 32 Examples of threatened species

Locality	Extent of threat	Source
Murray-Darling Basin	24 bird species on brink of being considered nationally threatened and 14 already threatened, 4 of which are locally extinct	Wildlife Australia (2000)
NSW sheep–wheat belt	38 bird species, 11 of which are considered threatened nationally and 27 listed as threatened in NSW; a further 20 species are declining, including the hooded robin	Reid (1999)
Western wheatbelt	Three bird species already threatened (with one locally extinct), and another 11 birds on the brink of being nationally threatened	Wildlife Australia (2000)

NSW = New South Wales

Table 33 shows the terrestrial fauna and flora species and ecological communities listed under the Environmental Protection and Biodiversity Conservation Act for which Conservation Advices exist for natural resource management (NRM) regions in grain-growing regions.

Table 33 Species or communities under threat for relevant NRM regions

NRM region	Species or community
NSW Border Rivers/Gwydir	*Peophila cincta cincta* (black-throated finch [southern]) Upland wetlands of the New England Tablelands and the Monaro Plateau White box–yellow box–Blakely's red gum grassy woodland and derived native grassland
NSW Central West	White box–yellow box–Blakely's red gum grassy woodland and derived native grassland
NSW Lachlan	White box–yellow box–Blakely's red gum grassy woodland and derived native grassland
NSW Murray	White box–yellow box–Blakely's red gum grassy woodland and derived native grassland
NSW Murrumbidgee	Upland wetlands of the New England Tablelands the Monaro Plateau
NSW Namoi	Upland wetlands of the New England Tablelands the Monaro Plateau White box–yellow box–Blakely's red gum grassy woodland and derived native grassland
Qld Border Rivers	*Peophila cincta cincta* (black-throated finch [southern]) White box–yellow box–Blakely's red gum grassy woodland and derived native grassland
Qld Burdekin	*Peophila cincta cincta* (black-throated finch [southern]) *Dasyurus hallucatus* (northern quoll)
Qld Condamine	*Peophila cincta cincta* (black-throated finch [southern]) White box–yellow box–Blakely's red gum grassy woodland and derived native grassland

NRM region	Species or community
Qld Fitzroy	*Peophila cincta cincta* (black-throated finch [southern]) *Dasyurus hallucatus* (northern quoll)
Qld Maranoa Balonne	White box–yellow box–Blakely's red gum grassy woodland and derived native grassland
SA Eyre Peninsula	*Prasolphyllum goldackii* (Goldsack's leek-orchid)
SA Northern and Yorke	*Acanthocladium dockeri* (spiny everlasting) *Neophema chrysogaster* (orange-bellied parrot) *Prasolphyllum goldackii* (Goldsack's leek-orchid)
SA Murray Darling Basin	*Allocasuarina robusta* (Mount Compass oak-bush) *Eucalyptus paludicola* (Mount Compass swamp gum) *Hylacola pyrrhopygia parkeri* (chestnut-rumped heathwren [Mt Lofty Ranges]) *Neophema chrysogaster* (orange-bellied parrot) *Prasolphyllum goldackii* (Goldsack's leek-orchid) *Pterostyus bryophila* (Hindmarsh Valley greenhood)
SA South East (SA)	*Neophema chrysogaster* (orange-bellied parrot)
Vic Corangamite	*Neophema chrysogaster* (orange-bellied parrot)
Vic Glenelg Hopkins	*Neophema chrysogaster* (orange-bellied parrot)
Vic Mallee	White box–yellow box–Blakely's red gum grassy woodland and derived native grassland
Vic North Central	White box–yellow box–Blakely's red gum grassy woodland and derived native grassland
WA Avon	*Acacia chapmanii* subsp. *Australia* *Acacia cochlocarpa* subsp. *velutinosa* (velvety spiral pod wattle) *Caladenia williamsiae* (Williams spider orchid) *Frankenia conferta* (silky Frankenia) *Frankenia parvula* (short-leaved Frankenia) *Haloragis platycarpa* (broad-fruited Haloragis) *Hydatella leptogyne* (few-flowered Hydatella) *Muehlenbeckia horrid* subsp. *Abdita* (remote thorny lignum) *Ptilotus fasciculatus* (Fitzgerald's mulla-mulla)
WA Northern Agricultural	*Frankenia conferta* (silky Frankenia) *Gyrostemon reticulates* (net-veined Gyrostemon) *Ptilotus fasciculatus* (Fitzgerald's mulla-mulla) *Stachystemon nematophorus* (three-flowered Stachystemon)
WA South Coast	*Calectasia cyanea* (blue tinsel lily) *Daviesia glossosema* (maroon-flowered Daviesia) *Gastrolobium lehmannii* (Cranbrook pea)
WA South West	*Brachyscias verecundus* (ironstone Brachyscias) *Gastrolobium lehmannii* (Cranbrook pea)

NSW = New South Wales; NRM = natural resource management; Qld = Queensland; SA = South Australia; Vic = Victoria; WA = Western Australia

Source: Species Profile and Threats Database, Department of the Environment, Water, Heritage and the Arts, http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl

The results in Table 34 show that a quarter of the area 'outside protected areas' and within GRDC agroecological zones is native vegetation in good condition. Five GRDC zones also have more than 25% of their land in good condition: WA Northern, WA Eastern, WA Mallee and Sandplain, NSW Central and Tasmania Grain.

New South Wales and Queensland GRDC zones have large areas with native vegetation, although much of this is in modified rather than residual condition.

Table 34 Area of native vegetation (outside protected areas) in good condition, by GRDC agroecological zone

Region	GRDC zone	Total area of native vegetation[a] (million ha)	Total zone area (million ha)	Proportion of zone with native veg in good condition
Northern	Qld Central	2.9	12.5	0.23
	NSW Northwest–Qld Southwest	3.7	16.2	0.23
	NSW Northeast–Qld Southeast	3.8	19.5	0.19
Southern	NSW Central	7.3	18.6	0.39
	NSW/Vic Slopes	0.4	8.1	0.04
	SA/Vic Mallee	0.7	9.8	0.07
	SA Midnorth–Lower, Yorke, Eyre	1.4	8.1	0.18
	SA/Vic Bordertown–Wimmera	0.4	8.4	0.04
	Vic High Rainfall	0.2	3.0	0.06
Southern	Tas Grain	0.3	1.1	0.27
	WA Northern	1.6	6.3	0.25
	WA Eastern	2.3	5.8	0.40
	WA Central	1.2	11.2	0.11
	WA Mallee and Sandplain	9.7	15.6	0.63
All regions	**All GRDC zones**	**35.9**	**144.2**	**0.25**

GRDC = Grains Research and Development Corporation; NSW = New South Wales; Qld = Queensland; SA = South Australia; Vic = Victoria; WA = Western Australia
a All types of native vegetation (ie bare, residual and modified)
Source: NLWRA (2006)

Even though broadscale clearing is no longer a threat, the fractured nature of remnants in grain-growing areas means that there is still the potential for continued biodiversity loss through other threatening processes. Such processes include collection of timber for firewood and fence posts from remnant vegetation, use of farm chemicals and fertilisers (adversely affecting small parcels of remnant vegetation), dryland salinity and waterlogging.

The grains industry may have some control over these threatening processes to reduce further biodiversity loss. The major consideration on farms is to improve 'connectivity' between areas of native or remnant vegetation.

Examples of benefits to the environment (on- and off-farm) and society from revegetation, and from the protection and enhancement of native vegetation include:

- conservation of biodiversity, including rare and threatened fauna and flora ecosystems
- prevention of soil erosion through maintaining groundcover

- contribution to greenhouse gas reduction through vegetation acting as a carbon sink
- contribution to maintenance of water quality, through the filtering of runoff
- reduction of accession of water to groundwater systems, reducing the possibility of salinity impacts
- improved visual amenity to the land-holder and to the wider community
- recreational values of land-holders and others in the community.

The capacity of the industry to address biodiversity is somewhat limited by the nature of grains production, where cleared land is a necessity. On land that is directly used for cropping, there is little that can be done to incorporate biodiversity into the farming system. Some options include:

- ensuring appropriate use of pesticides to prevent spray drift to areas of native vegetation, and to prevent killing 'beneficial' insects
- where 'alley farming' and other techniques in appropriate landscapes are to be used for controlling watertables, selecting species and types that enhance biodiversity.

On noncropped land, there is scope to manage biodiversity. This includes fencing and managing remnants on nonarable land, such as hills and riparian zones. It might also include using precision agriculture to identify land that is currently under production, but is not performing, and instead managing that land for biodiversity purposes that may even deliver income from carbon credits.

Grain farmers also have the opportunity to take a landscape approach to maintaining or developing appropriate corridors between remnants on different properties. The NLWRA Australian Agricultural Assessment (NLWRA 2001) reported that 28% of grain farmers in the northern region were Landcare members, 38% of grain farmers in the southern region were Landcare members, and 58% of grain farmers in the western region were Landcare members.

The NLWRA grains profile (Standing et al 2006) reports the results of an ABARE survey in 1998–99 that showed that approximately 55% of grain farmers were practising tree/shrub establishment, 18% were formally monitoring vegetation/pasture condition, and 48% maintained areas of conservation value.

ABS data again provide some indications of efforts made on farms to protect native or other vegetation and waterways (Table 35, 36 and 37).

Table 35 Areas fenced off for vegetation or waterway protection (2000–01 and 2005–06)

Agro-ecological zone	Area fenced to protect trees (ha) 2000–01	% of farm	Area fenced to protect trees (ha) 2005–06	% of farm	Area fenced to protect waterways (ha) 2000–01	% of farm	Area fenced to protect waterways (ha) 2005–06	% of farm
NSW Central	1 707	0.01	778	0.01	2 250	0.01	1 554	0.01
NSW Northeast–Qld Southeast	3 435	0.02	920	0.01	12 833	0.07	3 783	0.02
NSW Northwest–Qld Southwest	536	0.00	515	0.00	24 319	0.09	24 417	0.09
NSW/Vic Slopes	12 629	0.12	3 574	0.03	3 724	0.04	4 195	0.04
Qld Central	1	0.00	29	0.00	21 808	0.16	7 465	0.05
SA Midnorth–Lower, Yorke, Eyre	1 791	0.01	710	0.00	2 276	0.01	1 021	0.00
SA/Vic Bordertown–Wimmera	3 685	0.06	1 665	0.03	2 468	0.04	1 632	0.03
SA/Vic Mallee	1 303	0.02	1 031	0.01	2 487	0.03	2 086	0.03
Tas Grain	382	0.06	92	0.01	612	0.09	123	0.02
Vic High Rainfall	2 641	0.11	1 927	0.08	2 620	0.11	1 366	0.06
WA Central	11 572	0.07	2 516	0.02	8 993	0.05	4 082	0.04
WA Eastern	855	0.03	354	0.01	53	0.00	12	0.00
WA Mallee and Sandplain	2 856	0.05	948	0.02	2 609	0.05	1 147	0.03
WA Northern	2 520	0.03	1 123	0.02	2 730	0.03	14 258	0.19

NSW = New South Wales; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia Source: ASFPD (2008)

Table 36 Areas fenced off for vegetation and in total (2000–01 and 2005–06)

Agroecological zone	Area fenced to protect native veg (ha) 2000–01	% of farm	Area fenced to protect native veg (ha) 2005–06	% of farm	Area fenced off in total (ha) 2000–01	% of farm	Area fenced off in total (ha) 2005–06	% of farm
NSW Northeast–Qld Southeast	14 158	0.08	3 491	0.02	71 651	0.40	36 464	0.23
NSW Northwest–Qld Southwest	10 779	0.04	9 010	0.03	86 502	0.31	61 726	0.23 %
NSW/Vic Slopes	19 244	0.19	5 088	0.05	46 009	0.45	21 802	0.20
Qld Central	5 932	0.04	4 387	0.03	52 464	0.38	23 409	0.16
SA Midnorth–Lower, Yorke, Eyre	10 192	0.03	3 416	0.01	57 151	0.15	9 071	0.03
SA/Vic Bordertown–Wimmera	9 871	0.16	4 766	0.08	23 894	0.39	15 018	0.25
SA/Vic Mallee	14 780	0.18	12 355	0.16	31 542	0.38	20 840	0.27
Tas Grain	2 453	0.36	204	0.03	3 887	0.57	1 177	0.18
Vic High Rainfall	1 083	0.05	1 284	0.05	11 255	0.47	7 613	0.32
WA Central	17 411	0.10	10 306	0.09	62 824	0.37	84 766	0.73
WA Eastern	2 004	0.07	6 314	0.19	5 719	0.20	10 270	0.31
WA Mallee and Sandplain	5 055	0.09	3 986	0.09	14 254	0.26	9 264	0.21
WA Northern	3 850	0.04	8 764	0.12	39 934	0.45	31 126	0.42

NSW = New South Wales; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia Source: ASFPD (2008)

Table 37 Areas replanted for all purposes, 2000–01

Agroecological zone	Area replanted or planted with vegetation for all purposes (ha)	% of farm
NSW Central	8 115	0.05
NSW Northeast–Qld Southeast	14 945	0.08
NSW Northwest–Qld Southwest	3 846	0.01
NSW/Vic Slopes	14 188	0.14
Qld Central	222	0.00
SA Midnorth–Lower, Yorke, Eyre	4 113	0.01
SA/Vic Bordertown–Wimmera	8 284	0.14
SA/Vic Mallee	3 817	0.05
Tas Grain	239	0.04
Vic High Rainfall	6 557	0.27
WA Central	23 009	0.14
WA Eastern	3 087	0.11
WA Mallee and Sandplain	3 007	0.06
WA Northern	10 060	0.11

NSW = New South Wales; Qld = Queensland; SA = South Australia; Vic = Victoria; WA = Western Australia Source: ASFPD (2008)

Greenhouse gases and carbon sequestration

The grains industry emits greenhouse gases when preparing land, and fertilising, protecting and harvesting the crops. A key greenhouse gas emitted by the grains industry is nitrous oxide, which is mainly derived from denitrification processes in the soil and from applied nitrogen fertiliser. Nitrous oxide is estimated to make up 30% of greenhouse gas emissions from agriculture. Also, various nonrenewable fuels that emit carbon dioxide are required to support cropping activities, and methane is emitted from ruminant livestock on mixed grain and livestock farms.

It is estimated that about 16% of Australia's total net greenhouse gas emissions (excluding carbon dioxide and emissions from land use change) originate from the farm sector (AGO 2005). These gases are mainly methane from livestock; and nitrous oxide from fertilisers, crop residues, soil disturbance including tillage, and prescribed burning of grasslands and residues.

Of the 16% contributed by agriculture, 71% is from livestock (methane), leaving only 29% from other agricultural sectors (AGO 2005). Although methane emissions have declined from 1990 to 2005 by 6% (mainly as a result of fewer sheep), emissions of greenhouse gases from soil have increased by 15% (AGO 2005).

However, emissions from cultivation of soil are believed to have decreased significantly in recent years as minimum and no-till systems have increasingly been adopted.

The grains industry also offers the potential to produce renewable energy through the production of grain and biomass for conversion into ethanol or biodiesel. Some limited potential exists for capturing and storing carbon in the soil as organic matter (carbon sequestration).

Greenhouse gas emissions associated with grain production are described in Grace (2006). A key feature of this description is the 29% increase in emissions from soils from 1990 to 2002. The estimate made by Grace is that there has been a 130% increase in nitrous oxide emissions from nitrogen fertiliser applications over that period. The current loss of nitrous oxide to the atmosphere from cropping farms also involves an annual financial cost to farmers, with the cost of nitrogen loss through volatilisation and denitrification estimated at between $2000 and $20 000 for 1000 ha of cereal cropping (GRDC 2003).

A greenhouse emissions calculator at individual farm level has been developed (GRDC 2003). Using a series of assumptions about emissions and representative farm data from different regions, the calculator shows the following relative emission sources and total greenhouse gas production (tonnes of carbon dioxide equivalent per ha per year) (Table 38).

Table 38 Greenhouse emission estimates from typical grain enterprises (tonnes of carbon dioxide equivalent per year)

Source **Western region**	**Buntine (northern region)**	**Wickepin (Great Southern)**	**Grass Patch (South Coast)**
Soil	32%	44%	43%
Fuel	30%	25%	23%
Burning	10%	0%	0%
Fertiliser	28%	31%	34%
Total carbon dioxide equivalent (tonnes per year per ha)	**0.39**	**0.28**	**0.29**

Southern region	**S Mallee**	**Mallee**	**Wimmera**
Soil	43%	31%	36%
Fuel	25%	25%	24%
Burning	15%	17%	21%
Fertiliser	17%	27%	19%
Total carbon dioxide equivalent (tonnes per year per ha)	**0.28**	**0.39**	**0.33**

Northern region	**N NSW**	**Western Downs**	**Darling Downs**
Soil	42%	55%	27%
Fuel	30%	23%	10%
Burning	0%	0%	17%
Fertiliser	28%	22%	63%
Total carbon dioxide equivalent (tonnes per year per ha)	**0.29**	**0.22**	**0.45**

N = north; NSW = New South Wales; S = south

The information in Table 38 suggests that the Darling Downs cropping systems emits the most greenhouse gases, possibly due to nitrogen loss during fallows. In the west and south, crops are grown during the coldest and wettest time of year so there is less denitrification. The Wimmera and high rainfall zones of northern Victoria are most at risk of producing even more nitrous oxide if the trend to increasing nitrogen applications continues in those areas (GRDC 2003).

Umbers (2007) notes that Australian rain-fed cropping soils are generally low in organic carbon, which is frequently at levels of less than 1% in the top 10 cm. He considers that this cannot be attributed to land clearing and farming because much of Australia's remnant 'virgin' soil in the extensive cropping areas has organic carbon levels at only about 1.5% to 2%.

> Farmers involved in producing grain are generally net emitters of greenhouse gases through the use of fossil fuels and nitrogenous fertiliser. Farming to produce grain includes some form of soil disturbance, at least at planting, and in some cases additional tillages are still used. These operations and inputs result in greenhouse gas emissions, comprising both carbon dioxide (CO_2) and nitrous oxide (N_2O), the latter a potent greenhouse gas. (Umbers 2007)

Umbers calculates the net emissions to be up to 400 kilograms per hectare or 8 million tonnes over the whole Australian crop. However, he notes that the amount of tillage used has decreased dramatically in the past 20 years with the adoption of no-till practices and the retention of crop stubbles. This has led to a reduction in fuel use of 50% since 1990. As a result, there has been a reduction from 1990 levels of around 0.5 million tonnes of carbon dioxide per year for the whole industry.

Umbers notes that carbon levels and the rate of cycling in soil are difficult to measure or estimate. Of the main sources of emissions — fuel use, nitrogen fertiliser use and cultivation of soil — only greenhouse gas emissions from fuel use are able to be accurately calculated at present. Nitrous oxide and carbon dioxide emissions from soil are much more difficult to measure or accurately estimate, and are subject to strong influences of season and management.

The Department of Climate Change (until recently the Australian Greenhouse Office) is in the process of developing a more sophisticated greenhouse gas calculator suitable for use for grain farming operations. A national system is also being developed to gather data from grain producers as inputs to this system; the hope is that this will allow grain farmers to estimate their individual levels of emissions, and will generate amalgamated data for regional or national levels.

The National Farmers' Federation, in its submission to the Garnaut report on climate change policy, states that primary industry emissions have 'plummeted' by 40% over the past 15 years. They consider that the existing international greenhouse accounting rules, by taking account of emissions but not sequestration, fail to adequately recognise the carbon cycle of agricultural systems.

Reduced emission of greenhouse gases by the Australian grains industry is not likely to have a significant effect on global warming, as Australian emissions contribute only 1.5% of total world emissions (AGO 2005). Further, the grains industry contributes only a fraction of the 16% of Australian greenhouse gas emissions that are derived from farming. A precise estimate of the contribution of the grains industry is not available. However, there is a social imperative for Australia as a responsible society to make a contribution to lowering emissions. Within Australia, each industry is expected to reduce emissions.

Options to reduce nitrous oxide loss, use less nonrenewable energy, and increase carbon in the soil will provide benefits for cropping farmers — in the form of cost savings and higher yields — and to the environment. Hence, there is incentive for change in cultural practices and fertiliser management.

However, the potential to rapidly or dramatically increase soil carbon levels is limited (Umbers 2007). Higher equilibrium levels of carbon require sustainable increases in biomass inputs to compensate for greater losses — for example, from tillage operations.

One other constraint in dealing with the issue of greenhouse gas emissions from Australian farming systems is the difficulty of measurement. A number of recent initiatives are now addressing this issue, some funded by GRDC and others by state governments. Recent results for semiarid cropping environments in Western Australia suggest that nitrous oxide emissions from cereal crops appear to be low and less than the emissions reported for cereal crops in temperate climates (GRDC project DAW00103).

Other studies on winter wheat have shown that emission rates from soils under dryland wheat are low and around one-third of estimates from the Intergovernmental Panel on Climate Change (AGO 2007).

Opportunities for the grain industry to respond to this threat are:

- exploration of farming systems and practices that can reduce greenhouse gas emissions, including better tailoring of nitrogen to crop need, leading to lower fertiliser costs, optimum yields, and less nitrous oxide emissions
- increasing carbon in the soil via organic matter, which will contribute to greenhouse gas reduction while improving soil and raising crop productivity.

The prospect of carbon payments received by grain producers for increasing levels of carbon in the soil has potential, but faces a range of constraints. These include the low sequestration potential of Australian grain-producing soils, the enduring negative status of greenhouse emissions in grain production, longevity and stability of carbon stored in the soil, and sampling and measurement of the carbon status in the soil (Umbers 2007). The rules for greenhouse accounting, even if they change in Australia with a national carbon trading scheme, will have a significant impact on the realisation of carbon farming with continuing grain production.

> In farming, a natural 'life cycle' is at play. Although it is true agriculture is responsible for around 17% of Australia's total carbon emissions, no account has yet been taken of the carbon being sequestered in farm soils, crops and trees in this assessment. It needs to be. (NFF 2008)

The social contribution

This component of the Signposts framework aims to collect data on the contributions of the grains industry to social systems, thereby increasing or decreasing human and social capital.

Signposts notes that the industry can contribute in two ways — through changes in the value of its own human and social assets, and by changing the value of human and social assets held by others.

The industry's own stock of human capital is defined as residing in individuals in the industry, and social capital is defined as residing in industry institutions and organisations.

Attributes of the human capital component that will be measured by Signposts include health (occupational injuries), education and skill level. An attribute not identified is the age structure of individuals engaged in the industry as owners or employees. Although they have not been identified by Signposts, attributes of social capital could be the membership of industry institutions, employment by these organisations, roles and activities managed, and expenditure.

The other aspect of social contributions relates to those extending beyond the industry itself, including contributions to individuals associated with the industry, local communities, regions and nationally. The contributions identified include individual health and employment. Others that are not identified by Signposts could include the industry's expenditure in communities and the provision of goods or services that add to human welfare, such as contributions to nutrition.

Health

This relates to the impact of the industry on the health of individuals involved in the industry. Signposts states that the most direct impact is through injuries on farms, but there are also other potential impacts. These include long-term effects of working with chemicals and exposure to the sun, as well as the beneficial impacts of an active, outdoor lifestyle.

This report considers that both mental and physical health should be considered because health reflects the ability of individuals to contribute to society, including contributions to social structures or economic activities. At this stage of the development of Signposts, data are only provided in Signposts for the number of 'occupational injuries'. It may be possible to develop data sets for mental health — for example, using suicide rates as a crude indicator.

Data specific to the grains industry are not available, so occupational injuries on grain, sheep and beef farms are used as the indicator. 'Occupational injuries' are employment injuries that are the result of a single traumatic event occurring while a person is on duty or during a recess period.

The desired outcome is that the negative impacts of the industry on the health of individuals involved in it are reduced. Signposts uses a summary measure that shows the extent to which the desired outcome is being achieved on a scale of 0 to 1. A score of 1 for the most recent year means that occupational injuries are at their lowest level to date.

Figure 5 shows that performance has improved over the past 10 years. The summary measures are based on the indicator values from compensation statistics shown in Figure 6.

Figure 5 Summary measure for health

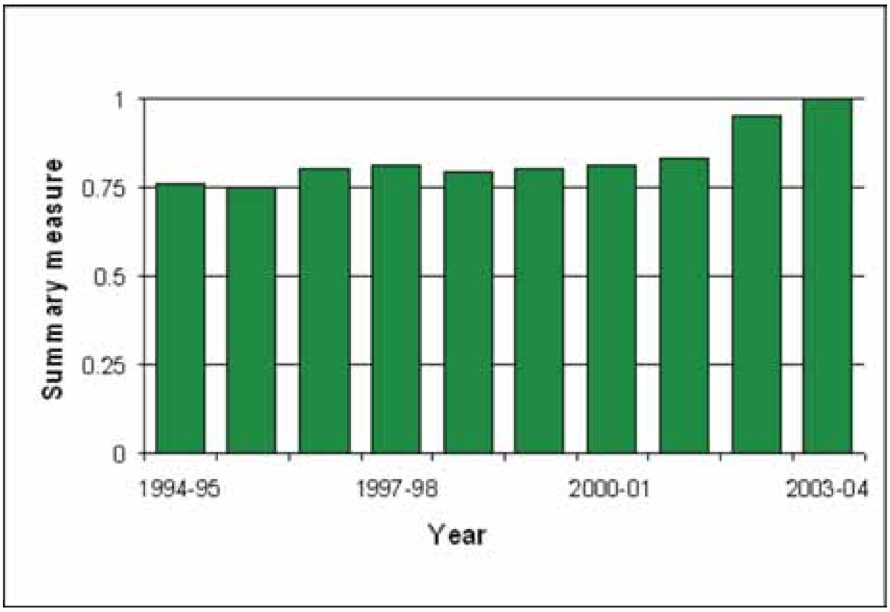
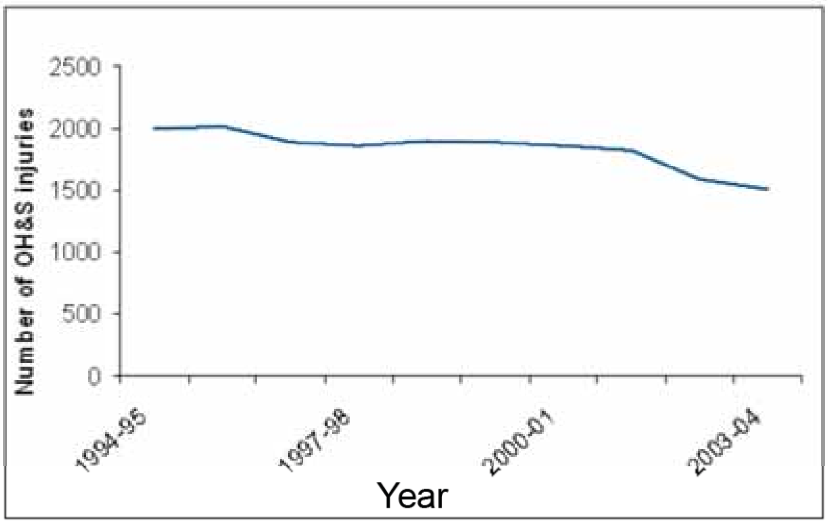


Figure 6 Number of reported occupational injuries, with duration of a week or more, on grain, sheep and beef farms



OH&S = occupational health and safety
Source: ASCC (2005).

Employment

This component of Signposts measures the contribution of the industry to employment opportunities in local and regional communities. The desired outcome is for the industry to maintain or increase employment opportunities provided by the industry to local and regional communities.

The industry's Single Vision strategy (GRDC and GCA 2004) has a goal of 'creating more sustainable rural and regional communities'. Similarly, the mission statement of the Department of Agriculture, Fisheries and Forestry has an objective of 'greater national wealth and stronger rural and regional communities'.

Signposts' indicator of the industry's employment contribution is the number of people employed in grain-related farming as a proportion of the total people employed.

The summary measure has been designed to help assess the industry's contribution relative to 'all of agriculture'. The methodology used has been to normalise the summary measure of 0.5 to 'all of agriculture's' share of total Australian employment (4%). As a result, it is apparent that the grains industry is the largest employer among all agricultural industries.

The data relate to the 2001 ABS Census of Population and Housing, but Signposts is working to provide data from the 1996 and 2006 censuses in order to show the trend in the industry's contribution to total agricultural employment.

Table 39 shows the proportion of people employed in grain-growing areas that are employed by the grains industry. The summary measure is greater than 0.5 for almost all of the zones. This indicates that in grain-growing areas the majority of people employed in agricultural activities are employed in the grains industry. For Western Australia, the summary measures for all the zones show that all people employed in agriculture in those zones are employed in the grains industry.

Table 39 Employment by GRDC agroecological zones, 2001

Region	GRDC zone	People employed in grain-related farming	Total employed people	Proportion (%) employed in grain-related farming	Summary measure[a]
Northern	Qld Central	1 026	28 254	4	0.43
	NSW Northwest–Qld Southwest	2 438	20 867	12	1.00
	NSW Northeast–Qld Southeast	7 782	165 691	5	0.64
Southern	NSW Central	5 080	44 721	11	1.00
	NSW/Vic Slopes	7 762	95 762	8	0.98
	SA/Vic Mallee	5 202	61 792	8	0.99
	SA Midnorth–Lower, Yorke, Eyre	5 656	54 492	10	1.00
	SA/Vic Bordertown–Wimmera	5 797	107 253	5	0.76
	Vic High Rainfall	1 151	140 068	1	0.06
	Tas Grain	191	11 705	2	0.12
Western	WA Northern	1 992	19 251	10	1.00
	WA Eastern	1 249	4 464	28	1.00
	WA Central	6 793	30 763	22	1.00
	WA Mallee and Sandplain	1 205	7 684	16	1.00
All regions	**All GRDC zones**	**53 324**	**792 767**	**7**	**0.91**

GRDC = Grains Research and Development Corporation; NSW = New South Wales; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

a This is a normalised measure based on the share of employment in the zone relative to the average for all agriculture (4%).

Source: ABS (2001)

Case studies of policy and management responses to key economic, environmental and social issues

Two case studies have been selected for incorporation into this grains industry Signposts report. They deal with:

- the adoption of conservation tillage and stubble management practices within a farming systems context
- the development of a database within the grains industry that measures the levels of farming practices, and can provide data to Signposts for use in indicators.

Selection of case studies

The case studies showcase:

- relevance to key issues identified in grains industry strategic plans and the *Grains Industry Environmental Plan* (in preparation at the time of this report)
- reporting on triple-bottom-line contributions to the wellbeing of both the grains industry and Australia
- development of significant causal relationships between change in farm practice and on-farm and off-farm benefits.

Case study 1 Conservation tillage and stubble management

Overview

Zero and minimum tillage techniques, together with stubble retention and incorporation, have been at the forefront of new grain farming systems. Introducing to these systems rotations with pastures, and bringing animals into these systems, have been the focus of more recent attention, through programs such as Grain & Graze. The net result is farming systems with greater groundcover across the year, more efficient water and nutrient use, reduced fuel use and carbon emissions, and reduced airborne dust and water sedimentation.

Characteristics

In traditional cropping systems, the crop stubble remaining following harvest is burnt in preparation for a clean sowing the following season or following a period of rest (fallow). This ensures the elimination of any weeds and diseases that would restrict successful planting.

However, in Australia's extreme growing conditions, systems that maximise infiltration and retention of water in the soil profile can be even more critical to successful establishment of crops. In Western Australia, for example, stubble retention trials showed that, after 50 millimetres of rainfall in early February, 85% more moisture was retained in the soil beneath the stubble than in paddocks that had been burnt. This is because of increased infiltration helped by the mulching effect as the rain collects below the straw. The system can also lock up more nitrogen for use by the following crop, helps bind the soil to resist wind and surface water erosion, and enhances soil structure and resistance to compaction.

Zero- or minimum-tillage systems seek to reduce the number of times per year paddocks are given a working over by farm machinery. This is to minimise soil disturbance to maximise soil heath, maintaining and enhancing soil biota, soil structure and moisture retention characteristics.

In combination, these systems are not without their challenges. Retaining crop stubble, for example, can create planting blockages and subsequent poor crop establishment. Incorporation of the stubble into the soil can overcome this, and improved plant machinery is also helping to assist direct drilling and seeding into paddocks with stubble.

In some systems, farmers introduce sheep onto the paddocks to reduce the total mass of stubble, while increasing the overall feed-base available to the animal side of their operation. The animals can also help reduce weeds, which is particularly important where herbicide resistance is becoming apparent.

Who is involved?

Unfortunately, the latest national surveys on stubble management practices date back to 2000–01, although it is safe to assume that adoption has increased further from the significant levels at that time. Table 40 outlines the adoption rate of the various practices described above for each state. Farmers across all states are involved in these practices; in 2000–01, they represented more than one-third of the grains industry.

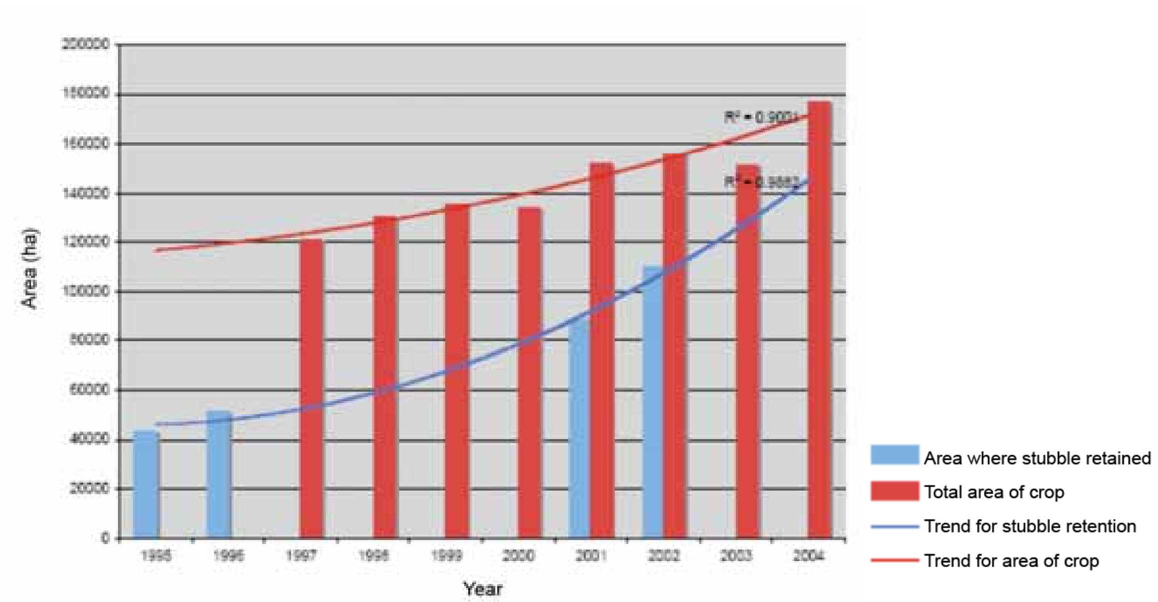
Table 40 Stubble management by state (2000–01)

	Area (000 ha)					
Response	**NSW**	**Vic**	**Qld**	**SA**	**WA**	**Tas**
Stubble left intact (no cultivation)	862	257	592	545	2756	3
Stubble ploughed into soil	1600	487	740	511	357	13
Total area treated	**2462**	**744**	**1332**	**1056**	**3113**	**16**

NSW = New South Wales; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia
Source: ABS (2003)

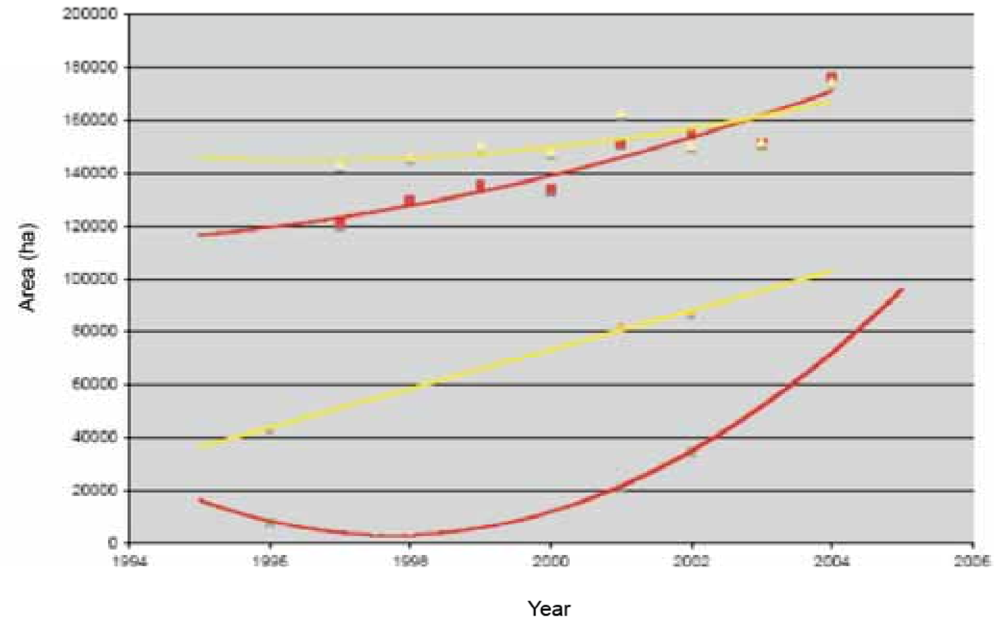
More recent data from the GCA shows an increasing trend towards improved stubble management and no-tillage practices (Figures 7 and 8).

Figure 7 Stubble retention — Parkes Shire



Source: ASFPD (2008)

Figure 8 Trends in no tillage — Parkes Shire



Source: ASFPD (2008)

Conservation farming groups, such as the Western Australian No-Till Farmers' Association, have proliferated across the country over the past decade to provide a focus for farmers to share their experiences in zero and minimum tillage and to share the cost of conducting local and regional trials. Such groups, while often regarded as 'production groups', play an important role in marrying production with social and environmental aspirations.

Closely related to these groups is the development of farming systems organisations, which provide the focus for GRDC and others to invest in research and development, and extension, in sustainable cropping systems. These groups also provide a good basis for longer monitoring of practice change at the regional level.

What are the benefits and who is benefiting?

The benefits of the uptake of conservation tillage practices are economic and environmental, both on-farm and across the general community.

The public

- Minimum and zero-tillage practices reduce the release of carbon dioxide and nitrous oxide into the atmosphere. Studies in the United States have reported typical carbon sequestration of more than 300 kg of carbon per hectare per year in no-till systems compared with conventional systems. Australian studies have shown benefits only where zero tillage is combined with stubble retention and application of fertiliser, but these benefits can be up to 2.3 tonnes of carbon per hectare per year (ASFPD 2008).
- The reduction of airborne dust and dust-storm events as a result of increased groundcover on farmland can reduce the incidence of respiratory dysfunctions such as asthma. CSIRO estimated that, in South Australia, as much as 20% of the state's asthma problems may be linked with windborne dust (Williams and Young 1999).
- The CSIRO study also showed that other off-site costs associated with agricultural dust include increased road accidents, increased road repair costs (removal of soil drift), electrical equipment failures and power leakages, and clean-up costs following dust storms. For Adelaide alone, these costs were estimated at around $16 million per year.

The producer

- Soil erosion can silt up banks and waterways. Over a 10-year period, it can cost up to 50% more to build and maintain banks in stubble-burn paddocks than in stubble-mulched paddocks (DLWC 1979).
- Benefits of zero or minimum tillage commonly cited by farmers include:
  - increased soil carbon
  - improved soil structure
  - improved soil microorganisms
  - nutrient retention
  - improved water infiltration
  - reduced compaction
  - reduced fuel bills
  - reduced soil erosion.

Case study 2 A grains industry and Signposts partnership for data gathering and sharing

Overview

The Signposts framework depends on the availability of appropriate data for compiling indicators against the various economic, environmental and social issues identified in the framework.

In many cases, data are available from public sources such as the ABS, ABARE or the NLWRA. However, in many other cases, data are not readily available, or are inconsistent in terminology, frequency of collection or measures used.

The grains industry sees an opportunity to assist Signposts with data about practices used on farms, and sees this as an important contribution to reporting on the industry's contribution to ESD.

In the past 30 years, traditional forms of integrating good natural resource management and agricultural production in formal programmed approaches have been difficult to implement. For example, the grains sector became one of the earliest agricultural industries to explore how environmental management systems (EMSs) might play a role in improving the performance of grain farms. However, the formal accredited systems, using tools and strategies based around the International Organization for Standardization (ISO) concept of continuous improvement, have not been popular with growers.

Farmers and scientists recognise the strong linkage between many farming practices, and both production and environmental benefits. The industry's Environmental Policy (GCA 2007) identifies improved environmental management on farms as being via the adoption of proven farming practices.

To this end, a national system has been developed that seeks to gather data from farmers about their farming systems, and the practices used, in quantitative terms. With knowledge of the indicators and data needs of Signposts, the grains industry can become a collaborative partner in providing datasets and indicators to Signposts data needs. It could act as a conduit of data from farms to agencies such as Signposts, using electronic means for data gathering, processing and transfer. This will supplement formal public data collections such as those conducted by ABARE and the ABS, or the activities of the NLWRA.

Characteristics

At the national level, the GCA, GRDC and the Australian Government have worked together under the government's Pathways to Industry EMS and Sustainable Industries' Initiatives programs to develop the a national database on farming practices. The Australian Sustainable Farming Practices Database links the farming practices of grain growers to the calculated environmental and productivity effects from these practices, against benchmarks of desired condition.

The database gathers information from grain (and mixed) farmers about their farming practices. It then delivers information and analysis reports about environmental management and productivity. The project's use of electronic media minimises costs and increases the ability to amalgamate information promptly.

Today's farming practices have established linkages with productivity and environmental effects. Signposts is a means of showing change and status of the industry.

The data, analyses and reports are about environmental indicators and production (economic) matters. They can be represented alongside the notional requirements of Signposts, as shown in Table 41.

Table 41 Indicators of interest to Signposts available from the Australian Sustainable Farming Practices Database

Signposts indicator data need	Available for Signposts from known sources	Able to be provided from database
Economic contribution		
Gross value of production	ABARE	No
Areas of crops	ABS, ABARE	Yes
Production (tonnes)	ABARE, ABS	Yes
Volume and value of exports	ABARE	No
Value of farmland	ABARE	No
Capital equity, rate of return etc.	ABARE, FM500	No
Total factor productivity	ABARE, others	No
Environmental contribution		
Soil nitrogen	NLWRA, ASRIS	No
Nitrogen applied on farms	ABS (2000–02 only)	Yes
Phosphorus applied on farms	ABS (2000–02 only)	Yes
Water use efficiency	NLWRA (some)	Yes
Tillage system (areas)	ABS (2000–02 only)	Yes
Soil cover	ABS (2000–02 only for stubble)	Yes
Soil erosion	NLWRA, ASRIS	Yes
Precision agriculture (various types)	No	Yes
Crop intensity	ABS (derived)	Yes
Cropping mix	ABS (derived)	Yes
Soil erosion control measures	ABS (2000–02 only)	Yes
Salinity (several measurements)	NLWRA, ASRIS, others	Yes
Perenniality	ABS	Yes
Area of pasture	ABS	Yes
Area of native vegetation by condition	ABS	Yes

Signposts indicator data need	Available for Signposts from known sources	Able to be provided from database
Replanting areas	ABS	Yes
Change in salinity risk	No	Yes
Areas fenced off for vegetation management	ABS	Yes
Areas of soil acidity	NLWRA, ASRIS	Yes
Areas treated with lime	ABS	Yes
Areas treated with gypsum	ABS	Yes
Native species under threat	DEWHA	No
Greenhouse gas emissions on-farm	No	Yes (future)
Integrated pest management strategies in use	No	Yes
Social contribution		
Human health (injuries)	Several, including NOHSC	No
Employment	ABS	Yes
Off-farm income	No	Yes

ABARE = Australian Bureau of Agricultural and Resource Economics; ABS = Australian Bureau of Statistics; ASRIS = Australian Soil Resources Information System; DEWHA = Australian Government Department of the Environment, Water, Heritage and the Arts; NLWRA = National Land & Water Resources Audit; NOHSC = National Occupational Health and Safety Commission

Key indicators that are required by industry are as follows.

Environmental data and indicators:

- soil management and erosion risk
- water use and potential for runoff or drainage
- nutrient use and balances
- energy and carbon management
- vegetation and riparian zone management
- integrated pest management practices

Productivity indicators:

- yield
- fertiliser use and nutrient use efficiency
- water use efficiency
- pesticide use profile
- time of sowing
- fallow use
- stubble management
- precision agriculture usage
- cropping intensity and rotations.

The proposed initiative aims to:

- provide grain producers with a tool for self assessing environmental and productivity performance
- provide data of value to Signposts and NRM bodies — the project has interacted with Signposts and NRM bodies to understand their needs; it aims to provide quantitative data amalgamated from farmers in the regions and agroecological zones of the grains industry
- provide industry with indicators and analyses of productivity for evaluating the adoption of research outcomes, identifying gaps, identifying the drivers of productivity and profit, and measuring industry trends and progress — these have value for planning and investment for research and development, and for policy development
- assist in communicating industry information to the public, through Signposts or in other ways
- keep abreast of changes in farming systems/practices; include indicators of interest as they develop (for example, from greenhouse gas research); and include these in data gathering and analyses, such that the information provided remains current and relevant
- provide a system attractive to farmers — the project aims to provide a cost-effective and time-efficient system using electronic methods, including the internet where possible.

Public data — for example, from the ABS and ABARE — often cannot provide detail about levels of farming practices or capture rapid changes in practices. These agencies do, however, provide value in enabling validation of the data in the database, and for general productivity information.

Who is involved?

By 2004, only about 400 farms across all agricultural industries were progressing towards the establishment of an EMS. By 2008, more than 600 grain growers were participating in the Farming Practices database, with full datasets received from half of these.

As of March 2008, the database has developed to the point where data can be entered by farmers using PDF files and email, with reports returned to them by email. Approximately 600 farmers are known to the database, and full datasets are in place for about half of these.

Signposts has expressed interest in receiving periodic reports containing data and indicators of interest, including many of those listed above.

Reporting capabilities to provide these have been designed and, when sufficient data are in the database, data exchange could begin.

What are the benefits and who is benefiting?

The public

- Environmental management, including on-farm environmental effects from farming, is an issue of growing importance in the community. The database, in partnership with Signposts, can assist with providing data and indicators of interest and a means of enabling producers and catchment managers to interact from a whole-farm perspective and not simply from a perspective of external environmental monitoring and compliance. In many cases, the adoption of good on-farm practices satisfies the need for resource condition maintenance, contributing to the wider health of the catchment.
- In addition to maintaining good resource condition on farm, measuring and reporting in a self-assessment fashion can lead increased production and environmental management — for example, more astute and efficient use of farm inputs such as chemicals, fuel, water and fertilisers. This reduces the possibility of excess and wastage that may have detrimental downstream impacts, while assisting with economic efficiency.

The producer

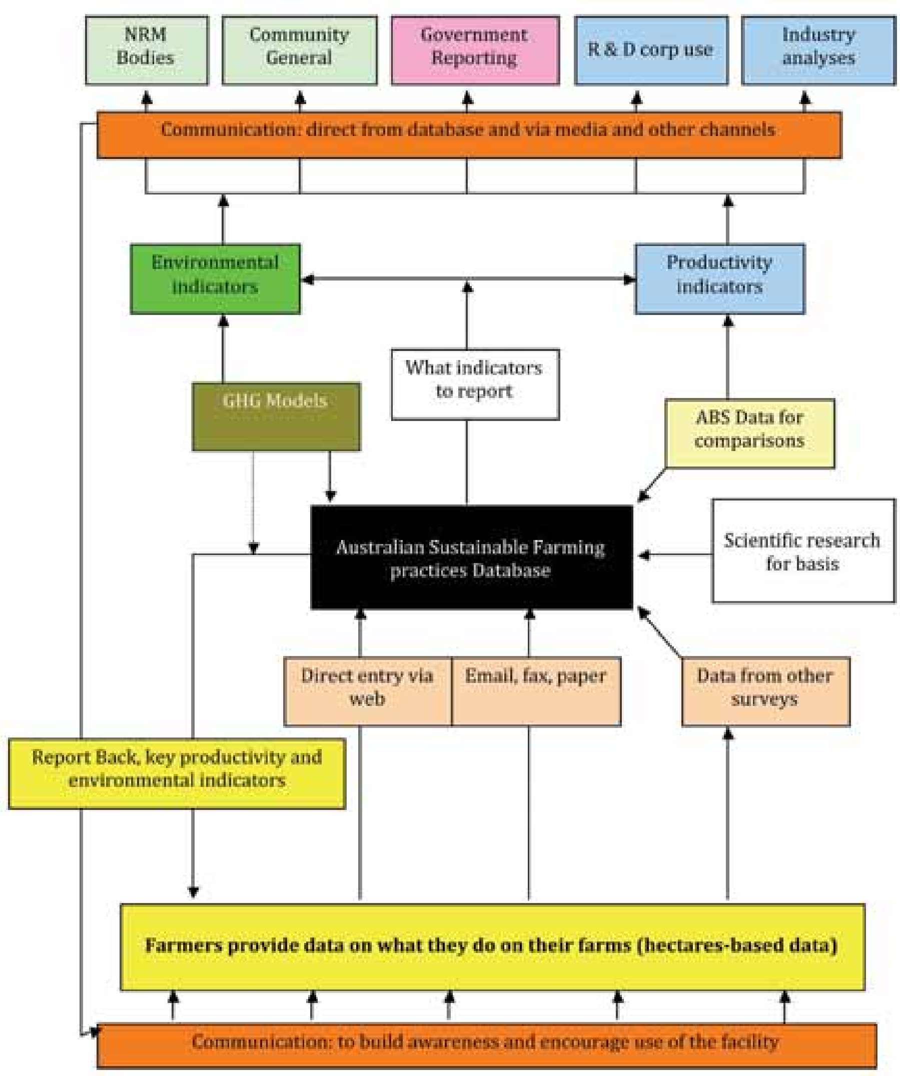
Participants in grain-related EMS trials have provided a broad range of reasons for their participation:

- supports more efficient property management
- helps improve communication with staff and management
- gives land-holders more control over debate on environmental issues
- provides a tool to demonstrate responsible land management
- provides the ability to demonstrate management practice connections to industry and catchment plans.

Figure 9 shows how the database project works.

Wheat fields (photo by Land & Water Australia 2004)

Figure 9 Grains industry and Signposts partnership database



ABS = Australian Bureau of Statistics; GHG = greenhouse gas; NRM = natural resource management; R&D = research and development

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About the Signposts for Australian Agriculture Report Series

The *Signposts for Australian Agriculture* project is a partnership between the Department of Agriculture, Fisheries and Forestry, Research and Development Corporations, and the National Land & Water Resources Audit.

The Signposts project aims to inform policy development by assessing and reporting on the environmental, economic and social contributions of Australian agricultural industries.

Six industry Signpost reports have been produced covering the following industries:

- Grains
- Beef
- Dairy
- Horticulture
- Wine
- Cotton