Futures

Exploring future landscapes: a conceptual framework for planned change

Stefan Hajkowicz, Tom Hatton, Jim McColl, Wayne Meyer and Mike Young

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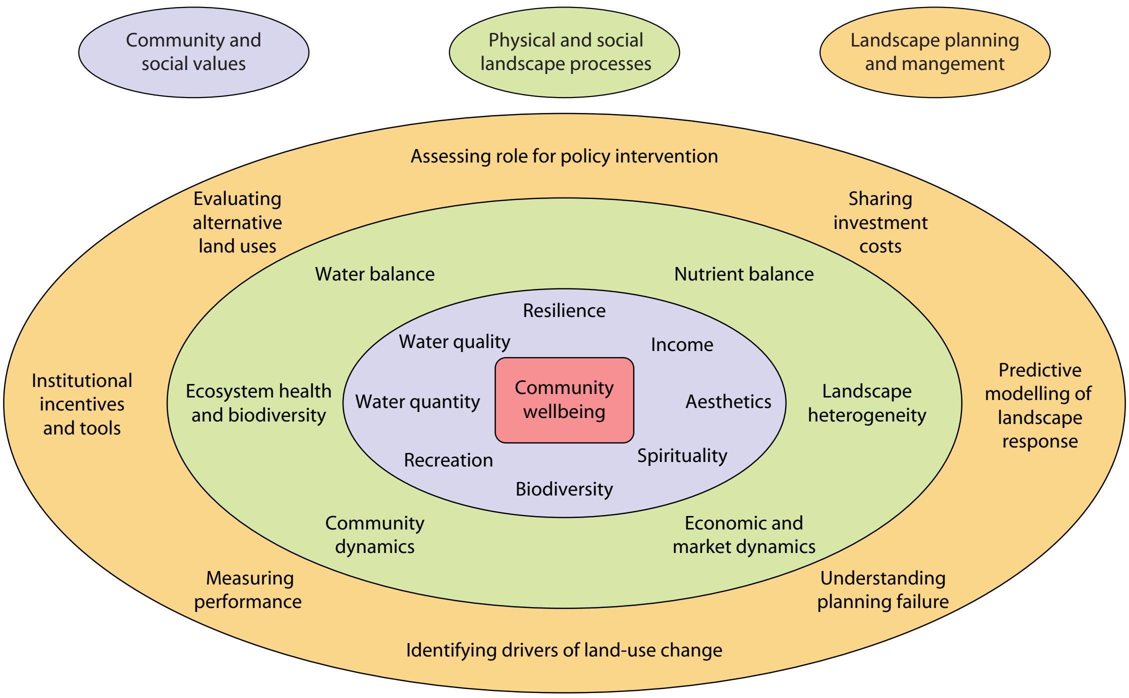
Summary

Despite ever-greater investments in Australia's natural-resource management, problems of land degradation, water-quality deterioration, declining farm income and stress in regional communities show few clear signs of improvement. In many cases these problems are becoming worse. Adjustment to avoid worsening outcomes is difficult, and win–win solutions are rare. In such situations, institutional failure is common.

One of the major causes of institutional failure in natural-resource management is a lack of integrated conceptual models that explain how a landscape (or catchment) functions and how landscapes respond to changes in management practice, market signals, or government policy. What are the fundamental physical and social processes that drive landscape change? What are the key components of planned and strategic institutional response? How can these issues be drawn together in an integrated framework that facilitates effective and targeted change?

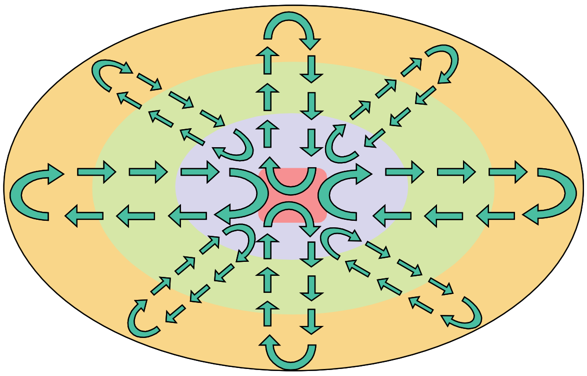
This report presents a conceptual framework for the planned change of Australian agricultural landscapes. The conceptual framework identifies the underlying landscape-scale processes that drive natural-resource condition and the fundamental principles of strategic institutional responses. These are assembled into an integrated conceptual framework for planned landscape change, as shown below.

The central goal is community wellbeing, broadly defined to include social, economic and environmental aspects (such as those listed in the inner ring). The middle ring contains a set of physical and social landscape processes that deliver the attributes valued by the community. The outer ring contains a set of institutional tools that can be



used to manage landscape processes, and thereby supply the attributes of community wellbeing.

Movement through this model is cyclical and adaptive. It usually commences at the centre, takes many different paths to the periphery and then returns to the centre (as shown below). In reality the system is highly iterative and unpredictable. It is impacted by political pressures, changing community values and new scientific information.



Community and social values

What are the long-term social, economic and environmental benefits that Australians are seeking from landscapes? The main objectives for managing Australian landscapes are:

- clean water (both surface and groundwater) used for environmental, industrial, commercial, agricultural and urban purposes
- sufficient flows and reserves of water to meet environmental, industrial, commercial, agricultural and urban uses
- rich terrestrial and aquatic biodiversity
- profitable land uses supporting regional development, vibrant communities and income requirements of individual land managers
- resilient social, economic and environmental systems capable of withstanding external shocks and adapting to new conditions
- resources that meet the aesthetic, recreational and spiritual needs of stakeholders.

While each objective is important, it will rarely be possible to deliver all simultaneously and to the same extent. Limited resources and technology constraints will inevitably force trade-offs. How these trade-offs are made, taking into account the conflicting requirements of multiple stakeholder groups, represents a major dilemma facing Australian natural-resource managers. A critical issue in making the trade-offs is understanding the response times for different landscape types. Often the lag between on-ground action and landscape response can span decades.

Physical and social landscape processes

Landscape capacity to provide broadly defined quality of life for communities (environmental, economic and social) will depend on a set of underlying physical and social processes. The major processes are tabulated in summary below:

Water balance	Hydrological processes drive the movement of salts, nutrients, sediments and pollutants through a landscape. They also govern rates of groundwater recharge and surface water flows. Disturbance of landscape hydrological processes can cause salinity and water-quality degradation. Use of water for irrigation, urban, industrial or environmental purposes will be limited by rates of groundwater recharge and surface water flows.
Nutrient balance	All animal and plant life is dependent on the supply of nutrients. As a finite resource, nutrient inputs must equal nutrient outputs if a production system is to be sustained. If nutrient inputs exceed plant capacity to capture those nutrients, an increased amount of nutrient will run-off into rivers and streams. This has a detrimental effect on water quality, affecting human health, recreation, aquatic ecosystems and water-treatment costs.
Landscape heterogeneity	A landscape has considerable natural spatial and temporal variability in geology, lithology, microclimate and hydrology. This drives varied terrestrial habitats and plant communities. Understanding this variability will assist the development of managed systems with superior economic and environmental performance. As a general rule, landscape diversity increases resilience (the capacity of a landscape to withstand external shocks and adapt to new circumstances).

Ecosystem health and biodiversity	Biodiversity and ecosystem health will be, in part, dependent on water and nutrient balances (described above). Some of the other main factors that play an important role at the landscape scale include environmental flows, remnant vegetation, waste assimilation and pest species. Management of these factors can help ensure biodiversity is maintained and ecosystems are healthy
Economic and market dynamics	The economic returns of land-use options (ie. profitability) will be a primary factor driving farmer decision-making relating to land-use change and adoption of new farming practices. Factors that change land use profitability over a long period (eg. an enduring change in commodity prices) are likely to change areas allocated to land uses, after a period of adjustment. Landscape redesign options will be considered in the social interest if total benefits can be demonstrated to exceed total costs.
Community dynamics	The demographic and socio-cultural characteristic of a community will have a significant impact on landscape form and function. An understanding of these characteristics will be important in assessing the effect of policies aimed at changing physical landscape condition. Some of the major factors affecting community capacity to change include farm income, farmer age, farmer education and learning style, family issues, attitudes and farm structure

Landscape planning and management

In tackling complex problems of land degradation, natural-resource managers will be challenged to resolve a suite of conceptual issues relating to institutional matters.

The major concepts of landscape planning and management include:

Assessing the role for policy intervention	Government policy aimed at changing land-management practice has a role where there is evidence of market failure. This occurs when the market is not delivering social benefits. Market failure can be caused by information failure, poorly defined property rights (public goods) or externalities. It is important to understand the nature and extent of market failure before implementing policies that will change the way the market operates.
Policy instruments and incentive mechanisms	Because land management and land-use change typically need to occur on privately owned land, government (and community groups) seeking to effect change will need to use institutional mechanisms. These include tools such as environmental accreditation, tradable property rights, grants and levies, fees for non-compliance, philanthropic investments and others. Careful application of these tools can lead to improved social outcomes from market forces.
Sharing private and public costs	Typically, projects or programs aimed at improving land-resource condition or management practice have both private and public benefits. This requires a cost-sharing arrangement. The arrangement will succeed if it holds clear benefit to both the private landholder and society, and if the landholder’s duty of care is externally defined and allowed to evolve.
Identifying the drivers of land use change	Understanding the determinants of land-use change allows an assessment future land use under ‘business as usual’ and a variety of policy scenarios. It also helps planning agencies understand where policy can be most effectively targeted. For most landscapes, it will be possible to identify a suite of factors that drive landholder decisions to change land use.
Evaluating land-use options	At the evaluation stage of the planning process it will be necessary to select a strategy from a set of alternatives. A range of complementary techniques can be used to evaluate landscape strategies. The purpose of these techniques is to inform decision-makers about the trade-offs involved in adopting a particular course of action

Predicting landscape responses	Sound natural-resource planning decisions will require information on the likely economic, social and environmental impacts of proposed landscape strategies. This can help reduce uncertainty and give decision-makers a better understanding of risk.
Understanding planning and institutional failure	There are many cases where plans fail to deliver desired outcomes and fall short of stakeholder expectations. Some of the major causes of landscape planning failure include insufficient funds, continual institutional change, marginalisation of stakeholder groups and a failure to reach the stage of implementation.

Perspectives on ways forward

The conceptual framework for planned landscape change can be approached from many different perspectives. Some of the major research fields and management styles that will contribute to planned landscape change in Australia include:

Improving production systems: research and development	Innovations in science and technology are continually providing farmers with production systems capable of improved environmental and/or economic performance.
Understanding ecosystem services	This perspective stresses opportunities to use natural processes to deliver outcomes, like flood control, fertilisation and water purification at less cost than conventional approaches.
Enhancing farmer attitudes, awareness and learning	Helping farmers to learn about improved techniques of land management and become aware of environmental issues will be an important component in attaining desired landscape change.
Improving and applying economic instruments	Developing economic instruments, such as tradable property rights and environmental certification, provides an option for attaining improved landscape health through the market.
Strengthening catchment planning, institutions and community processes	There is still much to be learnt about the institutional arrangements and processes for improved catchment planning. Taking a whole-of-catchment perspective to direct land-use change over time towards improved environmental, economic and social outcomes will help build healthy landscapes.
Understanding catchment-scale processes	Current knowledge of hydrological, geological, ecological, lithological and economic processes at the landscape scale is limited. This limitation places constraints on our ability to predict the future consequences of land-use change.
Understanding Australia's cultural and historical attachment to landscapes	An area of growing research and community interest is Australia's cultural relationship with its landscapes. How have Australian perceptions of landscape value and significance changed over time? What are the implications of this cultural change for land management policy and research? Understanding these factors will be pivotal to developing landscape plans that deliver community aspirations.

No single perspective will provide the entire solution. The challenge for the planning process is to integrate the perspectives and assist governments in making difficult choices. Lastly, we stress that each perspective depends on all other perspectives. The engineering perspective, for example, supports the farming perspective and these two are linked only through the catchment perspective.

Acknowledgments

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- Kathryn Bellette and a range of representatives from the Onkaparinga Catchment Water Management area (South Australia)
- Ned Rees and residents of the Collie Catchment (Western Australia)
- Di Bentley and residents of the Liverpool Plains Catchment (New South Wales)

Late afternoon landscape near Malanda, Atherton Tablelands, Queensland.
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Introduction

> "It is essential that we find new ways of managing and using our land that are more in tune with the needs of our valuable environment"
> (In a report prepared for the Australian Conservation Foundation and National Farmers' Federation, Madden *et al.* 2000)

> "We can have the landscapes we want, or we can endure the landscapes we let happen"
> (Hamblin 2000, p.1)

Agricultural industries have been a major driver of Australia's economic and social development over the past two centuries. However, over the 20th century the role of agriculture in the Australian economy has changed significantly. Today, agriculture contributes to around 25% of Australian exports, comprises 3% of gross domestic product, and employs around 5% of the workforce (ABARE 1999). Agriculture also characterises many Australian landscapes, being an important part of the national cultural identity. Agricultural land uses cover around 470 million ha, 62% of Australia's land surface area (NLWRA 2000a).

There is, however, a growing consensus amongst diverse community groups, scientists and policy-makers that agriculture needs to adapt to meet new challenges. This need has been highlighted by improved information on farm profitability, rural community structure, and salinity, water quality and other land-degradation problems. While these problems are well documented, the options and processes for achieving desired change are less clear. Many research, government and community groups are searching for an integrated framework that helps bring together scientific information, policy, community aspirations and on-ground actions to deliver real benefits.

This report presents a conceptual framework for the planned change, and where appropriate fundamental redesign, of Australian agricultural landscapes. The preliminary sections of the report discuss how the economics, institutions and natural-resource base of Australian agricultural landscapes have changed over time. This is followed by a consideration of alternative frameworks for conceptualising landscape change (sustainable development, ecosystem services, functional mimicry and strategic planning). The remaining three sections then present the conceptual framework for planned landscape change. This includes a description of the fundamental biophysical and social processes that guide landscape condition. Following this is a description of the institutional and policy options that can be used to guide the biophysical and social processes in desired directions. The concluding section draws all this together into an integrated conceptual framework.

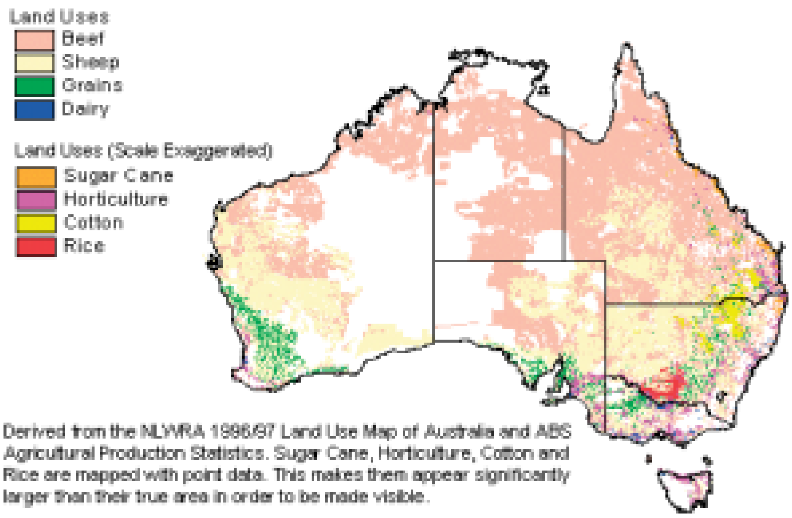

Figure 1. Agricultural land use in 1996–97. Source: NLWRA (2000a)

The report seeks to identify and discuss issues of direct and tangible relevance to landscape-scale natural-resource planning. Some additional facets of landscape planning not covered in the report, although still of significant importance, include major external perturbations, such as climate change, evolutionary responses of landscapes and recovery trajectories.

What is a conceptual framework?

The scope for developing this conceptual framework is extremely broad. The framework seeks to be potentially relevant to the whole of Australia, including all agricultural industries, all land-degradation problems and all landscape types.

The broad view taken in this project stems from the recognition that there are fundamental processes and approaches to managing landscapes that remain constant for different areas and different land-degradation issues. In developing the project, it was considered that narrowing the focus to specific land-degradation issues, industries or regions would hamper the development of a genuinely integrated framework that meets the needs of local, regional and national landscape management. Because the framework is integrated, across regions and issues, it requires a broad focus. Consequently, the framework seeks to examine fundamental and universally applicable concepts of planned landscape change and sustainable resource use. This brief has challenged the authors to look back through to the fundamental causes of land degradation and underlying theories of strategic, planned policy responses.

What a conceptual framework does

A conceptual framework is a tool to aid thinking. Typically, a conceptual framework structures the underlying methodologies, principles and rationale for a particular concept or project. Good frameworks tend to be simple: they show what is important. They also inspire people to take actions to address complex and challenging issues. In the context of Australian landscapes, a conceptual framework would be of much value to:

- the communities who live in them and use them
- researchers interested in contributing to their improvement
- those responsible for governance.

Ideally, the conceptual framework for landscape redesign should help scientists, policy advisers, farmers and community groups work through the complex processes of determining desirable changes to land use and land management activities at the landscape scale and how such changes might best be achieved. It should help give clarity to seemingly intractable problems.

What a conceptual framework does not do

The conceptual framework presented in this document has no mandate for policy implementation. It is not prescriptive, makes no policy recommendations and does not say what ‘should’ or ‘ought’ be done. The conceptual framework is purely a tool to aid thinking and assist decision-making.

What should be done is a complex policy question that generally requires input from the whole community. The role for a conceptual framework is to aid the thinking and learning of those responsible for developing policy. As with any aid to thinking and learning, it can be used to any extent that decision-makers, scientists, policy analysts, project officers or community members consider appropriate.

While the conceptual framework presented in this document takes a national view, it also recognises there will always exist limitless regional variations. There is no single conceptual framework that can provide comprehensive answers to natural-resource management policy questions throughout Australia. However, a good conceptual framework will be adaptable to suit the requirements of localised regions, industries and community groups.

Development of the conceptual framework

This document arises from a Land & Water Australia (LWA)-funded project entitled “Conceptual framework for landscape redesign”. The project was funded under the Redesigning Agriculture for Australian Landscapes (RAAL) research and development program, a joint initiative of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and LWA. A major objective of the RAAL program is the identification, development and evaluation of food and fibre production systems that meet landholder financial requirements, while avoiding or ameliorating a broad range of land-degradation problems.

Given the diversity of issues and perspectives on ‘redesigning agriculture’, the RAAL steering committee funded this project to explore the underlying concepts. This has helped characterise the underpinning concepts of landscape change in Australia, providing a conceptual framework for researchers, farmers, policy-makers and the community. The project involved broad consultation with community groups and experts around Australia, the results of which have been incorporated into this document. The groups consulted included:

- the Rural Futures Network in Pomona, south-eastern Queensland

- the Liverpool Plains Catchment Management Group in Gunnedah, New South Wales
- the Onkaparinga Catchment Group in Adelaide, South Australia
- the Collie Catchment Recovery Team in Darkan, Western Australia
- a group of agricultural scientists, ecologists, economists, policy-makers and natural-resource management experts in Canberra.

Applying the conceptual framework

This conceptual framework is designed to assist community groups, researchers and policy-makers address complex problems of natural resource planning at the landscape scale. This section describes the ways in which the conceptual framework is likely to be useful to each group.

Community groups

Over the past few decades, community groups such as catchment coordinating committees, have been allocated increased responsibility for regionalised natural-resource management. This is occurring through moves towards decentralised (bottom-up) governance systems. Community groups are sometimes granted significant influence over public funds, being able to decide on which projects to fund and where to prioritise on-ground works within their local region. Community groups also have a substantial ability to leverage private funds, from landholders or industry. In a few cases, community-based catchment-management groups may have statutory powers derived from a catchment plan.

With increased responsibility there is also emerging an increased need for guidelines and conceptual frameworks to help community members handle complex problems of catchment management. Often, natural-resource management community groups are faced with:

- overwhelming amounts of complicated data but very little useful information of direct relevance to critical decisions
- conflicting priorities held by multiple stakeholder groups
- insufficient funds to cover all matters of concern comprehensively, or even adequately;
- high degrees of uncertainty surrounding the future impacts of land-management decisions
- conflicting advice from scientists and experts
- no agreed or accepted framework for catchment planning, decision-making or resolving stakeholder conflicts.

Our conceptual framework is designed to help community groups avoid many of these problems. It will help community panels assess the values for their particular region, and show how relevant scientific and technical expertise can be drawn upon to protect and enhance those values. It is hoped that the framework will help provide community groups with a basis to developing strategic catchment plans suited to their own region. In particular it will help community groups determine:

- What are the values held by stakeholders? What trade-offs in these values may be required?
- What scientific knowledge is required to understand the physical and social processes that will guide landscape condition?
- What are the institutional tools available to implement the desired land-use or land-management practice change?

Researchers

A noticeable trend in natural-resource management research is the shift towards interdisciplinary investigations. Problems such as dryland salinity or sediment deposition generally involve agronomic, hydrological, ecological, social and economic components. Very rarely does any one discipline provide all the answers. However, operationalising an effective interdisciplinary team to deliver workable solutions is a complex task, often prone to failure. It is arguably one of the major challenges facing natural-resource management research agencies today.

While there are many obstacles to effective interdisciplinary research, one major barrier is the lack of conceptual models that allow each player to see their component within a broader system. This can lead to individuals believing their own particular area holds all the solutions, and difficulties in the exchange of information between groups.

Urban and agricultural landscape, Blue Lake at Mt Gambier South Australia. © CSIRO

The conceptual framework is intended to assist research teams assess how their work might fit within a broader solution to a natural-resource management problem. It will also help research teams identify how they might best supply information to catchment groups or policy-makers. We hope that this will help researchers better pitch their research to stakeholders and prepare improved research proposals.

Policy-makers

With so large an area of Australia under private freehold or leasehold ownership, it is not sufficient for society to merely want change in land use. Policy-makers, acting on behalf of politicians and other decision-makers, need to create a policy environment in which change is likely to occur. This requires careful application of a suite of institutional tools such as incentive mechanisms, environmental accreditation, tradable property rights and regulation.

The success of these policy instruments will partly depend on how well they are targeted. Being able to develop a targeted policy response will, in turn, depend on identifying the natural and social processes associated with landscapes and how they need to change in order to deliver community values. The conceptual framework identifies the suite of options open to policy-makers to influence and manage land-use change.

What are landscapes?

As landscapes are the focus of this report, it is worth exploring briefly what is meant by the term 'landscape'. A landscape is a geographic region containing interconnected biophysical, social and economic processes. Landscapes derive spatial definition through a range factors (see Figure 2). Which factors are used to develop a boundary, and the relative importance of those factors, will depend on the task at hand.

A commonly used delineation of a landscape boundary in Australia is that of a catchment. Catchments provide useful spatial units within which to manage natural resources. This is largely because catchment form governs hydrological processes, which, in turn, determine many land-use options and the ultimate fate of many of the assets that form a landscape. Salinity, soil erosion and deposition, nutrient run-off and water-quality degradation are all examples of processes influenced by catchment hydrology. Catchment hydrology also has a strong influence on the pattern of land-use activities, crop/pasture yields and profitability of agricultural enterprises.

Alternative regional frameworks to catchments include biogeographic regions or administrative regions (eg. local government boundaries or funding regions). Clearly, the selection of a boundary for delivery of localised natural-resource management strategies is highly dependent on the specific issue at hand. In some cases, it will be more important to develop administratively consistent boundaries, where in others the biophysical boundaries will be of greater import. There have been some suggestions that administrative boundaries could be more closely aligned with biophysical landscape boundaries.

Why change Australian landscapes?

Over the past several decades, the impetus for landscape change in Australia has expanded from production to encompass environmental and long-term sustainability issues. Landcare, the Natural Heritage Trust and a suite of other community-driven programs have largely facilitated this change in focus. Today, the land-management debate is being driven by concerns relating to the profitability of agricultural enterprises, the quality of rural life, water quality, soil health, biodiversity and landscape aesthetics. While a great many factors prompt the need for landscape change, five major factors, as detailed overleaf, are of key importance:

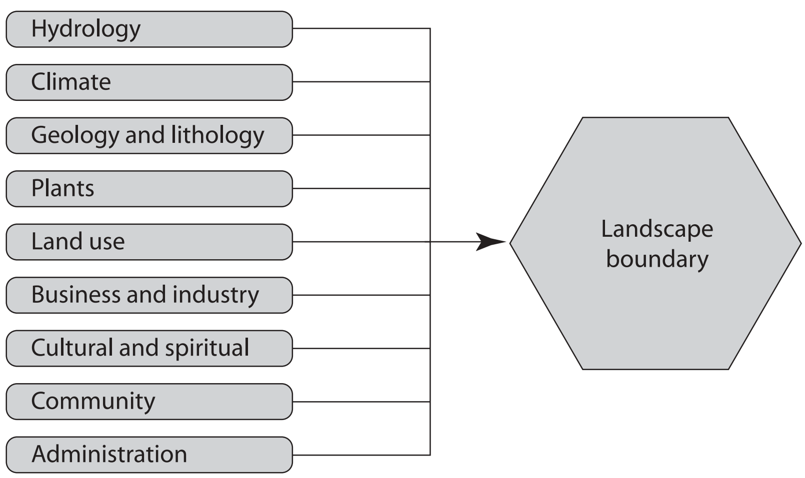

Figure 2. Factors that give landscapes definition

Losses in soil productivity	Land-resource productivity problems such as salinity, acidity, acid sulphate soils, sodic soils, soil compaction, soil erosion and soil contamination have generally increased in area over the past century, and some are likely to continue to increase. For example, it is estimated that dryland salinity nationally affects 5.7 million hectares and that this may increase to 17 million hectares in 50 years without intervention (NLWRA 2000b). The need to halt or reverse these problems is prompting the need for landscape-scale change.
Water-quality degradation	There is much anecdotal and scientific evidence indicating that Australia's surface-water resources are deteriorating in quality. Examples of water quality degradation problems include changing environmental flows, increasing levels of salinity, algal blooms, eutrophication, turbidity, acidity and increased nutrient loads. The annual cost of algal blooms alone is estimated at between $180–$240 million (LWRRDC 1999). Many of these water-quality problems have been linked to current and historical land-management practices.
Biodiversity loss and risk	There has been a significant loss of biodiversity and landscape amenity. The *Australian State of the Environment Report* (SEAC 1996) presents data on pressures to biodiversity, suggesting that agriculture is the major cause of 78 species extinctions and is placing a further 105 species at "present or future threat". The Western Australia State Salinity Strategy (State Salinity Council 2000) forecast the potential loss of 450 species of plants to dryland salinity in the absence of intervention.
Farm income decline (industry and region specific)	Farm incomes in some rural regions for some industries have not kept pace with other parts of Australia. Farmers, particularly those in the broadacre regions, are increasingly relying on off-farm income. The decline in profitability of some agricultural enterprises is having negative effects on whole regional communities. Through landscape change, such as the adoption of new industries, farming practices or technologies, it may be possible to help improve the profitability of agricultural enterprises. This will help sustain employment in the agricultural sector and will have many other community benefits.
Rural population decline	Some rural communities are in population decline, with many people migrating to urban areas and important services being withdrawn. The portion of Australians living in rural areas has dropped from 37.4% in 1921 to 15% in 1986 (ABS 1992). The drift of Australia's population to cities is partly why many rural communities are actively seeking ways to rejuvenate the local regions, encouraging more people to stay or return. Landscape renewal, ie. the rejuvenation of landscapes, may offer opportunities for assisting such efforts.

The challenge for landscape renewal today is primarily one of implementing new systems of food and fibre production and regional-scale patterns of land-use that perform well not only financially, but also ecologically and socially. In meeting this challenge, researchers, policy-makers, farmers and the general community will be able to draw upon a wide range of technological advances, knowledge of natural resource management issues and institutional frameworks that have hitherto been unavailable.

Australian agricultural landscapes

The history of Australian agriculture and land management is one of continual change and adaptation. The first human-induced changes to Australian landscapes trace back to Indigenous Australians who farmed not with fences and ploughs, but with fire. Evidence for this type of farming comes from archaeological research and accounts by early European explorers (Barr and Cary 1992). Through the use of fire, Indigenous Australians opened up areas of grassland that attracted kangaroos and other wildlife, making for easy hunting. In so doing, they significantly altered parts of the Australian landscape to better suit their purposes. The modified landscapes occurred through processes of learning, experimentation and adaptation.

The first European attempts at agriculture in Australia can be traced back to Governor Arthur Phillip shortly after the first fleet's arrival in 1788 (Bromby 1986). These early beginnings saw hopelessly inadequate agricultural production techniques and the colony facing a real possibility of starvation. Some practices that led to inadequate yields from crops included mixing different varieties of seed, resulting in the crop ripening at different stages, and sowing the land with the same seed year after year, leading to its exhaustion. Crops often failed and yields were mostly inadequate. Ships were dispatched to India and other places to obtain much-needed rice, wheat and other grain (Bromby 1986).

However, the early European arrivals were quick to learn and redesign their agricultural practices. One of the early entrepreneurs, often credited with having started the Australian wool industry, was James Macarthur. Through some clever management, Macarthur was able to float the Australian Agricultural Company in 1824 with a reported 1 million pounds in capital (Bromby 1986). This represents rapid and impressive development when contrasted to the state of affairs in the first few years after the first fleet's arrival.

Since these beginnings, Australia's agriculture and its landscapes have undergone continual change. New farming practices, crop rotations and technologies have led to significant jumps in yields and production efficiency. For example, Figure 3 shows changes in mean wheat yields since 1870. After an initial decline in yield from nutrient exhaustion, wheat yields grew from around 860 kg/ha/year in 1870 to 1,375 kg/ha/year in 1990 (Hamblin and Kyneur 1993). Similar improvements in yields could be found for most other crop, horticulture and livestock production forms. Most advances have been associated with the development of fertilisers, herbicides, pesticides, new plant species, adoption of improved farming practice and adoption of better farm equipment.

Throughout the later part of 20th century, some negative consequences of rapid agricultural expansion became

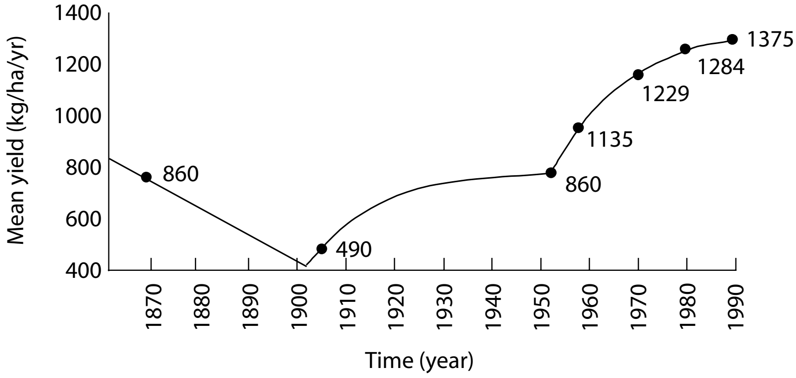

Figure 3. Increase in mean wheat yields since 1870 in Australia (Hamblin and Kyneur 1993)

apparent. The first nationwide assessment of land degradation problems was conducted in 1975–77 by the Commonwealth Department of Environment, Housing and Community Development (Conacher and Conacher 1995). This study found that 815 km^2 of Australia required treatment due to problems of water erosion, wind erosion, vegetation degradation, dryland salinity and irrigation salinity (Woods 1983). Since this time, there have been many more projects documenting the emergence of environmental problems associated with agriculture. For example, the National Land and Water Resources Audit (NLWRA) is currently providing information on the extent and severity of salinity, erosion, water-quality degradation, habitat damage and socio-cultural changes in the rural sector.

Agriculture's changing economic environment

Agriculture has been a primary driver of Australia's economic development. The 1901 population census recorded around 23% of Australians employed directly in agricultural and pastoral industries (Pollard 2001). Many more Australians were employed in industries providing services to agriculture or processing agricultural goods. During the period 1860–1940, agriculture contributed to around 20–30% of Australia's total economic output (Wonder and Fisher 1990). Until the 1960s, Australia obtained at least a third of its export income from wool alone (Cornwall *et al.* 2000). At the height of wool prosperity, 1950/51, the Australian economy was said to be "riding on the sheep's back" (Pollard 2001).

However, over the 20th century, the role of agriculture in the Australian economy has changed significantly. It now contributes around 3% of gross domestic product (GDP), employs around 5% of the workforce and contributes around 25% of exports. These trends are fairly similar for most industrialised nations. There is a general trend for the relative contribution of agriculture to decline, whilst other sectors, primarily the services sector, have rapidly grown. Nevertheless, with such a substantial contribution to world exports, agriculture remains an industry of great importance to the nation.

Another important characteristic of Australian agriculture is the spatial concentration of economic returns to the natural resource base. New data sets are showing that economic returns from agriculture are highly spatially concentrated. Taking into account Australia's intensively and extensively (rangelands) used agricultural regions, around 1% of land produced 80% of the total net returns in 1996/97 (NLWRA 2001a). Also, while covering only around 0.5% of Australia's agricultural land area, irrigated land uses contribute around 50% to net economic returns. The spatial variation of returns from agriculture can be seen in Figures 4 and 5. These maps indicate that large areas of Australia are not making a return from the natural-resource base through agriculture. Many of the areas shown as making a loss are being heavily supplemented by off-farm income.

There is a likelihood that in regions where agriculture's relative economic importance is diminishing, local and more distant communities may draw upon landscapes for a wider range of services than food and fibre production. For example, the values placed on clean water, biodiversity and landscape aesthetics may become of greater importance. This is particularly likely, and already evident, in catchments that supply water to large cities or

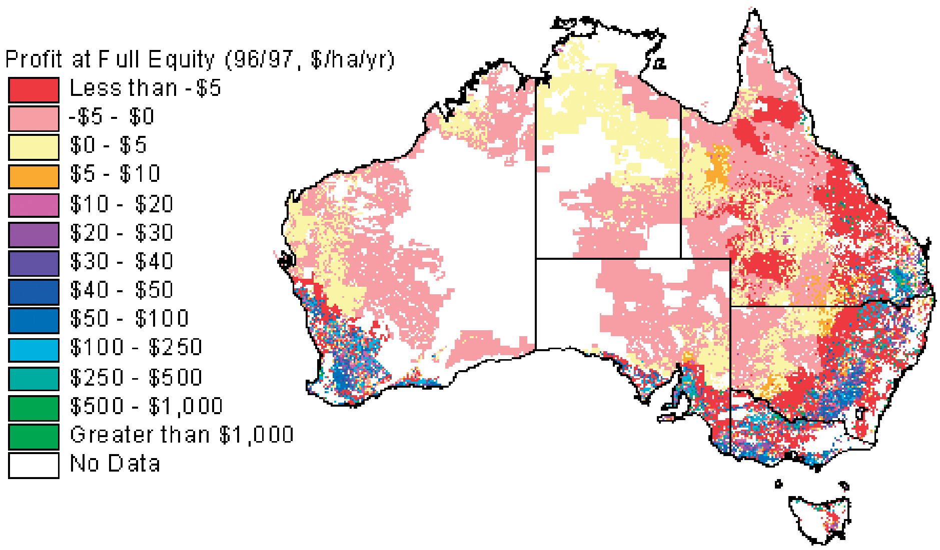

Figure 4. Profit at full equity in 1996–97. Sources: CSIRO and NLWRA (2001a)

have high tourism or recreational value. In such catchments, farmers may be in a position where they are supplying a broader variety of services to the community, not merely foods and fibres. The community may derive services such as clean water, aesthetically pleasing landscapes and diverse ecosystems. As these benefits are shared, issues will undoubtedly arise surrounding the sharing of natural-resource management investments. Currently, the marketplace rarely provides a private return for the provision of public environmental goods and services, despite their obvious value.

Another observation that emerges from Australian agriculture's changing economic setting is the notion of reinvestment in natural capital. There is evidence to suggest that in some regions, natural capital has been degraded, particularly biodiversity and water quality, in order to accumulate human capital. Indeed, it could be argued that Australia's current prosperity was largely derived by running down natural capital. The clearing of land for agriculture, and subsequent degradation of the natural environment, enabled an agricultural industry to develop from which much of the nation's economic development was derived. However, with an economy less dependent on agricultural resources than it has been previously, Australia may be in position to reinvest in natural capital. The wealth accumulated through exploitation of natural resources has enabled new industries to develop, which themselves have created further wealth. As social values placed on the natural environment continually increase, there mounts a strong case for reinvestment in natural capital.

Agriculture's changing natural-resource base

The productive capacity of soil in many agricultural areas of Australia has been diminished through degradation processes such as salinisation, acidification and soil-structure decline. For example, the NLWRA (2000b) estimates that around 5.7 million ha of land currently has a salinisation risk and this will grow to 17 million ha by 2050. Other problems are also likely to affect very large areas, but are less well documented. However, in many other areas, the productive capacity of Australia's nutrient-poor soils has been increased, primarily through the application of fertilisers and other soil treatments. Have the losses been offset by the gains?

Net primary productivity (NPP) is an indicator of the land's capacity to generate useful carbon, in the form of food and fibre. Under the NLWRA, surfaces of NPP have been generated for Australia by CSIRO (NLWRA 2001b). One of these surfaces shows the ratio of NPP with agriculture to NPP without agriculture (see Figure 6). Perhaps surprising to many, this ratio is greater than one almost everywhere. This suggests that by-and-large, agricultural practices have increased the productive capacity of the soil. Strictly from an agricultural production perspective, the data suggest that Australian soil resources have been improved, not degraded, by agriculture.

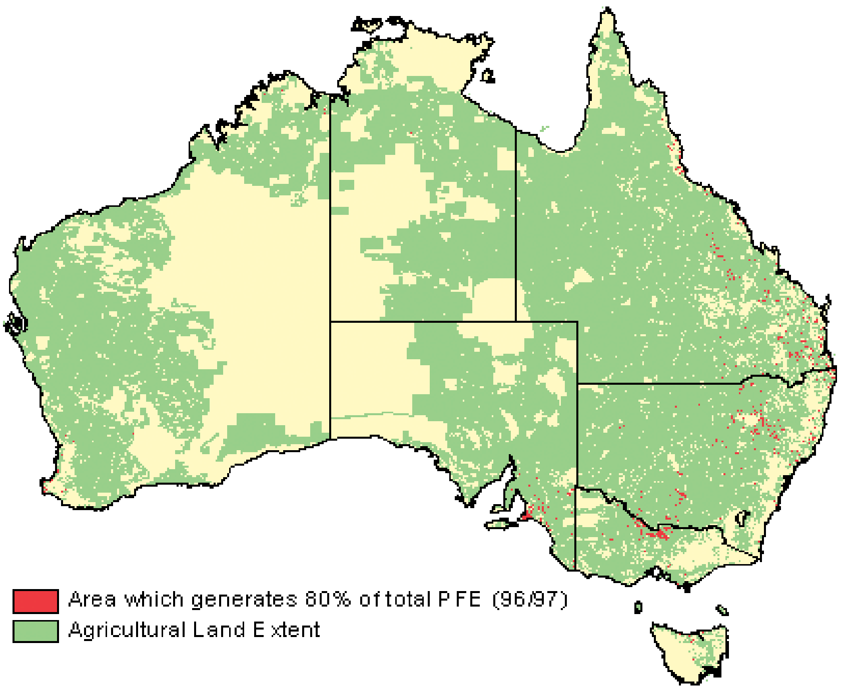

Figure 5. Area from which 80% of net economic returns from agriculture were obtained in 1996/97. Source: NLWRA (2001a)

The findings of increased NPP resulting from nutrient inputs associated with European-style agriculture should be tempered by two important related trends. Firstly, the productive capacity of the soil is dependent on continued fertiliser inputs. If the fertiliser inputs were ceased or suspended, soil fertility would drastically decline as a result of leaching and erosion processes. In many regions, sustained food and fibre production at current levels is dependent on continued nutrient inputs. Secondly, the increase in soil nutrients has resulted in an increased throughput at both 'ends' of the nutrient cycle. More nutrients are entering the system, through fertiliser inputs, and more nutrients are exiting the system. Nutrients exiting the system are having a detrimental impact on surface and groundwater quality.

Whilst there can be debate over whether, and the extent to which, Australia has degraded its soil resources, the degradation of natural habitats, stream/river water quality and groundwater resources is more apparent. For example, the Australian State of the Environment Report indicates that agriculture is the major cause of 78 species extinctions and is placing a further 105 species at "present or future threat". The Western Australia State Salinity Strategy (State Salinity Council 2000) forecast the potential loss of 450 species of plants to dryland salinity in the absence of intervention. Surface and groundwater resources have also been severely degraded and depleted as a result of post-European land-management practices. For example, the NLWRA (2000c) found that:

- 26% of Australia's surface-water resources are either close to or overused compared with sustainable flow regime requirements
- 30% of Australia's groundwater resources are either close to or overused when compared with their estimated sustainable yield
- 65 of Australia's 246 river basins had major exceedences of State or Territory guidelines for nutrients, salinity or turbidity.

There is widespread acceptance that negative environmental impacts from current and historical land-management practices need to be addressed. It is worth noting that much of the historical land clearing that has resulted in environmental degradation was supported by government. At the time these actions were taken, cultural values were different and there was limited knowledge of the potential to cause land degradation. Today, problems of natural-resource degradation are a collective issue that will require a whole-of-community response.

A multi-functional landscape. Housing, recreational space and farming in Griffith, New South Wales. © CSIRO

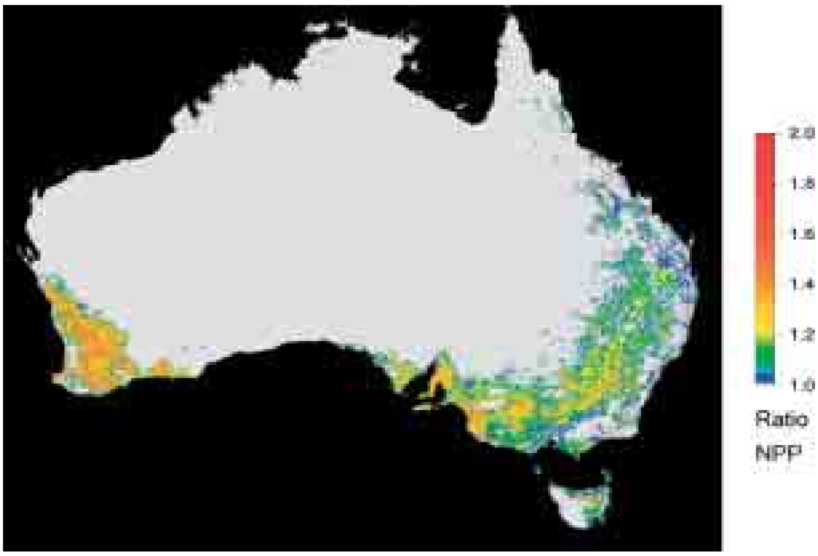

Figure 6. Net primary productivity with/without agriculture ratio. Sources: NLWRA (2001b); Raupach *et al.* (2001)

Agriculture's changing institutional setting (Jim McColl)

Land settlement and development loomed large in public thinking in the early days, and *Lands Departments* were one of the earliest and most important government agencies established by state governments. Upon federation of the Australian states in 1901, administration of land and responsibility for agricultural and pastoral production was left as a responsibility of the states. Each of the states had a department of agriculture or an equivalent agency, with control over the movement of plants and animals being a primary focus of regulatory activities.

In the early years of the 20th century, research and extension in agriculture remained predominantly functions of state administrations. Formal coordination of Commonwealth and state activities did not occur until 1934, with the establishment of Australian Agricultural Council of Ministers and the Standing Committee of Agriculture consisting of heads of departments.

In research, change began with the establishment by the Commonwealth Institute of Science and Industry in 1920, eventually becoming the Commonwealth Scientific and Industrial Research Organisation (CSIRO). After World War 2, state departments of agriculture also expanded both research and extension capabilities with a major focus on stimulating increased agricultural production and contribution by the agricultural export sector to address the balance of payments problem during the post-war period. The Commonwealth established the Department of Primary Industry with major sections including such agencies as the Bureau of Agricultural Economics, the Forestry and Timber Bureau, and the Bureau of Animal Health. The Tariff Board, which was replaced by the Industries Assistance Commission (IAC, now the Productivity Commission) in 1973, advised on assistance for industries, including those in the rural sector. The Reserve Bank, the Commonwealth Banking Corporation and the Primary Industries Bank — in fact, a wide range of agencies, both state and Commonwealth — provided specific services to the rural sector.

The focus of resource management during this period was mainly directed at soil conservation to address soil erosion from both wind and water, and to animal and plant pest and disease control. Early signs of salinity impacts were also recognised, particularly in certain irrigation areas (eg. Kerang in northern Victoria) and, to a lesser extent, in dryland areas. Soil conservation branches in departments of agriculture or independent soil conservation agencies were established by states.

The early 1970s heralded the beginning of a management/marketing phase resulting in significant change in both community and government policies for agriculture. Britain had joined the European Community, and new markets needed to be developed. Assistance to industries, initially agricultural industries, came under intense scrutiny, mainly through the activities of the IAC. This resulted in the removal of tax incentives for land development, reduction in tariff protection for many industries, removal of input subsidies (eg. superphosphate), and changes in marketing arrangements. Agriculture was progressively exposed to the competitive international marketplace. Rural assistance and adjustment schemes were established, aiming to smooth the increasing structural adjustment pressures.

Farm organisations, for example, the National Farmers Federation in the late 1970s, became comparatively well organised and began to employ trained, professional staff. The policy positions taken by most farm organisations were increasingly well researched and argued.

Departments of agriculture began to be placed under financial pressure with increased accountability for the justification of and quality of service. Improved research management became important, and farmers began to provide increased funding support through research councils and later through research and development corporations.

Since the early 1970s, governments and primary industry organisations have shown a developing awareness of long-term sustainable management of the natural-resource base. The establishment of departments of environment, and the gradual change in overall community attitudes to environmental issues — local, national and global — has been very important in stimulating some changes in the institutional environment. The extraordinary rate of development of Landcare and the progressive involvement of communities through total or integrated catchment management over the last ten years has created an expectation by local catchment communities of effective government support in addressing environmental requirements.

Pathways for change

The emergence of negative social and environmental impacts arising from human activities throughout much of the 20th century prompted widespread debate about alternative and improved ways of doing business. The notion of sustainable development, first gaining prominence in 1972 at a United Nations conference in Stockholm, was arguably the most notable conceptual shift towards changed approaches to natural-resource management.

Under various guises, sustainable development was adopted in many countries as an overriding objective of natural-resource management during the period 1980–2000. Australia responded in the early 1990s with a National Strategy for Ecologically Sustainable Development. However, since the publication of "Our Common Future" (The Bruntland Report) and the 1992 Rio Conference on Environment and Development, the notion of sustainable development has fragmented into a multitude of ideas and philosophies on how natural resources should be managed.

In this section, a handful of these frameworks, ideas and philosophies for attaining desired future landscapes are briefly explored. These represent alternative conceptual approaches for thinking through and tackling landscape-scale change.

The rise and fall of sustainable development

Sustainable development is primarily adopted in Australia through the National Strategy for Ecologically Sustainable Development (NSESD) published in 1993. The Commonwealth Government defines ecologically sustainable development (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". The concept of ESD has provided an overriding objective for much of Australia's natural-resource management policy since its inception. Much of the debate surrounding natural-resource management directions for Australia relates to ESD.

While widely adopted in principle, the operational and practical implications of ESD have been harder to identify. The difficulty associated with operationalising broad concepts of sustainability at a practical level, leading to tangible on-ground changes, has been one of ESD's major stumbling blocks. At a conference on *Visions of Future Landscapes* Byron (2000) identified three phases in Australia's ESD journey:

- *Early concepts.* This stage facilitated the adoption of a common language to discuss issues of natural-resource management. It provided a platform for debate and informed discussion about how Australia's natural resources could be managed. Some have suggested that the early phases of ESD were characterised by much enthusiasm and the emergence of some rhetoric. The language of ESD was sufficiently generalised to be attractive to diverse stakeholder groups.
- *Minor adjustment phase.* In this phase, Australia has identified and adopted win–win options for natural-resource management that provide both economic and environmental benefits — examples include energy-efficient cars and solar power. Byron argues we are nearing the conclusion of the second phase and entering the third.
- *Trade-off phase.* This phase will require difficult decisions involving conflicting social, economic and environmental priorities. In some cases, decisions will be made favouring environmental outcomes, in others preference will be given to economic development. How these trade-offs are made will be dependent on values held by decision-makers, and those they represent.

The eagerness to move beyond concepts and rhetoric towards real, tangible landscape change was reaffirmed at a series of community workshops held by CSIRO, funded by Land & Water Australia, in early 2001 (these workshops were part of the project for which this report was prepared). An issue raised repeatedly by those attending the workshops was that of frustration with repeated attempts to define and redefine the concept of sustainable land management. There was a feeling that these debates on 'defining sustainability' had been held to the point of no longer yielding useful outcomes. The desire was to move forward towards tangible change.

The implication for new conceptual frameworks from this shift away from sustainability language is that they must, in simple terms, identify the primary drivers and issues behind improved land management. What are the fundamental biophysical, social and economic attributes that are sought from a landscape? How are they attained? What are the trade-offs? There will be fundamental laws of science (physical and social) that drive these outcomes.

A failure to make the necessary trade-offs now, ie. indefinitely delaying difficult decisions, could result in a fourth phase of the sustainable-development journey. This phase would be marked by drastic actions responding to crises in the Australian landscape. Such actions would require sudden and far-reaching changes, with major ramifications for regional communities. To avoid this situation, difficult natural-resource management decisions will need to be made over the next few years.

Ecosystem services

Some important research into identifying and assessing values derived from natural landscapes has been conducted under a CSIRO research project entitled *Ecosystem Services* (Binning *et al.* 2001; Cork 2002; Cork *et al.* 2001, 2002; Sheldon *et al.* 2001). An ecosystem service is any benefit derived by humans from the natural environment. This includes a diverse range of goods and services such as clean water, clean air, productive soil, scenery and recreational opportunities. A generalised list of ecosystem services is shown in Box 1.

One of the major international proponents of ecosystem services, Gretchen Daily, suggests that ecosystem services provide a new 'conceptual framework' to describe, monitor and manage landscape changes and their impacts on society. Daily (2000) identifies four key elements of the ecosystem services conceptual framework:

1. *Identification of ecosystems services*. This involves a systematic and, where possible, quantitative cataloguing of all goods and services provided to people by the natural environment.
2. *Characterisation of ecosystem services*. This involves understanding the processes that provide ecosystem

Box 1. A summary of ecosystem services (from Daily 2000)

Production of goods

Food: terrestrial animal and plant products, forage, seafood, spice
Pharmaceuticals: medicinal products, precursors to synthetic pharmaceuticals
Durable materials: natural fibre, timber
Energy: biomass fuels, low-sediment water for hydropower
Industrial products: waxes, oils, fragrances, dyes, latex, rubber, precursors to many synthetic products
Genetic resources: intermediate goods that enhance the production of other goods

Regeneration processes

Cycling and filtration processes: detoxification and decomposition of wastes, generation and renewal of soil fertility, purification of air, purification of water
Translocation processes: dispersal of seeds necessary for revegetation, pollination of crops and natural vegetation

Stabilising processes

Coastal and river-channel stability, compensation of one species for another under varying conditions, control of the majority of potential pest species, moderation of weather extremes (such as of temperature and wind), Partial stabilisation of climate, regulation of the hydrological cycle (mitigation of floods and droughts)

Life-fulfilling functions

Aesthetic beauty, cultural, intellectual, and spiritual inspiration, existence value, scientific discovery, serenity

Preservation of options

Maintenance of the ecological components and systems needed for future supply of these goods and services and others awaiting discovery services or, in other terms, determining the production functions. For example, clean water might be a function of the catchment area covered with trees and urban land uses.

3. *Establishing safeguards*. This involves two tasks. Firstly, establishing safeguards requires determining the desired mix of service production where there exist trade-offs (eg. timber extraction versus habitat provision). Secondly, when the desired mix of services is identified, policy and institutional mechanisms are applied to ensure delivery of ecosystem services.
4. *Monitoring the services and evaluating the safeguards*. Monitoring ecosystem services involves identifying and collecting data on indicators. An assessment of whether the indicators are changing in the desired direction allows an evaluation of the safeguards.

The ecosystem-services framework potentially provides a holistic and integrated approach to the management of landscape resources. The notion of linking all services back to ecosystems helps focus stakeholder attention on fundamental natural processes that deliver human needs. For many farmers, this is a new way of thinking about landscapes and the services they provide. It is possible, even likely, that from recognition of ecosystem services, communities may start to value, and subsequently protect, the ecosystem functions that provide those services. By thinking about ecosystem services, Australian land managers may discover that natural ecosystems are capable of providing community needs at a much lower cost than managed systems. In short, ecosystem services might be a great way to save money!

Functional mimicry of natural systems

Initiated in 1996, the *Redesigning Agriculture for Australian Landscapes* research and development program (Land & Water Australia and CSIRO) represents a major research effort related to the development of improved agriculture, delivering environmental and economic benefits. An early question guiding this program was “Can we design agricultural farming systems which mimic natural systems?” (Clarke 2000).

In various forms, this question has shaped much thinking relating to landscape redesign over the past few years. In part, it emerged from suggestions that many of the negative impacts of current agricultural production systems have arisen from their fundamental conflict with longer-term natural processes of the Australian landscape. Land-degradation problems such as salinity provide evidence suggesting that some current Australian agriculture may be fundamentally ill-suited to the Australian environment in the long term. A logical inference is that by making current agricultural practices behave similarly to natural ecosystems, many land-degradation problems could be avoided. In other words, agriculture should seek to mimic the natural environment where possible. The challenge is to maintain or improve profitability whilst mimicking the natural system. The key features of natural systems that managed systems could seek to mimic include (Passioura 1999):

- *Persistent groundcover and minimal soil disturbance*. This has the important benefit of controlling soil erosion by wind and water. Reduced soil erosion helps maintain the productive capacity of soils and avoids off-site damage associated with sediment deposition.
- *Presence of deep-rooted perennials.* Deep roots allow use of water deep in the soil profile (beyond reach of many crops) and perenniality ensures year-round use of that water. This results in minimal leakage of water into the groundwater system — a major factor contributing to salinity.
- *Matching nutrient release to nutrient demand*. Leaching of nutrients under native vegetation is much lower than under most crops and pastures. The latter situation can cause a variety of land-degradation problems such as acidity and degraded water quality. The aim of mimicry is to replicate the tight nutrient cycling that occurs under natural systems with minimal losses.
- *Habitat provision (ensuring adequate biodiversity).* Biodiversity has a range of cultural and production benefits. Production benefits largely arise from the complementary nature of different species. Culturally, biodiversity is important due to the high value people place on the existence of diverse plant and animal species.
- *Mosaic nature of land.* Natural landscapes tend to display great diversity that does not adhere to regular cadastral boundaries. This is largely because the vegetation has adapted to spatial variations in soil properties and microclimates. Managed plant production systems that account for these spatial variations are also likely to be more productive and profitable.

The proposition of developing agriculture that mimics natural systems shares much in common with the broader concept of biomimicry (from the Greek *bios*, meaning life, and *mimesis*, meaning imitation), suggested by some as a new science or paradigm relevant to all natural resource management issues. Benyus (1997) defines biomimicry as “a new science that studies nature’s models and then imitates or takes inspiration from these designs and processes to solve human problems, eg. solar cell inspired by a leaf.” From some perspectives, biomimicry is based on a belief that through billions of years of evolution, nature has developed systems far more capable of sustaining life than can be achieved through human innovation.

There is a broad spectrum of perspectives on the biomimicry concept. Some see biomimicry as desirable solely because humans should seek to better integrate with nature due to its intrinsic value. Others take a more pragmatic approach. Lefroy *et al.* (1999), having undertaken pioneer research in the field in Australia, state that their interest in the biomimicry concept is one of improving the sustainability of agriculture. The starting point for their work was research seeking to incorporate the diversity of ecosystem functions into agricultural systems for improved persistence, resilience and efficiency of resource use.

If a pragmatic perspective is adopted, it becomes important to think about the means and ends of biomimicry. If mimicry of natural systems is solely to achieve sustainable natural resource use, should it be compared against alternatives that potentially achieve the same end without mimicking natural systems? In other words, can something other than mimicry be done to achieve preferred economic, ecological and social outcomes?

For example, in some catchments, the most effective means of reducing stream/river salinity levels may be the construction of salt-interception schemes that pump salty groundwater to an evaporation basin before it enters the watercourse. These are engineering works that clearly do not mimic the natural system. However, they may be capable of providing a much more direct and tangible benefit to river water quality than revegetation options that reduce water recharge to levels similar to that under native bushland.

Another key consideration in the application of the biomimicry paradigm for landscape redesign is the degree to which changes in the landscape are hysteretic. Using the dryland salinity example, once the groundwater systems are filled with the excess water arising from conventional agriculture, will introducing new farming systems that mimic the recharge values under native vegetation restore the original hydrological condition of the system? Or has the system undergone a fundamental and largely irreversible change of state, implying that mimicry of the original biological component is no longer appropriate?

Strategic planning

Catchment-scale planning is already undertaken by many community groups across Australia with varying levels of success. For example, integrated catchment management has been a Queensland government program since 1991. Similar programs for catchment management exist in other states.

Whilst there exists a great diversity of approaches to planning, the major stages of the generic planning process are shown in Figure 7. Feedback loops indicate the cyclical, ‘never finished’ nature of the planning process. Early stages in the process are continually revisited due to changes in political realities, changing community values, the emergence of new information, or the occurrence of other unforeseen events.

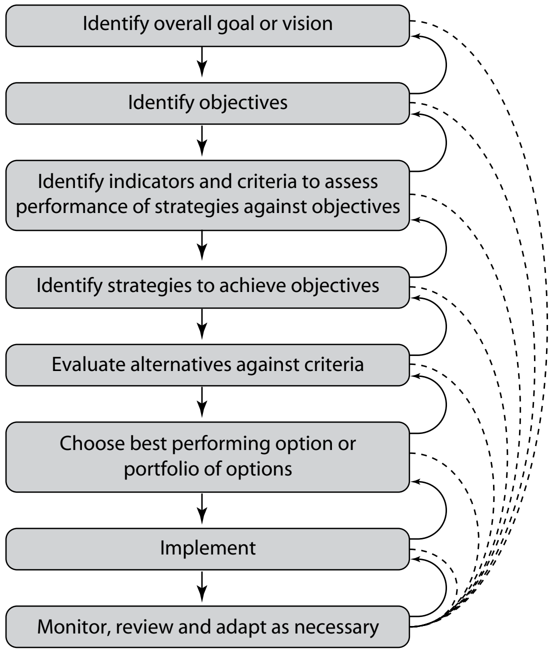

Figure 7. The strategic-planning process

Whilst the model seems neat, in reality there are many external factors that require repetition or skipping of various stages, changes to the sequence of stages, and/or addition of new stages. There are countless examples of the real world failing to adhere strictly to a unidirectional and rigid rational model. Some researchers have suggested more ‘fuzzy’ models that claim to give better representation of real-world processes. However, as a model, the generic planning process provides a useful starting point for strategic and planned activity aimed at achieving pre-determined outcomes.

An important barrier to strategic planning for landscape change is the difficulty of translating plans into on-ground changes. While governments may have identified a desirable path for land-use change within a catchment, much of the change will be at the discretion of private landholders who hold property rights. A complex suite of policy and institutional mechanisms is needed to effect change on private properties.

Landscapes and community wellbeing

What do we want from future Australian landscapes? Is the maintenance of a resource base capable of sustained food and fibre production of primary importance? Is there emerging a much broader range of goods and services that Australians are likely to draw upon? An example of a vision for future Australian landscapes, provided in a Commonwealth government discussion paper (Commonwealth of Australia 1999) on developing a national policy for rural natural-resource management, reads:

> We aspire to a future in which we achieve from our natural resources the greatest possible long-term social, economic and environmental benefits for all Australians.

What are the long-term social, economic and environmental benefits that Australians are seeking from landscapes? The main objectives for managing Australian landscapes are:

- clean water (both surface and groundwater) used for environmental, industrial, commercial, agricultural and urban purposes
- sufficient flows and reserves of water to meet environmental, industrial, commercial, agricultural and urban uses

Landscape near the Lower Molonglo sewage-treatment works, Canberra. © CSIRO

- rich terrestrial and aquatic biodiversity
- profitable land uses supporting regional development, vibrant communities and income requirements of individual land managers
- resilient social, economic and environmental systems capable of withstanding external shocks and adapting to new conditions
- resources that meet the aesthetic, recreational and spiritual needs of stakeholders.

Whilst each objective is of importance, it will rarely be possible to deliver all simultaneously and to the same extent. Limited resources and technology constraints will inevitably force trade-offs. How these trade-offs are made, taking into account the conflicting requirements of multiple stakeholder groups, represents a major dilemma facing Australian natural-resource managers. The resolution of these issues will depend on regionally specific priorities and value systems held by relevant stakeholders.

Valuing landscape services

Understanding what people value helps decision-makers to assess the relative merits of proposed landscape changes. The basis for decision-making is to identify values, assess how those values are affected by alternative management strategies and then choose appropriate strategies. In the planning process, the assessment of values dominantly occurs in the stages of drafting a vision and setting objectives.

Whose values?

Generally, the natural resources within a catchment hold value for diverse societal groups residing both inside and outside the catchment boundary. Identifying individuals whose values can be used to guide the planning process is a complex problem with no easy resolution. Water resources provide a common example of this dilemma. Many catchments supply water for use within the catchment and for use in nearby towns or cities. In these cases, both rural and nearby urban communities hold a stake in how the catchment is managed. In some cases, a catchment may contain internationally significant habitats or landforms that hold value to people living in other countries.

The emerging policy dilemma is identifying people, or groups of people, who derive value from catchment resources and devising means by which their concerns can be reflected in catchment management strategies. A useful starting point is to classify how people derive value from natural resources. It is then possible to identify social groups on the basis of the values they are likely to receive (see Table 1). Some social groups that might commonly be identified include:

- farmers
- tourists and recreational users of a landscape
- urban communities dependent on catchment water supply (indirect use value)
- Indigenous communities dependent on the landscape for livelihoods and with deep spiritual connections to the landscape
- people living outside the catchment who derive value from the mere knowledge that its natural resources are in good condition
- future generations in all of the above categories.

A problem that can emerge when this approach is taken is that individuals often fit into multiple groups. For example, a farmer might also be a recreational user of catchment resources. This necessitates the making of some generalisations in the identification of stakeholder groups. There is also the taxing question of who is chosen to represent the identified stakeholder groups.

Another question that arises in assessing "whose values?" relates to the extent to which nature is assigned intrinsic value, existing above and beyond human value. It has been argued by some that land management is an anthropocentric exercise through which humans seek to extract from the environment a narrow range of services deemed to be of value only to themselves. It can be suggested that such an approach fails to recognise the intrinsic rights of nature, eg. other species have the right to habitat and existence regardless of whether such existence is valued by humans. This dilemma, for which there can be no correct solution, raises complex and philosophical questions concerning the capacity of humans to understand values held outside their realm of existence.

Measuring landscape values

Monetary units provide the most commonly used measure of value. They allow the value of one object (or service) to be compared directly against the value of another. A common purpose for monetary valuation of environmental impacts is so they can be incorporated into benefit–cost analysis. Some of the frequently applied techniques include contingent valuation, choice modelling, hedonic pricing, and the travel-cost method. There is often much debate surrounding the application of these techniques to attain monetary values for environmental resources. Some of the major benefits and problems associated with monetary valuation of environmental resources are as follows:

Benefits:

- helps to remind people that the environment is not a free resource
- helps to ensure that difficult-to-quantify impacts are included in the decision-making process on an equal footing with the more tangible financial impacts
- reduces (although can never eliminate) the need for subjective judgments in important decisions
- provides a realistic indication of economic performance
- if used properly, valuation can help inform policies relating to taxation and/or charging for environmental services.

Problems:

- placing dollar values on environmental impacts that are inherently non-quantifiable can mislead and devalue decision-making processes
- the use of valuation in benefit–cost analyses can be used to bias the outcomes because of its subjectivity
- the costs of undertaking a reliable valuation exercise are typically very large and hard to justify.

Table 1. Example of assigning cultural values to stakeholder groups.

Stakeholder groups	Landscape assets			
	Drinking water	Soil productivity	Biodiversity	Landscape amenity
Farmers	✔	✔✔	✔	✔
Tourists and recreational users	✔	–	✔	✔✔
Urban communities (outside catchment)	✔✔	–	✔	✔
Indigenous communities	✔	✔	✔	✔✔
People who derive existence value	–	–	✔✔	✔
Future generations	✔	✔	✔	✔

While monetary units dominate many valuation exercises, monetisation is not the only way of measuring environmental values such that they can be included in decision-making. Other techniques, such as multiple criteria analysis, can handle measures in qualitative or quantitative units of any type. These techniques seek to help inform decision-makers about trade-offs associated with alternative courses of action in addition to providing indices of project performance. Dissatisfaction with non-market valuation is leading to a search for alternative means of measuring value and assessing how it will be affected by policy decisions.

Segregating analytical and judgmental tasks

The planning, evaluation and monitoring of landscape strategies generally involve judgmental and analytical tasks. A judgmental task is one that concerns people's value systems, such as deciding upon what constitutes an aesthetically pleasing landscape. There is no correct answer to judgmental questions as they are wholly dependent on values held by different stakeholders and the weight given to each of them. In contrast, an analytical task is capable of being undertaken objectively by a scientific or policy analyst. Analytical tasks can be resolved through the application of scientific methods.

Where community members, policy analysts, technical experts and scientists are working collaboratively toward planned landscape change, there can often emerge tensions between judgmental and analytical tasks. It is generally argued that scientists, analysts and technical experts should work within the analytical realm. In this capacity they can inform community members about the impacts of strategies, but cannot make judgments on the relative desirability of alternative options. The classic approach to this judgment problem is to engage stakeholders in the judgmental components of planning such as setting the broad policy objectives and choosing their relative importance.

An alternative view separates the planning process into ends and means (McAllister 1980). The ends, or final outcomes, of planning are chosen by the community. Analysts and technicians become involved only in developing a means to reach those ends. In theory, if the community properly and comprehensively specifies the ends, technicians can meet community aspirations.

While it is easy to draw a neat, theoretical distinction between ends and means or analytical and judgmental planning tasks, in practice complex interplay occurs between these aspects. Sometimes the community members have expertise that can inform analytical tasks and, likewise, experts often have information that can aid the assessment of values. There is no clear line that delineates the role of the community from that of the technical expert or scientist.

Warren River at the bottom of Heartbreak Trail near Pemberton, Western Australia.
© CSIRO

Physical and social landscape processes

The capacity of the landscape to provide broadly defined quality of life for communities (environmental, economic and social) will depend on a set of underlying physical and social processes. These processes give shape to landscape form and function. In some cases, it will be possible to manage these processes using natural processes, present before European arrival, as a benchmark. In other cases, the changes since 1788 will be hysteretic and landscape processes may need to be reshaped into new systems that still deliver desired end-point outcomes.

Water balance (Tom Hatton)

Australia is not unique in terms of widespread land and water degradation resulting from development. However, the Australian landscape has particular qualities, especially hydrological that, on one hand, leave us prone to serious degradation and, on the other hand, make restoring degraded resources extremely challenging.

European settlers changed the landscape of southern Australia to a remarkable degree in a relatively short time. While this process began 200 years ago, vast portions of the continent have only been converted from native bush to agriculture in the past 50 years. Nevertheless, the consequences of this conversion are already having dramatic impacts on the health and productivity of the Australian landscape.

Water cycling in the natural landscape

Two key aspects of southern Australia must be understood to fully appreciate the hydrological cycle as it existed at the time of European settlement. The first, and most important of these, is that Australia's geology has been relatively quiet over the past 60 million years; in some cases, what uplifting has occurred has actually restricted drainage. Little renewal of surface material means that soils are old and nutritionally poor, profiles are deeply weathered, and geomorphological units result from differential erosion of an ancient surface (McArthur 1993). This geological history has resulted in the flattest continent on Earth with generally low hydraulic gradients and transmissivities. Water (and solutes) cannot move quickly through the Australian landscape as surface water or groundwater.

The deeply weathered regolith typically encompasses several, often interacting, aquifers, including a shallow, seasonally perched system, a local semi-confined aquifer, and often a deeper, confined regional system (McFarlane *et al.* 1993; George *et al.* 1994). In the native state, these latter systems may be only rudimentary and watertables (if present) are normally quite deep (Salama *et al.* 1993). The overlying unsaturated zone typically contains a large amount of accumulated salt of largely atmospheric origin stored in the soil water, mostly below the major rooting zone, which is largely immobile before land clearance.

The second key aspect of southern Australian hydrology is the high climatic and hydrological variability. McMahon *et al.* (1992) showed that in terms of mean annual run-off, Australia is not particularly distinctive (420 mm versus 620 mm for the world), but that the variability of stream flow is far higher than the rest of the world, with the possible exception of South Africa. This variability is in part the result of the El Niño Southern Oscillation phenomenon. Australia is the only continent where the overwhelming influence on climate is non-annual climatic variation (Flannery 1994) — that is, the high degree of predictability associated with seasonal cycles elsewhere on Earth is small in Australia relative to variations on a longer cycle. This lack of predictability has major implications for the evolutionary adaptation of Australian biota and the productivity of Australian ecosystems.

The seasonality in climate in the south-western part of the continent tends toward a Mediterranean distribution of rainfall, ranging between 250 and 1200 mm annually. In the south-east, the distribution is more uniform with a similar range. In both regions, potential evaporation exceeds rainfall in most months and in all months in the lower rainfall zones.

In the natural state, the hydrological cycle of the agricultural areas of southern Australia has the following functional generalities that result from the combination of the above attributes:

- virtually all of annual rainfall is evaporated or transpired except in the highest rainfall areas which, while limited in extent, generate the bulk of fresh water resources
- the vast majority of rainfall reaching the soil infiltrates locally, and thus surface run-off to streams is small, fresh and generally episodic in nature (Nulsen *et al.* 1986; McFarlane *et al.* 1993)
- water use by native vegetation is somewhat conservative in winter, when water is quite plentiful, with much more physiological activity toward summer (Farrington *et al.* 1992)
- net groundwater recharge to the semi-confined and confined systems is a very small proportion of rainfall, usually less than 1 mm/year, except in the higher rainfall areas (Nulsen *et al.* 1986; Allison *et al.* 1990; George 1992)
- what little groundwater discharge and run-off is generated supports limited areas of riparian vegetation, which are able to switch their source of plant water from local rainfall to groundwater over the dry season (Thorburn *et al.* 1993; Walker *et al.* 1996)
- in some cases, there is sufficient groundwater discharge to form natural saline surface features, but alluvial systems are often fresh at the surface (Farrington and Salama 1996)
- there is generally little or no natural base flow of rivers in streams originating in the agricultural zone — what base flow or other forms of groundwater discharge do take place are associated with ecosystems dependent on that discharge.

In short, the conservative water use of the native vegetation of southern Australian resulted in systems in which very little rainfall was discharged in liquid form except in the highest rainfall areas. As one consequence, millennia of atmospherically deposited salts built up in the unsaturated zone at some depth below the root zone. The exchange of water between the soil and the atmosphere can be characterised as mostly vertical, with the rain that falls on a given piece of ground evaporated from that same surface.

Changes to the water cycle following clearance for agriculture

The hydrological impacts of land clearance for agriculture in southern Australia are documented and reviewed in detail by a number of authors (Peck and Hurle 1973; Williamson and Bettenay 1979; Schofield 1990; McFarlane *et al.* 1993; Nulsen 1993; Farrington and Salama 1996). These impacts result from the replacement of the native sclerophyll vegetation with annual crops and pastures over vast areas, largely this century. For instance, Walker *et al.* (1993) estimate that 12 to 20 billion trees were removed, without replacement, from the Murray–Darling Basin alone. It should be noted that some of these impacts were recognised early on (eg. Bleazby 1917; Teakle and Burvill 1938) but with little influence on land policy.

The pattern of water use of these agricultural systems varies dramatically from that of the original vegetation. McFarlane *et al.* (1993) asserted that annual crops cause the evaporation of more water than annual pastures, at least in south-western Australia; this was demonstrated by Nulsen and Baxter (1987) and Farrington *et al.* (1992). In either case, however, annual evaporation falls significantly short of that under native vegetation (Greenwood and Beresford 1982; Greenwood *et al.* 1985; Farrington *et al.* 1992).

Other aspects of the hydrological cycle can change in addition to the seasonality and amount of evaporation. Tillage and grazing can have a direct impact on the hydraulic properties of soils, while soil erosion has obvious and dramatic impacts on fertility, structure and water-holding capacity. Land-degradation issues such as soil acidification, soil structural decline and waterlogging have strong impacts on the hydrological cycle, and affect more regional-scale phenomena, such as salinisation and stream flow (Williamson and Bettenay 1979; Nulsen *et al.* 1986; Flavell *et al.* 1987; Nulsen 1993).

A major consequence of these changes is a dramatic increase in groundwater recharge, particularly under annual crops and pastures; two orders of magnitude increases are typical (Peck and Hurle 1973; George 1992; Kennett-Smith *et al.* 1992a,b).

In summary, the hydrological characteristics of agricultural landscapes in southern Australia can be summarised as follows:

- a dominance of physiological activity and evaporation during the wet (winter–spring) season;
- soil moisture surplus during the growing season
- enhanced groundwater recharge and rising groundwater tables
- the development of perched and/or active near-surface aquifer systems, and the activation of deeper aquifers and the mobilisation of stored salts
- the increased discharge of water and salt to streams.

The social and environmental consequences of these changes in hydrology are immense. For instance, Ferdowsian *et al.* (1996) suggested that by the middle of the next century we will lose one-third of the Western Australian wheatbelt to salinisation; this region currently produces about one-half of Australia's grain. Australia's largest river system, the Murray–Darling, is salinising at an accelerating rate (Williamson *et al.* 1997); due to other hydrological changes resulting from land clearing and settlement, it is also eutrophicating and subject to increased toxic algal blooms (Davis 1997).

Responsiveness to remediation

The properties that give Australia such unique hydrological and eco-hydrological characteristics also give rise to characteristic responses to attempts to either develop or restore land and water resources. From a development point of view (over and above the impacts resulting from agricultural clearing as described above), nutrients and water are scarce and probably limit the productivity and character of natural ecosystems. Thus, the abstraction of groundwater or surface water for industry invariably comes at a consequence to the terrestrial or near-shore environment.

Low gradients and fluxes of water also tend to result in slow response times to remedial works. It can take centuries for a hydraulic impact to propagate from the point of intervention to the place to be protected. This is particularly true for applications involving recharge reduction. While remediation of local saline seeps using trees can show results in a few years, the control of salt loads to Australia's major southern river systems may take hundreds of years to achieve following revegetation. This is due to the low gradients and long length scales of these regional systems.

Surface water systems can be just as resistant to recovery. For example, the nutrient and sediment loads now in the rivers may have originated in erosion events over 100 years ago; now that these materials are in the channel, the impact of upland revegetation on river water quality may be effectively irreversible within society's normal time constraints.

It is unlikely that the full complement of hydrological functions can ever be restored with revegetation, even using the original genetic material. Some changes in the hydraulic and hydrochemical characteristics of the system may be irreversible. The most pessimistic assessment suggests that Australia's southern landscape will not be renewed until the next geologic orogeny or a large change in climate.

Hydrological processes drive the movement of salts, nutrients, sediments and pollutants through a landscape. They also govern rates of groundwater recharge and surface water flows. Disturbance of landscape hydrological processes can cause salinity and water quality degradation. Use of water for irrigation, urban, industrial or environmental purposes will be limited by rates of groundwater recharge and surface water flows.

Nutrient balance (Wayne Meyer)

Access to nutrients — essential minerals (macronutrients) and micronutrients (Box 2) — in sufficient quantity and at appropriate times is fundamental to all life forms. Given that life forms are a major part of shaping landscapes, it is important to understand and manage nutrient cycling as part of landscape redesign and planning.

Erosion continues to shape landscapes and is a major factor in nutrient transportation. The vegetation disturbance of the last 150 years has resulted in major erosional deposition. Water is the transport medium and water quality an integrative expression of landscape processes. Gross levels of phosphorus and potassium input exceed exports in agricultural produce, but this is regionally variable.

Apart from the direct application of nutrients to waterbodies and movement by dust particles, almost all movement of nutrients around the landscape is mediated by water. Soils, and their associated biophysical processes, modify, dampen and provide capacitance in the transport pathway from terrestrial agro-ecosystems to aquatic ecosystems.

Box 2. Summary of major nutrients (macronutrients) and micronutrients required by plants (Glendinning 2000)

- Macronutrients are used in the greatest quantity by plants and are usually the first to become deficient. The macronutrients include nitrogen (N), phosphorus (P), potassium (P), calcium (Ca) and sulfur (S).
- Micronutrients are used in smaller quantities, but are also essential for plant growth. The micronutrients include boron (B), chloride (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and Zinc (Zn).
- The elements of sodium (Na), cobalt (Co), vanadium (V), nickel (Ni) and silicon (Si) are also essential for growth of some plants. However, Australian soils are seldom deficient in these elements with problems of excess toxic levels more common.

Water is not only the primary transport medium over and through soils, but in rivers and lakes it serves as the integrative medium that largely reflects the results of landscape and soil processes. However, waterbodies are not inert; they are substantive ecosystems in their own right that process, change and store nutrients and chemicals coming from soils.

The transport of soil materials (erosion) is the major landscape-sculpting process. It not only brings clay into water but, importantly, the nutrient and heavy metal ions most often associated with the charged clay particles. Rates of soil loss and sediment yield of catchments indicate annual rates of erosion varying from <20 t/km^2 in temperate areas under pastures to more than 1500 t/km^2 in tropical areas with high rainfall intensity (Wasson 1994). Interestingly, on a catchment scale, there is only a weak correlation between sediment yield and agricultural land use (Wasson 1998) which indicates that differences in catchment size, climate (particularly rainfall intensity and seasonality), topography and soils exert a greater influence than land use on its own.

The implications of surface soil loss are loss of nutrients and loss of organic matter, both of which may end up in waterbodies, and a loss of agricultural land productivity. McLaughlin *et al.* (1998) estimated the effects of erosion on soil nutrient loss at a continental scale (Table 2). Erosional losses are very episodic so that ‘average data’ can be misleading in not accurately representing the process. In addition, the reliability of the estimates is hard to determine.

At a landscape scale, there is increasing evidence that much of the noticeable erosion in agricultural areas is the result of significant sediment movement in the last 100 to 150 years. Sediment tracing studies indicate that the extensive changes in landscape vegetation cover associated with clearing and agriculture have also been accompanied by large erosion events. Further, the origin of much of the suspended sediment in rivers of south-eastern Australia is from eroding gullies and river banks rather than from surface soils as would be the case with extensive sheet erosion (Olley *et al.* 1995).

Of the macronutrients nitrogen (N), phosphorus (P), potassium (K), and sulfur (S), most attention has focused on P because of the controlling influence it has on biological function. In Australia, much of the focus on managing potentially toxic blue–green algal blooms has been on reducing further introduction of phosphate to waterbodies. Point sources of phosphate, such as sewage treatment discharges, have been diverted from rivers onto land while diffuse sources, such as phosphatic fertiliser use, have been scrutinised. However, in the south-eastern tablelands of Australia, it appears that significant amounts of P reaching surface waters do so through erosion of subsoils from streambanks and gullies, rather than from erosion of surface-fertilised soil (Wasson 1998).

While N in water is not given the same attention as P, primarily because nitrates are more readily lost to the atmosphere through volatilisation, high concentrations are a cause for concern. This is particularly true for nitrate, and especially nitrite, contamination of groundwater, as this poses a direct human-health risk.

Nutrient sources

Table 3, from McLaughlin *et al.* (1998), indicates that at a gross national level, the rate of P and S fertiliser input to Australia’s agriculture exceeds that exported through crop off-take. This generalised situation hides regional variation, as shown by a more recent audit (SCARM 1998) that P input is often less than export in northern Australia while K exports seem to exceed inputs in 8 of the 11 agro-ecological zones of the continent. Input often exceeds export in intensively farmed soils (eg. horticulture, irrigated agriculture), which is reflected in the concerns in these areas for off-site movement of P and other nutrients to surface and groundwater.

Drainage from irrigation areas typically shows that for pasture, total P is high (>0.5 mg/L, often attached to particulate matter) and total N low (<1 mg/L), while for horticulture, the reverse is true (total P <0.1 mg/L, total N >5 mg/L; Harrison 1994).

Table 2. Estimated losses of nutrients through soil erosion from agricultural areas of Australia. Source: McLaughlin *et al.* (1998)

Land use	Area (10^3 km^2)	Annual soil loss (t/km^2)	Nutrient lost in eroded soil		
			Phosphorus (kt)	Sulfur (kt)	Nitrogen (kt)
Crops	190	10–500	1.0–47.5	0.7–33.3	2.9–142.5
Pastures(natural)	160	5–50	0.3–3–2	0.2–2.0	2.8–28.0
Pastures(improved)	140	5–50	0.5–4.9	0.4–3.5	2.8–28.0
Forest/woodland	1050	1–10	0.3–3.2	0.2–1.6	1.1–10.5
Total			2.1–58.8	1.4–40.4	9.6–209.0

Establishing a gross input/output balance for N is difficult because of the uncertainty in the fluxes of nitrogen with its many reaction pathways. Use of N fertiliser is increasing in Australia, and it is expected that more N will appear in groundwater, particularly under intensively managed crops, such as vegetables.

Organic matter plays a critical role in nutrient cycling. Most Australian soils have low levels of organic matter (0.5–5%) by world standards mostly because net primary production is limited by low rainfall and generally low levels of inherent soil fertility, while respiration rates are high because of high daily mean temperatures. Gifford *et al.* (1992) estimated that up to 39% of the organic carbon in Australian surface soils has been lost during the period 1880–1990, although it is difficult to apportion losses to *in situ* mineralisation and to losses through erosion.

The best evidence for general organic-matter dynamics under different agricultural practices comes from the few permanent rotation trials around Australia. Plots under continuous cultivation and cropping show a steady decline in organic matter to asymptote towards a low value, while permanent fertilised pasture with moderate grazing often shows a steady or sometimes increasing amount of total carbon (Grace *et al.* 1995; Heenan *et al.* 1995).

Erosion

Any activity which increases the exposure of the ground surface to the erosive forces of water and wind and which causes a decrease in aggregation of the soil will potentially lead to increased soil loss. There is a fairly direct relationship between levels of soil organic matter and soil loss (Malinda 1995), probably mediated through the combined effects of increased duration of groundcover and increased carbon entering the soil food web and thus stimulating biological activity. It follows that soil organic matter declines as the frequency of fallow phases increases. Under South Australian conditions, a 10% increase in fallowing frequency results in a 0.16% decrease in soil organic matter (Grace *et al.* 1995).

Leaching

Leaching, or the movement of solutes through the profile, is a critical soil process affecting the movement of nutrients. As our understanding of water movement in field soils has improved, it is increasingly recognised that leaching events are often episodic in occurrence and that solutes are often moved through preferential pathways in soils rather than accompanying horizontally uniform wetting fronts.

Recent evidence (Chittleborough *et al.* 1992) shows that surprisingly high amounts of P can be moved through soils if it is attached to or is part of very small organic carbon particles. These particles are so small that they are suspended in water and are referred to as dissolved organic carbon (DOC).

The major changes in Australian landscapes associated with native, perennial vegetation replacement with annual species and the increased amounts of nitrogen moving through soils will cause change in the leachate products appearing in groundwater and waterbodies. Increased dissolution of soil minerals associated with increased water movement and increased acidity will change the composition of transported ions. It would therefore not be surprising to see increased concentrations of both macronutrient and micronutrient or trace element ions in the discharged waters.

Biological activity

Continued biological activity is essential if the detrimental effects of nutrient and pollutant movement from soils to waterbodies is to be ameliorated and controlled. There is increasing evidence that high rates of carbon turnover in soils associated with high levels of biological activity is an essential part of maintaining aggregate stability and providing a high level of detoxification of introduced chemicals. Therefore, the fostering of conditions that encourage high carbon turnover, namely adequate amounts of organic matter, adequate and balanced nutrient supply, and optimum soil water and temperature will be beneficial for maintaining

Table 3. Fertiliser input (I) and product export (O) ratios for phosphorus and sulfur in major agricultural enterprises. Source: McLaughlin *et al.* (1992)[a]

Land use	Phosphorus			Sulfur		
	Fertiliser input (I) (kt)	Crop off-take (O) (kt)	Ratio (I/O)	Fertiliser input (I) (kt)	Crop off-take (O) (kt)	Ratio (I/O)
Winter grains	120	58.0	4.2	79.9	26.1	3.1
Summer grains	8	4.3	1.9	4.0	2.0	2.0
Fresh fruits	6	0.4	15.0	8.2	0.3	27.7
Vegetables	8	1.3	6.2	10.8	0.6	18.0
Wool, meat, milk and live animals	179	35.8	5.0	201.4	45.0	4.5

[a] Note: the gross nutrient budgets indicated do not take losses due to erosion into account nor the effect of soil fixation of nutrient ions.

soil stability, retaining nutrients and assimilating chemical additives.

Managing nutrients and erosion

Healthy nutrient cycling can be restored to a landscape through appropriate management actions. The following principles can be used to guide nutrient management activities:

- nutrients need to be protected by reducing erosion events — problems are expressed in off-site impacts (groundwaters, rivers, estuaries) and on-site impacts through soil fertility decline
- losses through leaching can be reduced by improved water management — maintaining green leaf area for longer duration (and changing to perenniality) will have major benefits of nutrient retention
- increased biological activity, providing food (organic matter) and nutrients for subsoil insects and other organisms, will drastically improve nutrient retention and turnover
- introduction of nutrients, such as phosphorus, should not introduce contaminants.

In most Australian dryland farming areas, organic-matter turnover is limited by climate and agronomy. In this respect, good agronomy that optimises crop growth and yield together with reduced tillage and reduced grazing will be beneficial. Any practice that encourages crop or pasture growth for longer annual duration, accompanied by reasonable groundcover will be beneficial. The amount of leaching that occurs will depend on soil and climate conditions but will be greatly influenced by plant growth patterns and management. Making the best use of rainfall for production rather than have it transport nutrients and chemicals off-site should be encouraged. With respect to nutrients appearing in waterbodies, the contribution from applied fertilisers can be reduced by encouraging more precise application. This means assessing requirement by sampling and measurement before application and then applying in amounts and at times that match plant requirements.

In contrast to dryland, irrigated practices have the potential for organic matter production and turnover is high. The fate of organic matter that can enter the soil is largely controlled by grower action. Growers determine the amounts removed, burned, grazed or incorporated. In irrigation areas, it is almost inevitable that increased profile drainage will occur — indeed, it is necessary for adequate leaching of salt brought in with the irrigation water. It follows that the groundwater in these areas will be affected and contamination by high levels of salt, nutrients (especially N) and applied chemicals can and does occur. Because most irrigation areas are intensive agricultural areas, there will always be heightened risk of drainage contamination either by direct application into drainage lines or by collection from farm run-off.

It is clear that there will be increased emphasis on appropriate land use on the landscape. This will include reduced cultivation, improved management of soil biota by increasing carbon and nutrient supply through reduced grazing and better use of crop residues and more precise use of applied nutrients.

All animal and plant life is dependent on the supply of nutrients. As a finite resource, nutrient inputs must equal nutrient outputs if a production system is to be sustained. If nutrient inputs exceed plant capacity to capture those nutrients, an increased amount of nutrient will run-off into rivers and streams. This has a detrimental effect on water quality, impacting human health, recreation, aquatic ecosystems and water treatment costs.

Landscape heterogeneity

An aerial view of most Australian agricultural land reveals countless fields organised in rectangles or regular geometric shapes. Generally, the fields comprise a single land use, sometimes with vegetation along the perimeter. Such designs generally do not match production activities with the natural variability of hydrology, lithology and geology across a landscape. There are few examples of paddocks where crops, pastures and trees are closely integrated.

Can this design be improved? The development of integrated tree, crop and pasture landscape designs is a major objective for Australian natural-resource management. New research into crop yield over an individual paddock is showing that this may be economically efficient, as well as environmentally preferable. For some, the challenge is all about attaining greater precision (spatial and temporal) in agricultural land management.

Several research projects (eg. Bramley and Proffitt 1999; Bramley and Cook 2000) have shown that yield and gross margins vary considerably over an individual farm paddock. Importantly, gross margins — the net returns of agricultural production excluding fixed operating costs — often vary from negative to positive values within a paddock. This means that farming in some parts of the paddock is creating a loss for farmers. Examples of gross margins showing this variation within an individual paddock for grape growing are shown in Figure 8. It can be seen that significant parts of the paddock are creating a loss. Overall profits would be increased if these areas were removed from production, or subject to alternative management practices.

Farmers are already taking up the revegetation challenge and moving towards more integrated landscapes. In a survey of around 2000 broadacre farms in 1994, Wilson *et al.* (1995) found that 35% of farmers planted trees on their properties between 1991 and 1994. It was also found that 35% of farmers had tree belts and corridors, 14% had tree blocks, 6% had alley belts of at least two strips of trees with cropping or grazing in between, and 6% had widely spaced plantings. Through the tools of precision agriculture and development of industries based on tree-products, it may be possible to design better-integrated tree–crop–pasture farms.

An important issue related to strategic revegetation is the competition between trees and crops/pastures for limited water and nutrients. This has been well researched in alley farming (also known as alley cropping), which is defined as "a farming system where crops and pastures are cultivated in the alleys between rows of trees and shrubs" (Kang *et al.* 1990, cited in Stirzaker and Lefroy 1997). Ong and Leakey (1999) describe resource capture in integrated systems as competitive, neutral or complementary. Which of these three conditions prevail will depend on a complex interaction of many factors such as climate, soil type, plant species and stage of tree development.

The level of competition will influence the design of the tree–crop interface. If the relationship is complimentary and trees increase yields of neighbouring crops, it makes sense to maximise the perimeter-to-area ratio of new plantations. Conversely, if trees have a negative impact on crop yield it is better to plant trees in blocks with minimal perimeter-to-area ratios. Six alternative designs of integrated tree–crop/pasture fields with the same area but different perimeters are shown in Figure 9. The shape of planted areas will also be influenced by the nature of within-paddock yield and profit variation. Clearly it makes sense to plant trees in areas that have lower and/or negative returns.

The spatial arrangement of land uses within a paddock or farm can be designed to complement a broader spatial arrangement of land uses within an entire catchment. As with an individual paddock, there will be spatial

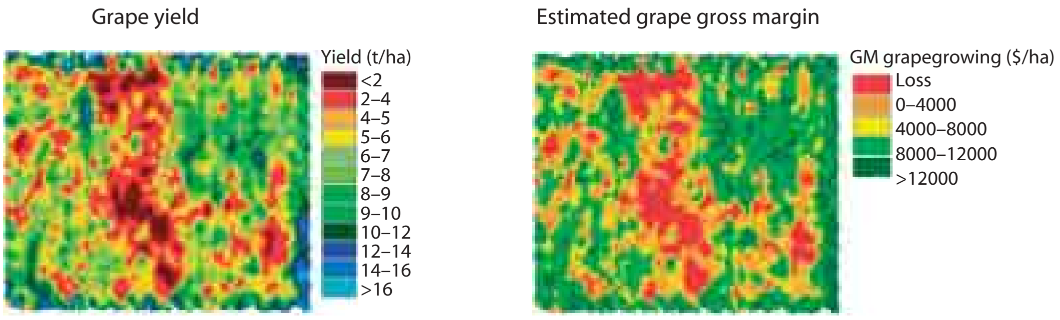

Figure 8. Variation of crop yield (grapes) within a single vineyard in Coonawarra in South Australia (Bramley and Proffitt 1999)

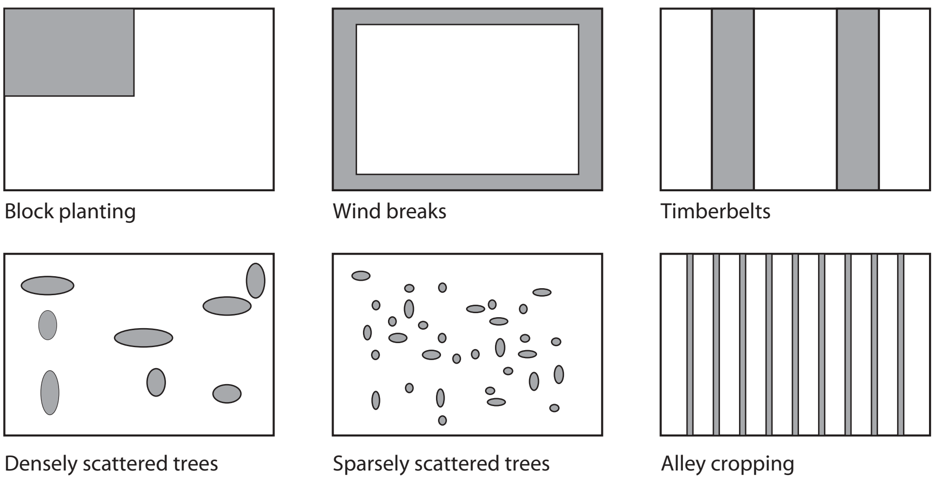

Figure 9. Six alternative integrated tree, crop and pasture field designs. Source: Young (1987), cited in Stirzaker and Lefroy (1997)

arrangements of trees across the catchment that are more economically and environmentally efficient. For example, Stirzaker *et al.* (2000) suggest that convergent or concave hillslopes with slopes exceeding 3–5% may be ideal locations for planting trees to control groundwater recharge and salinity problems.

A key question for landscape change is whether the spatial arrangement of revegetation options and land-use activities is a primary focus. Is landscape redesign fundamentally about how we spatially arrange different trees, crops and pastures throughout a catchment? From this perspective, landscape planning, primarily at the catchment level, has much in common with the broader concept of regional and urban land-use planning. Land-use planning has long been employed by local, state and Commonwealth governments in both cities and rural areas. A fundamental concern of land-use planning is developing a spatial arrangement of human activities that contributes towards sustainability or quality of life in general. Could agricultural activities in a landscape be planned in a manner similar to urban planning?

Landscape heterogeneity and resilience

Viable, healthy landscapes tend to be characterised by two features: diversity and resilience. As a general rule, diversity increases resilience. Resilience is the capacity of a system to recover from adverse pressures and to take advantage of opportunities as they arrive. Diverse biophysical systems tend to contain many species and much spatial variability. For much of the time, many of the options embodied in this diversity seem redundant or surplus to requirements. During times of collapse, ecological pressure etc., these same, apparently redundant, elements of a landscape provide the functions and ecosystem services necessary to enable recovery, restoration and transition to a new equilibrium.

Similarly, economic and social diversity creates opportunities for innovation and adjustment as circumstances change. Socially resilient communities tend to be characterised by farms of varying size, people of varying skills, and a wide range of industries and a variety of approaches to management.

Ecosystem health and biodiversity

Biodiversity can broadly be defined as the diversity of all animal and plant life. High levels of biodiversity are generally considered indicative of a healthy and resilient ecosystem. Biodiversity can exist at three levels: species, habitat and ecosystem. At the species level, biodiversity refers to the diversity of flora and fauna within a particular habitat. Habitat biodiversity relates to the diversity of habitat types, eg. mangrove, estuarine, rainforest or dry sclerophyll forest. Ecosystem biodiversity is the broadest level of biodiversity. It refers to the diversity of ecosystems comprised of several habitat types, eg. coastal, semi-arid etc.

Many of the requirements for a healthy ecosystem are described under the previous sections on Water balance and Nutrient balance. Disturbing these processes, ie. causing them to function in ways significantly different to their natural state, generally has negative impacts on all plant life — both native species and those used for agricultural production. For example, leaching of soil nutrients caused by tree clearance and subsequent changes to surface water flows will decrease crop/pasture yields and damage the health of native vegetation. That is, it will have an impact on both the agricultural and natural systems. As a general rule, the requirements for nutrient and water balance discussed previously apply to the maintenance of biodiversity, in addition to crop/pasture condition.

> *A landscape has considerable natural spatial and temporal variability of geology, lithology, microclimate and hydrology. This drives varied terrestrial habitats and plant communities. Understanding this variability will assist the development of managed systems with superior economic and environmental performance. As a general rule, landscape diversity increases resilience (the capacity of a landscape to withstand external shocks and adapt to new circumstances).*

However, there are many other ways by which landscape change can impact on biodiversity and ecosystem health, without harming agricultural production systems. The main requirements for ecosystem health and biodiversity across a landscape include:

1. Environmental flows

Estuarine, riverine, stream, lake and wetland habitats are all dependent on the supply of fresh water. A change in the quantity of water supplied to these habitats will have an impact on biodiversity. If these habitats are significantly deprived of water, fish, insect and amphibian species may decline or become lost from an area altogether. Generally these impacts will be transferred onto higher-order predators, such as bird species. Wetland, riverine and estuarine habitats also are important breeding grounds for many migratory birds and fish. A loss of wetland habitats can significantly hamper the capacity of these species to breed, thereby affecting populations over large areas.

Environmental flows are also closely linked to water quality. Extraction of fresh water from rivers and streams can result in downstream flows containing higher concentrations of toxins, nutrients, salt and other contaminants. This results because there is a lesser volume of water within which contaminants can be dissolved, thus increasing their concentration.

2. Remnant vegetation

The size, shape and connectivity of native bushland remnants across a landscape will have important implications for terrestrial biodiversity. While clearly a larger area of native vegetation is beneficial for biodiversity (ie. more area for plants and animals to live in), shape and connectivity also play an important role. This is largely due to edge effects on habitat capacity to provide shelter and food for plant and animal species. For example, a long, narrow bushland remnant will have a lesser capacity to shelter fauna than a circular remnant of equal size. This is because the long narrow remnant has a greater perimeter and provides poorer shelter to plant and animal species. Connectivity between remnant vegetation is also important as it facilitates more effective movement of animals across a landscape.

3. Waste assimilative capacity

Human activities have resulted in many contaminants, harmful to plant and animal species, entering landscapes. These contaminants are often classified as having point or non-point sources. Point-source pollution can be traced back to a single outlet, eg. a pipe releasing industrial sewage into a waterway. This form of pollution is generally easier to control because it is easily located and identified. Non-point-source pollution emanates from many outlets across an entire landscape and often results from many different human activities, companies and individuals. Herbicide and pesticide run-off are common examples of non-point-source pollution. These forms of pollution can be harder to control because they have diffuse sources and individuals or specific locations cannot easily be targeted.

Most pollutants are generally transported and concentrated through the landscape by hydrological processes. This can result in concentration of contaminants in areas of most ecological and human importance. Often, streams, rivers and wetlands support high levels of biodiversity and have important anthropogenic uses, such as drinking water or recreation.

Generally, ecosystems have a capacity to absorb small quantities of contaminants without showing signs of stress, depending on the type of contaminant. However, many Australian catchments have exceeded levels of contamination that ecosystems can tolerate. For example, many rivers and streams have undrinkable water and are incapable of supporting native species due to extremely high nutrient concentrations and toxic loads.

An important impact of contamination is the biological magnification of contaminants through the food chain. Higher-order predators, eg. sea eagles, can be more severely affected because they absorb a greater amount of the contaminant through the food chain. By consuming a large number of first-order consumers, eg. fish, each containing a small amount of the contaminant, the higher-order predator will build up greater levels of the contaminant. This can place certain species at greater risk.

4. Pest species

The invasion of weeds and feral animals can disrupt a native ecosystem and harm biodiversity. In Australia, many species that are now pests were deliberately introduced by humans — often to control some other species — or have been inadvertently spread by human activity. Pest species can be harmful to native species by occupying habitat space, consuming limited sunlight, water or nutrients, preying upon native species, and obstructing movement.

Most ecosystems in Australia have been damaged through problems associated with at least one of the above factors. Whilst this change is often gradual, Scheffer *et al.* (2001) indicate that many ecosystems can undergo sudden shifts when a certain threshold is reached. For example, when sediment loads reach a certain level, estuarine environments can experience ‘catastrophic’ and hysteretic change.

Biodiversity and ecosystem health will be, in part, dependent on water and nutrient balances (described above). Some of the other main factors that play an important role at the landscape scale include environmental flows, remnant vegetation, waste assimilation and pest species. Management of these factors can help ensure biodiversity is maintained and ecosystems are healthy.

Economic and market dynamics

Clearly, one of the major functions performed by Australian landscapes is the production of food and fibre, providing income to farmers and other people who derive income indirectly from farming (i.e. support services). Understanding the landscape-scale economic systems that drive farmer decision-making is critical to predicting the outcomes of policy intervention. There are well-established theories, translated into a multitude of models, that indicate how land use and farming practice might change in response to changes in commodity prices, costs of production, financial risk and productivity. These models can inform policy-makers on how intervention will change the way a landscape functions.

The most fundamental requirement for economically viable land uses is that profit from agricultural production provides net income at least equal to that which could be attained by some other means. Profit is equal to the revenue (price by quantity) minus the variable and fixed costs of production, and is a key indicator of a production system's economic performance. A great many people can be impacted by the profitability of agricultural land uses, including farmers residing within the region and people employed under secondary or tertiary industries who may live a considerable distance from the region.

Approximately 570 million ha (74%) of Australia is under private freehold and private leasehold ownership (NLWRA 2000a). This means that for real landscape-scale change, proposed redesign options must be preferred to alternative land-use activities by landholders and farmers. It is not sufficient for society to merely want a new land management practice adopted. Pannell (1999) describes four conditions that must be met for farmers to adopt new innovations:

1. Farmers must be aware that the innovation exists and has potential practical relevance to their situation.
2. There must be a perception that it is feasible to trial the innovation. Farmers generally prefer low-investment trials with low risk.
3. There must be a perception that the innovation is worth trialing. If farmer perceptions of the innovation are not sufficiently positive, they will be unwilling to take the risk of a trial.
4. The innovation must be perceived to promote the farmer's objectives. These are likely to include a range of factors such as profit, risk, leisure and environmental performance.

Of all the requirements placed on a new farming system or land use by private landholders, profitability is often one of the most important. Pannell (1999) notes that overcoming the hurdle of profitability is sometimes higher than recognised by scientists. A profitable system not only generates benefits in excess of input costs, but also performs financially better than alternative systems (ie. covers opportunity costs). The alternative system must also be deemed by the farmer to carry an acceptable level of risk and effort (eg. its implementation cannot require unacceptable loss of leisure time).

Commodity prices are one of the primary drivers of profitability and land-use change. For example, the conversion of grazing land to vineyards and olives in South Australia represents a shift from low-priced commodities to higher-priced commodities. Economic models, based on rudimentary concepts of supply and demand, are able to predict changes in land use as a consequence of changes in commodity price. In simple terms, as the price of a commodity rises, there will generally be an increase in the area of land used for its production, after a period of adjustment. Likewise, land uses supplying a commodity that has fallen in price will generally decrease in area.

While farmers will tend to select a farming system that best meets their objectives, the adoption of less profitable but environmentally superior systems may still occur through the use of social and institutional policy mechanisms. Adaptation of some economic modelling of salinity on the Lower Eyre Peninsula by Hajkowicz and Young (2000) shows that revegetation options need to be 75–90% as profitable as current land uses to deliver social benefits in excess of social costs. The policy question is whether the total cost of filling the shortfall in profits (between the current system and the revegetation option) is worth the non-market benefits of reduced saline land and water salinity. If society considers the non-market benefit worth this amount, then it will be in their interest to bolster the profitability of revegetation options (eg. through incentive payments) to obtain the desired land-use change.

The economic returns of land-use options (ie. profitability) will be a primary factor driving farmer decision-making relating to land-use change and adoption of new farming practices. Factors that change land-use profitability over a long period (eg. an enduring change in commodity prices) are likely to change areas allocated to land uses, after a period of adjustment. Landscape redesign options will be considered in the social interest if total benefits can be demonstrated to exceed total costs.

Community dynamics

The demographic and socio-cultural structure of regional communities is a critical factor influencing landscape response to external stimulus. The community capacity to change is influenced by factors such as farmer income, farmer age, educational level, involvement in land-awareness programs, farm structure, and farm family issues. An understanding of how these factors influence land management and the adoption of improved farming practice is critical to the design and implementation of effective policy. Following is a summary of how these factors are likely to influence land-management practice, drawing heavily upon recent research conducted under the National Land and Water Resources Audit (Cary *et al.* 2001).

Farmer income

Agricultural land managers will often state that "it's hard to be green when you're in the red". The observation that conservation activities and sustainable farming practices are more likely to be adopted by farmers with higher income levels is well supported by overseas research, mostly from the United States (Camboni and Napier 1993; Saltiel *et al.* 1994; Witter *et al.* 1996, cited in Cary *et al.* 2001). Greater farm income and lower debt-servicing requirements will allow farmers to carry higher levels of risk and make larger investments associated with new production systems.

Declining terms of trade (the ratio of prices received to prices paid, often referred to as the 'cost–price squeeze') over the past several decades has made on-farm conservation activities financially more difficult for many farmers. As commodity prices have fallen and costs of production have risen, an increase in production has been necessary to remain financially viable. In many areas, this increase in production has led to increases in environmental degradation, eg. over-cropping or over-grazing or high rates of fertiliser application and run-off.

Another important trend in Australian farm income is the increasing reliance placed on off-farm income. The ratio of off-farm income to farm cash income in broadacre industries has risen from 29% in 1985 to 42% in 1999 (ABARE 2000). In many broadacre regions, the farm enterprise has been kept running through off-farm income sources, such as wages obtained by a spouse. The capacity of farmers to obtain alternative income sources will influence their capacity to maintain the farming business through economically difficult periods. It may also have an effect on their capacity to invest in sustainable land-management practices.

Farmer age

Australia has an aging farmer population (see Figure 10). The average age of the Australian farmer has risen from 49 to 52 years over the period 1981/82 to 1996/97 (Garnaut and Helali 1999). The implications of an aging farmer population are not fully understood. There is a possibility that agricultural production systems will not benefit from an influx of new ideas held by a younger population. Younger farmers tend to have attained higher levels of education and training. However, research findings on whether older farmers are more or less likely to adopt environment-benefiting land-management practices are inconclusive. For example, tree planting has increased rates of adoption up until the age cohort of 45–55 years and then shows a subsequent decline (Solutions 1999). Other studies have found no clear correlation between age and best practice adoption and yet = suggest that older farmers have higher levels of stewardship (Cary *et al.* 2001). Despite the complex interrelationships between farmer age and land-management practice, the age profile of farmers within a region is likely to have significant impacts on responses to agricultural policy.

Farmer education and learning style

There is an expectation that higher levels of farmer education and training will lead to increased adoption of improved farming practice. This is supported by survey data emanating from the National Land and Water Resources Audit (Cary *et al.* 2001), which finds that participation in training courses is strongly associated with adoption of improved farming practice. The relationship between adoption of improved farming practice and broader educational levels, as opposed to training, is less clear. There is some evidence to suggest that capacity to obtain off-farm income and the level of on-farm income is positively related to educational level

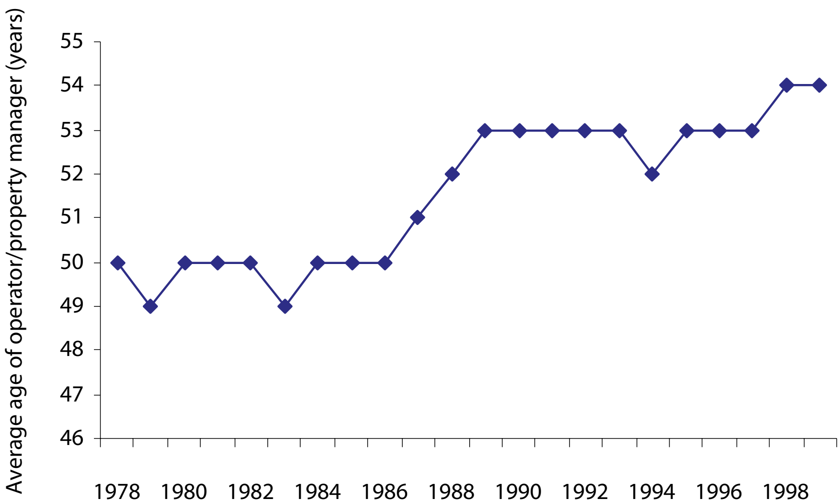

Figure 10. Average age of farmers in broadacre industries.
Source: ABARE (2000)

(Cary *et al.* 2001). The impact of education is likely to be strongly influenced by the learning style of farmers. Many farmers may not have a learning style associated with formal education — deriving an understanding of landscape function and farming practices through many other avenues.

Other factors influencing community capacity to change

Around one-third of Australian farm owner-manager households consist of couples and another third of couples with children aged 19 or younger (Garnaut and Lim-Applegate 1998). The stage in family life cycle is likely to be a significant factor affecting adoption of new farming practices. There is evidence to suggest that farm investment is less likely to occur when children are unlikely to remain on the farm; looking elsewhere for employment opportunities (Cary *et al.* 2001). In a longitudinal study of Australian farmers, it was found that just under 61% had farms owned by their parents, while only 29% believed their farm would be run by their children (Reeve 2001).

There is also an expectation that involvement in government programs, such as Landcare, will lead to improved farmer attitudes towards the environment and, consequently, improved land-management actions. It has been found that over the period 1991–2000, farmers with membership of a Landcare group did not have significantly different changes in environmental attitudes compared with farmers who were not in a Landcare group. However, active involvement in Landcare activities did produce "more favourable environmental attitudes" (Reeve 2001).

Lastly, studies tend to suggest that farms covering a greater area are more likely to adopt improved farming practice (Cary *et al.* 2001). Larger farms tend to have greater gross farm incomes, and consequently, greater resources for investment in new farming practice. There is also a possibility that production demands placed on smaller farms can lead to overcropping and overgrazing, and subsequent soil erosion. Larger farms are able to spread grazing activities over larger areas, providing a better opportunity to keep stocking rates within acceptable levels.

The demographic and socio-cultural characteristic of a community will have a significant impact on landscape form and function. An understanding of these characteristics will be important in assessing the impact of policies aimed at changing physical landscape condition. Some of the major factors affecting community capacity to change include farm income, farmer age, farmer education and learning style, family issues, attitudes and farm structure.

Landscape near Mt Stuart, Queensland. © CSIRO

Landscape planning and management

In tackling complex problems of land degradation, natural-resource managers will be challenged to resolve a suite of conceptual issues relating to institutional matters. These include assessment of market failure, sharing costs for investment between landholders and society, evaluating strategies, measuring progress and many others. Resolving these concepts is a prerequisite for effective natural-resource planning at the landscape scale. The concepts are generic, being equally applicable to addressing salinity in southern, cropping, winter-rainfall areas or stream sedimentation in northern, high-summer rainfall grazing land.

Assessing the need for policy intervention

Many economists would argue that policy intervention, in the form of planned landscape change, is only necessary where there is a clear case of market failure. A market failure occurs when the exchange of goods and services between consumers and producers fails to deliver the greatest attainable benefits to society. In order to best target government policy, it is necessary to understand the nature of market failure. As with natural systems, markets are complex systems and changing one component can lead to unforeseen, and potentially damaging, changes to other components. There are three main causes of market failure: information failure; public goods; and externalities.

Information failure

Information failure can occur when the producer and/or consumer are unaware of any important financial, social or environmental impact associated with the production of a particular good or service. For a case of information failure to be established, awareness of these impacts would cause the consumer to purchase an alternative product and the producer to adopt an alternative production process. A market failure can only be considered an information failure if subsequent supply of that information changed consumer and/or producer behaviour. For example, it is sometimes suggested that lime application (to treat acidic soils) delivers a net financial benefit to individual landholders in certain regions. If this is correct, it is possible that problems of acidic soils result from information failure. If farmers were made aware of the net benefits and subsequently applied lime, then the information failure would be corrected.

It is often very difficult to be certain of information failure because individual consumers and producers weigh information in a decision-making process according to their own unique values. Consumers and producers may be privy to information relevant to their consumption and production decisions that is not easily attained by those seeking to identify information failure for purposes of public policy. For example, a great variety of factors influence a farmer's decision to apply lime in the treatment of acid soils. These vary from financial considerations through to trading-off personal leisure time versus time spent applying lime. Hidden considerations of this type can easily give false impressions of information failure to those viewing the problem from a distance.

Public goods

A public good is a resource from which individuals cannot be excluded from consuming due to ill-defined or unenforceable property rights. There are two types of public good: rival and non-rival. A non-rival public good can be consumed by an individual without diminishing the benefits that other individuals can attain from the same good. Sunshine and scenery (typically) can all be classed as non-rival goods. We can consume any amount of these goods without detracting from another person's ability to also derive benefit from their use. In contrast, a rival good is one that is diminished for all consumers if consumed by an individual. Groundwater, surface water, vegetation and wildlife are all rival public goods.

The problem of market failure arises from the consumption of rival public goods. Many of the natural resources used in agriculture fall into this category. For example, ground and surface water resources often have poorly defined property rights. This can lead to their degradation either through over-extraction or pollution.

Externalities

An externality emerges when the negative impacts of a production activity do not affect the firm or business involved in the production activity. Many types of land degradation are examples of externalities. For example, increased sediment loads to rivers resulting from soil erosion may not have a direct, negative impact on farmers whose land-management practices are causing the problem. Rather, farmers downstream and all other users of the river incur the negative impact. The farmers causing the problem do not have a price incentive for its prevention. There is no financial benefit for taking measures that avoid the downstream impacts and no financial cost for continuing externally damaging actions.

This is a classic example of an externality. It demonstrates a case where the market is failing to deliver benefits to all users of a resource. A response is to correct for the market failure by applying policy instruments such as incentive payments or regulation.

> *Government policy aimed at changing land-management practice has a role where there is evidence of market failure. This occurs when the market is not delivering social benefits. Market failure can be caused by information failure, poorly defined property rights (public goods) or externalities. It is important to understand the nature and extent of market failure, before implementing policies that will change the way the market operates.*

Policy instruments and incentive mechanisms

There is a considerable body of opinion suggesting that agricultural land uses and farming practices will change in appropriate ways if the institutional framework through which agriculture is managed is appropriately structured. Institutional restructuring can involve subtle and minor changes to guide markets and correct for market failure. Some of the major institutional tools for affecting desired land management and use change include:

- *Voluntary environmental management and accreditation systems*. Industry-adopted accreditation can sometimes allow produce to fetch a higher price in the market and/or access markets otherwise unavailable. Such accreditation is developing in response to consumer demand for 'environmentally friendly' produce — examples include International Standards Organization (ISO) 14000 accreditation, certification of organic produce and other forms of eco-labelling. A well-managed certification system can provide significant environmental benefits that the market would not otherwise supply. A certification system will generally require an independent authority and/or checking system capable of verifying that required environmental performance standards have been met by the producer.
- *Tradable property rights*. Many environmental problems result from poorly defined property rights. One approach is to develop a legal framework that defines new property rights, with penalties for violation of those rights. This is the basis of a tradable property-right scheme. Generally, the administrators of tradable property-right schemes first decide upon a socially 'acceptable' level of environmental damage. Permits to cause damage are then distributed to producers. The total number of permits should deliver a level of environmental damage equal to or less than the socially acceptable level. Buyers of the permits will be those producers for whom reduction of environmental damage is most costly. Sellers of the permits will be those producers for whom reduction of environmental damage is least costly. If the trade in permits works well, it should allow society to attain environmental benefits efficiently, ie. at the least possible cost (ABARE 2001).
- *Levies and grants*. Levies on environmentally damaging activities and grants for environmentally beneficial activities can be effective mechanisms for influencing farming practices and land use on private land. The basic principle is that through astute pricing, private costs and benefits of land uses can be made equal to social costs and benefits. In principle, this should align private land-management decisions more closely with social priorities.
- *Fees for non-compliance*. This involves the development of requirements for land management or land use, for which failure to meet incurs some type of penalty. Generally, the penalty is some form of non-compliance fee. A non-compliance fee is a charge levied on a producer if their actions cause damage beyond a set standard (ABARE 2001).
- *Philanthropic investments*. Over the past few decades there has been significant growth in philanthropic investments in environmental conservation and enhancement. Such investments can come from businesses, industry groups and individuals. The investments can be made either through the purchase of land for nature conservation purposes or the payment of landholders for undertaking some type of environmentally beneficial action.

In addition to those listed here, there is a multitude of other institutional approaches for delivering improved land management, such as performance bonds (where a deposit is returned following acceptable environmental performance within a particular project) and leasehold conditions (which can limit the types of activities on leasehold land).

All of these policy instruments are dependent on the extent and nature of land-management change required to obtain a social benefit. Generally, the change will incur some cost either to society (through government payments or subsidies) or to the producer (through the need to adopt a more costly but environmentally superior production technique). For efficient expenditure, the benefits of such changes should exceed the costs. Often information required to make this assessment is unavailable or based on rough approximations.

Difficulties of targeting policy instruments require that they be used within a broader planning framework (typically at the implementation phase as shown previously). Such a framework will help governments assess community aspirations for change, community values placed on different resources and the nature changes required to protect or enhance those values. Once a sound understanding of these matters has been established the appropriate mix of policy instruments can be implemented to effect desired change.

Because land-management and land-use change typically needs to occur on privately owned land, government (and community groups) seeking to effect change will need to use institutional mechanisms. These include tools such as environmental accreditation, tradable property rights, grants and levies, fees for non-compliance, philanthropic investments and others. Careful application of these tools can lead to improved social outcomes from market forces.

Sharing private and public costs

Many natural-resource management projects have costs that exceed benefits from the perspective of individual stakeholders. For example, riparian revegetation, fencing to protect habitat remnants and weed removal are sometimes not in the financial interests of a landholder, despite having broader social benefit. If left to the landholder alone, these strategies may not be implemented. The majority of projects aimed at providing community natural-resource management benefits fit into this category.

However, where there are multiple beneficiaries of a project, it can sometimes be in the interests of each individual stakeholder to share a portion of the cost, such that they can gain the benefits. If the benefit-share for an individual is greater than their cost-share, then it is in their interest to enter into a cost-sharing or joint investment arrangement. This is because from each stakeholder's point of view the benefits exceed the costs. In practice, cost-sharing and joint investment strategies are implemented by government on behalf of those members of society who benefit from the arrangement.

Often the two parties entering into a cost-sharing arrangement are a public funding body and an individual landholder, or group of landholders. This occurs where an action has both private landholder benefit and public benefit. Where the beneficiary pays principle applies, both landholders and government should cover part of the costs, as both are beneficiaries. There is a considerable literature on cost-sharing arrangements under these conditions. The desired outcome is a cost-sharing arrangement that has a net benefit for both society and the landholder.

A related issue is the nature of property rights held plus obligations and duties faced by each landholder. As a general rule, it is inefficient to use cost-sharing arrangements to help landholders to meet duties and obligations, as these are already reflected in property values. Cost-sharing arrangements, however, can be used to speed the introduction and acceptance of new duties and obligations.

The approach taken to cost-sharing has important implications for public investment in strategic landscape planning. Those managing the planning process will need to assess the requirement for cost-sharing based on the environmental standard required of certain land-management activities. For actions beyond the environmental standard, it becomes important to assess the financial benefits and costs accruing to landholders and the economic benefits accruing to society. The development of cost-sharing arrangements is further complicated by the change in environmental standards over time.

Typically, projects or programs aimed at improving land resource condition or management practice have both private and public benefit. This requires a cost-sharing arrangement. The arrangement will succeed if it holds clear benefit to both the private landholder and society, and also if the landholder's duty of care is externally defined and allowed to evolve.

Measuring performance

A shared landscape vision for the future among stakeholders is an ambitious goal, given the diversity of values, drivers and means for change. To have an agreed set of targets that formalises the collective expectations for change is an attractive prospect. Targets can provide the context for determining the level of investment required, and the terms of monitoring program success or failure. For example, the Integrated Catchment Management Strategy for the Murray–Darling Basin Commission contains a section on setting targets to guide actions and measure progress. Over the next 10 years, this strategy sets out to provide targets for (MDBC 2001):

- water quality (salinity, nutrients and other measures)
- water-sharing (environmental flows and consumptive use
- riverine ecosystem health
- terrestrial biodiversity (native vegetation and other measures).

While there are a great many reasons and frameworks for adopting targets, some general criteria that can be used to help guide the selection of suitable targets include:

- *Feasibility.* Meeting targets generally requires considerable investment. Often the causal relationship between physical actions and changes in the value of an indicator, against which a target is set, is poorly understood. For example, water-quality targets may require changes to land use over large parts of a catchment. In setting targets, it is necessary to estimate the likely costs of their attainment and the time frame over which they will be attainable.
- *Meaningfulness to decision-makers*. Targets are often based on complex scientific and technical measurement procedures. Decision-makers are more likely to apply targets that have been explained clearly, in non-technical terms.
- *Relevance to policy objectives*. Often the natural-resource outcomes for which the best data and models are available are not of primary relevance to decision-makers or policy questions. Targets should be sought that are clearly related to the natural-resource management policy objectives.
- *Comprehensiveness*. Targets chosen should comprehensively measure the attainment of desired future landscape outcomes sought by the community. This will require careful selection of measures relevant to community objectives. For example, measures of vegetation areas provide only partial information on the status of terrestrial habitats. A more comprehensive set of measures might look at the shape and connectivity of vegetation remnants across a landscape along with measures of biodiversity.
- *Level of commitment and accountability.* In some cases there may arise managerial, and potentially legal, obligations in meeting targets by certain dates. This can create risks for the agency or group setting the target.
- *Measurability.* It is desirable to have targets that can be measured through objective and repeatable scientific procedures. This helps ensure the credibility of targets, and helps remove subjective measurement bias.
- *Non-redundance.* A set of targets should not contain overlapping measures involving double counting. For example, targets for river/stream nutrient loads and nutrient run-off measure very similar outcomes. Ideally, the target should measure attainment of the end-point outcome sought by the community.

Provision of a target from an external agent (often a government agency), such as an end-of-valley water-quality target, can accelerate the planning process by focusing and abbreviating the debate on values and visions. It can also enhance the confidence of the planners and stakeholders that their process will enjoy at some stage the resources of that external agent (state, territory or Commonwealth funds in aid of landscape change). A common analogy here is that of a "Manhattan Project": undertake a project without concern for costs or external impacts, the focus is solely on meeting narrow objectives. In other words, this might be described as the end justifying the means. This has a certain appeal as an effective approach for achieving tangible change where change is desired. However, a closer look at the implications and practicalities of targets quickly reveals the negatives.

Firstly, facilitation of the planning process through provision of an externally provided target will only occur if the target is *a priori*, acceptable, palatable, relevant and credible in the eyes of the stakeholders in that local landscape. If it is not, then one can expect failure of the planning process and failure of adoption.

Secondly, technical understanding required to set realistic, feasible, quantitative targets expressed in terms of water- or land-quality outcomes (salinity level of a river, area salinised, etc.) is generally lacking in Australia. This is due to several factors. The first is the lack of sufficient historical monitoring to establish the trend; most of our landscapes are in a non-stationary condition as well as subject to large, natural, annual variations in response. For instance, in the Blackwood River, the annual variation in salinity is greater than the annual long-term trend (Figure 11). Setting and assessing targets in this context is hugely uncertain. Where was the indicator (eg. salinity) headed if we were to do nothing?

Thirdly, however the target is set, and however the baseline is assessed, the issue of assessing (even detecting) the impact of land-use change on the target remains. Many of the processes related to water quality as a function of land-use change are slow as well as insensitive to all but the highest levels of change. The time frame of the target must be consistent with the expected rate of adoption and the reaction time inherent in the system. It is entirely reasonable and practical that the target may be set at a value of poorer quality than the present condition, if the forecast trend would lead to even poorer water quality at some point in the future without the agreed level of land-use change.

Fourthly, acceptance of a target has unknown implications of accountability. If the target is not achieved, is there a consequence, and to whom? With respect to the issues of accountability, two types of target can be identified: indicative and binding. An indicative target provides an indication of the level of environmental performance that is to be reached. It helps a community group, government agency or farmers focus their efforts on an outcome. However, those responsible for an indicative target are not legally accountable if the target cannot be met. In contrast, a binding target is one that can be used to hold concerned individuals, groups or agencies accountable.

Given these potential shortcomings, for targets to be employed effectively, the process of their development should therefore have the following attributes:

- an assessment of the current status of the indicator, and how it will change if no action is taken
- there should be an agreed place, time and way of measuring the target
- targets should be set after broad objectives are set, and options considered, analysed and costed. Stakeholders will be in a better position to assess the acceptability of a target with information on the level of effort required and path to land-use change
- there should be a clear understanding and agreement as to what the target is and all of the implications for meeting it or not meeting it.

Relevant to this is the experience of Land and Water Management Planning in irrigated areas. Here they have initially agreed on licences to operate requirements — they are able to question these as they get more experience — they are not told how they should go about meeting the requirements.

Identifying drivers of land-use change

In order to predict the effect of policy on land-use change, it is necessary to understand and model the interactions that determine the nature of any change that occurs. By understanding determinants of land-use change, it is possible to assess the most efficient way to effect desired change and predict future land use under a ‘do nothing’ or ‘business as usual’ scenario. Describing the ‘do nothing’ scenario is important as it provides a base case against which land-use change policies can be assessed.

Approaches to predicting land-use change generally involve (a) identifying the factors that influence change, (b) determining how these factors influence land-use decisions, (c) predicting how these factors are likely to change over time, and (d) developing scenarios of future land uses based on these relationships. Often, several scenarios are produced to take into account variations in uncertain variables such as climate or commodity prices.

There have been many models developed to predict land-use change based on biophysical, economic and, to a lesser extent, social factors. The CLUE (Conversion of Land Use and its Effects) model (Veldkamp and Fresco 1996) developed in Europe seeks to encompass all these factors. In predicting land-use change, the CLUE model considers biophysical drivers, human drivers, technology, affluence levels, political structures and economic conditions.

There have been few attempts to identify a comprehensive set of factors that are likely to drive land-use change in Australia. Such a list could be a useful

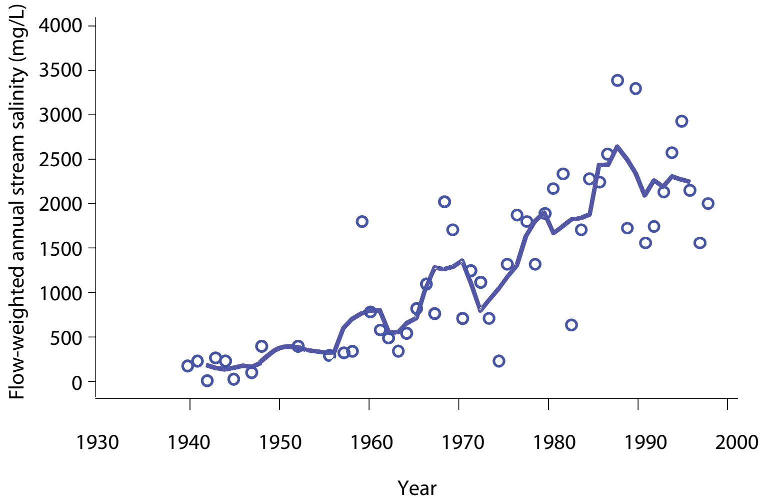

Figure 11. Annual salinity in the Blackwood River, with the five-year moving average indicating trend. Source: Water and Rivers Commission, Western Australia

starting point for applying policy instruments to implement landscape change strategies. As a rough guide, Figure 12 maps a set of factors that influence land-use decisions from the perspective of an individual farmer. The major factors are profit, risk, landholder (or land manager) cultural preferences, legislation (driven by social processes) and urban land pressures. These factors are, in turn, driven by a range of other social and biophysical factors. Changes in factors on the periphery of the diagram have the potential to cause significant changes to land use (at the centre).

Once the determinants of land-use change are understood, it is possible to identify which ones can be influenced through government policy in order to effect desired change. For example, government subsidies, regulation and legal instruments can all be used to affect change. However, policies can also affect change in less direct ways such as through providing information to landholders that might lead to changed attitudes and, thereby, changed land-use activities.

Understanding the determinants of land-use change allows an assessment future land use under 'business as usual' and a variety of policy scenarios. It also helps planning agencies understand where policy can be most effectively targeted. For most landscapes, it will be possible to identify a suite of factors that drive landholder decisions to change land use.

Evaluating land-use options

Once a set of alternative land uses has been identified, each comprised of an assemblage of on-ground actions, the question of which is 'best' for the catchment or landscape can be addressed. A variety of approaches is available to assess the relative performance of alternative land uses. These approaches need not necessarily be mutually exclusive and are often most powerful when applied in unison. A list of the major approaches includes:

- *benefit–cost analysis* — involves identifying all benefits and costs associated with a strategy and monetising those benefits and costs; usually, benefits and costs occurring in the future are devalued using a discount rate
- *multiple criteria analysis* — involves identifying a set of alternative strategies, identifying a set of criteria against which those strategies can be appraised, weighting the criteria, and ranking the strategies based on their performance
- *environmental impact assessment* — seeks to identify and manage all impacts on the environment that can occur as a result of development or change
- *social impact assessment* — assesses the social and cultural consequences of development or a proposed action; provides a framework for actively engaging communities
- *risk assessment* — a framework to identify potentially damaging impacts, the probability of their occurrence, and options for their avoidance
- *citizens' juries* — a small group of people representative of stakeholder interests are presented

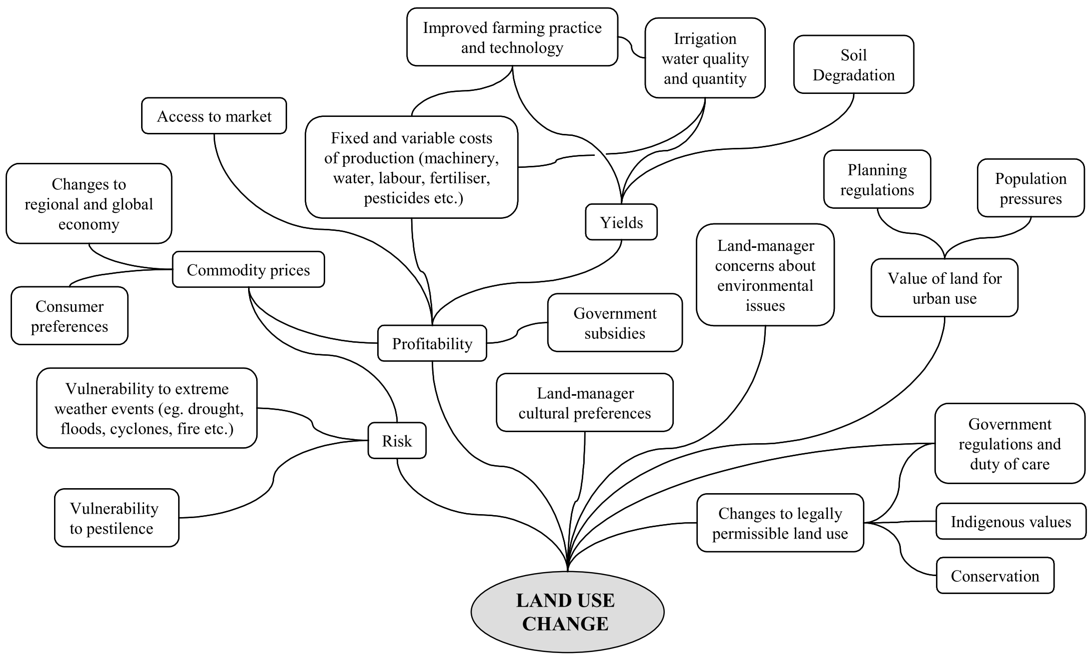

Figure 12. Factors influencing agricultural land-use change in Australia.

with arguments supporting or against proposed change; based on the use of juries to decide cases in the legal system
- *energy analysis* — similar to benefit–cost analysis, except all project impacts are expressed as energy losses or energy gains in energy units such as kilojoules; the alternative with the greatest energy gains is recommended.
- *matrices and checklists* — a great many matrices and checklists can be used to evaluate the landscape suitability of alternative actions; most are based on identifying a set of criteria and scoring alternative actions, similar to setting up the effects table in multiple criteria analysis.

All of the approaches/tools to evaluation can assist decision-makers select a preferred strategy. However, there must always be room for external factors that lie beyond a structured framework. This means that any evaluation of alternative strategies must be sufficiently flexible to incorporate political factors or other issues that cannot be neatly incorporated within an analytical framework.

At the evaluation stage of the planning process, it will be necessary to select a strategy from a set of alternatives. A range of complementary techniques can be used to evaluate landscape strategies. The purpose of these techniques is to inform decision makers about the trade-offs involved in adopting a particular course of action.

Predicting landscape responses

Landscape processes are governed by extremely complex interplay between social, environmental and economic factors. Altering a few aspects of the landscape can easily lead to unforeseen changes to many other aspects. This interconnectedness of landscape functions makes planning for landscape change an inherently risky activity. Operating under these conditions, natural-resource managers will generally seek to:

- identify the range of possible outcomes associated with a strategy expressed in economic, environmental and social terms
- assess the probability of each outcome occurring
- make decisions about the desirability of alternative strategies based on the expected benefits, levels of risk and uncertainty.

One of the most common approaches to handling the first two tasks, relating to uncertainty and risk, is to model the impacts of landscape changes before their implementation. This is generally done by constructing computerised models of landscapes and estimating how they will respond to physical or institutional change. The challenge is to build models that measure important impacts, relate these impacts to realistic policy options, and provide results with satisfactory levels of accuracy.

Currently, there is a wide variety of specialised computer models available that can be used to predict the impacts of salinity-management strategies, changed cropping practices, changed fertiliser-treatment practices and other changes to land management. Comparatively few of these models handle change at the landscape scale in an integrated manner. A comprehensive directory (Hook 1997) of Australian models for predicting farm production and catchment processes describes 93 models and decision-support systems.

In Australia, there is a pressing requirement to develop improved, integrated models that provide decision-makers with information on relevant social, economic and environmental impacts at the landscape scale. There currently exist very few models that can provide insights to landscape-scale responses to land-use change occurring over 10-, 20- or 30-year periods.

As integrated models are developed, they are likely to draw upon many of existing, specialised models. Figure 13 presents a framework for how the specialised models could feed into policy and decision-making. The biophysical and economic models are used to support the requirements of decision-support frameworks. In turn, these feed information on to decision-makers. The shaded inner circle represents and interpretation buffer that exists between policy/decision-makers and the biophysical/economic modelling. Arrows show linkages between all biophysical models, economic models and decision-support frameworks.

Through predictive modelling of future land use scenarios the likely economic, social and environmental impacts can be understood. This will provide a key foundation to the assessment and management of risk and uncertainty. Much research is still needed to improve catchment scale models such that they can provide decision makers with information that is both of sufficient accuracy and relevance to the decision-making problem.

Sound natural-resource planning decisions will require information on the likely economic, social and environmental impacts of proposed landscape strategies. This can help reduce uncertainty and give decision-makers a better understanding of risk.

Understanding planning and institutional failure

In landscape planning, there are numerous cases where the articulation of planning objectives, based on a vision, is at odds with final outcomes. Often what is envisioned is not implemented in practice. Sometimes the end result can fall well short of stakeholder expectations. This section explores some of the causes of planning failure — many of these observations are based on consultation with stakeholder groups as part of this project. Some of the major sources of planning failure include:

- *Insufficient funds*. Sometimes funds required to implement a strategy for landscape change are not made available to the extent originally envisaged. This can result in critical projects being discarded or only partially completed. Funds differ from expected amounts due to changed budgetary conditions that may be externally imposed or inaccurate estimates of project costs.
- *Continual institutional change*. Whilst it may be true that planning objectives and the information environment are continually changing, there is a requirement for a period of time during which a strategic landscape plan is pursued unchanged. This provides the many participants in the planning process with a period of time during which they can focus on a clear set of objectives. If the institutions and people involved in the planning process are continually changing the required momentum, resolve and expertise may be lost.
- *Marginalisation of stakeholder groups*. A failure to give all stakeholder groups a sense of ownership over the planning process can lead to the marginalisation of some groups. This can result in these groups being unwilling to assist in the implementation of a plan. In some cases, the support from all stakeholder groups is essential for the plan to deliver desired outcomes. For example, the plan may require revegetation or weed removal activities on private land, requiring the support of private landholders.

Failure to implement. Some planning processes reach the stages of setting objectives, identifying alternative strategies and selecting a desired strategy, but fail to reach the stages of implementation and review. A variety of external and internal factors can create these situations, such as a lack of political will or loss of key staff.

> *There are many cases where plans fail to deliver desired outcomes and fall short of stakeholder expectations. Some of the major causes of landscape-planning failure include insufficient funds, continual institutional change, marginalisation of stakeholder groups, and a failure to reach the stage of implementation.*

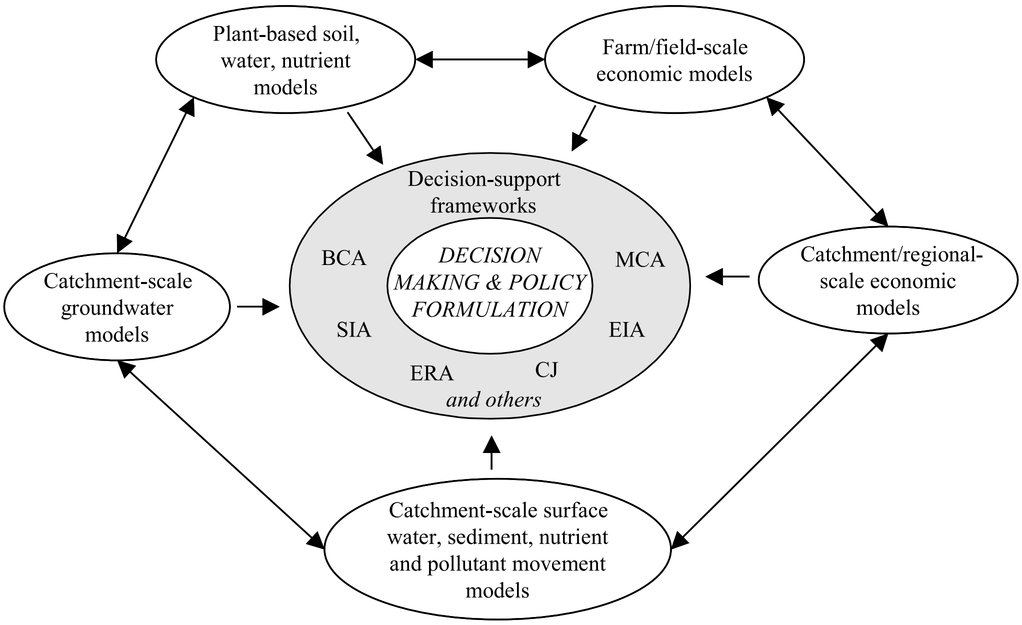

Figure 13. A framework for modelling to support decision-making and policy formulation. (Abbreviations are as follows: multiple criteria analysis (MCA), benefit cost analysis (BCA), social impact assessment (SIA), environmental impact assessment (EIA), environmental risk assessment (ERA), citizens juries (CJ).

An integrated conceptual framework

This report has raised and explored a great many issues relating to the management and functioning of Australian landscapes. How can all these issues be drawn together into an integrated framework? Clearly there exists a multitude of perspectives on how this should be achieved. It is unlikely that any single document provides a definitive answer to such a grand question. This section describes the major components of an integrated conceptual framework.

Two models of landscape planning are presented in this section. Each provides a different perspective on how the material covered thus far can be assembled into an integrated conceptual framework. The circular model of landscape planning shows the interrelationships among community values, physical and social processes that drive landscape form and function, and institutional responses. The procedural model provides more detail on the stages of landscape planning and how they are sequenced.

Circular model of landscape planning

The circular model of landscape planning is represented by a set of concentric circles (see Figure 14). At the centre of the model is *social wellbeing* as derived from natural resources. Social wellbeing is broadly defined to include all economic, cultural and environmental benefits humans derive from a landscape. The inner ring lists the major landscape attributes that provide social wellbeing. This is a list of what the community seeks to attain from the landscape. The next ring lists a set of fundamental processes that drive landscape form and function. These processes supply landscape attributes valued by the

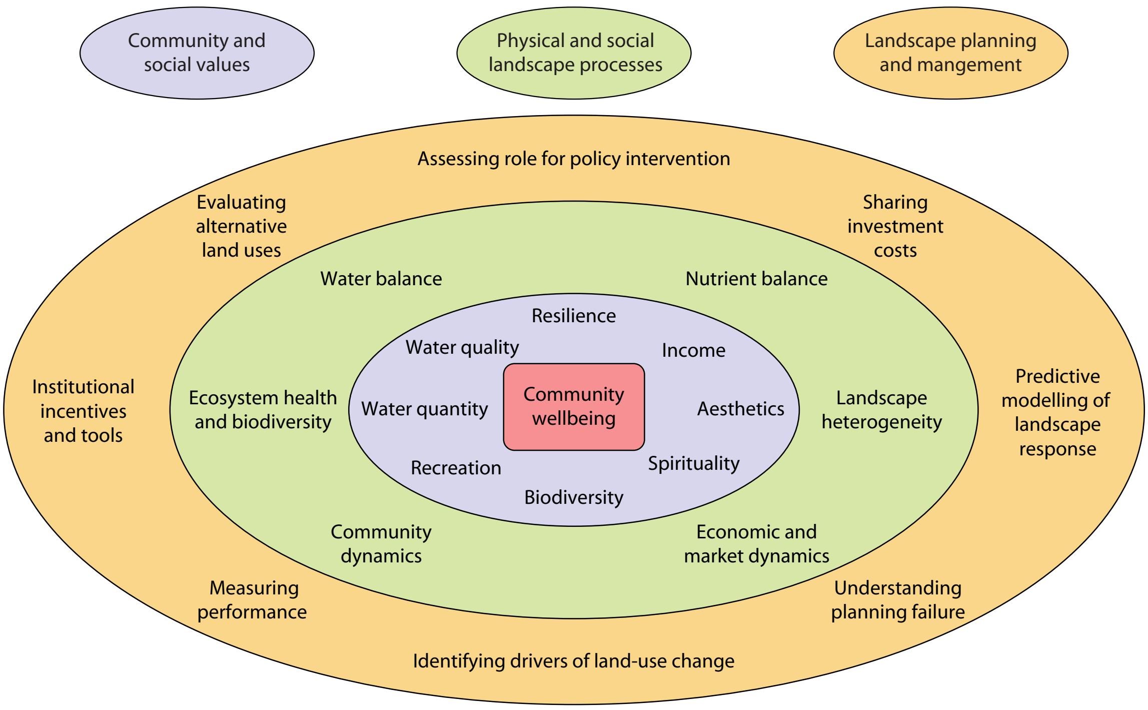

Figure 14. Circular model of landscape planning

community. Within the outer ring is a set of policy and institutional concepts that guide planning for desired landscape change. In practice, the list of items in each ring is likely to be much more detailed than is shown in the diagram.

Movement through the circular model generally commences at the centre, spreads outwards to the perimeter and then returns again to the centre through a set of alternative paths (as shown in Figure 15). This process reflects an initial understanding of what the community values, constrained by broader social requirements. This is followed by an understanding of how physical and social processes, active at the landscape scale, contribute to those values. The next phase involves identifying and assembling an appropriate mix of institutional tools/strategies to modify the landscape processes and return improved values demanded by the community. The planning system would be adaptively managed, continually revisiting each of the three rings through a set of different pathways.

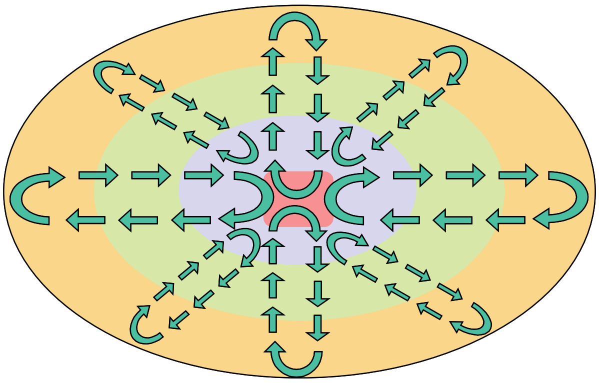

Figure 15. Movement through the circular landscape-planning model.

Procedural model of landscape planning

The procedural model of landscape planning provides more detail on the stages of planned landscape change and how they are sequenced (Figure 16). The procedural model contains three main phases, each producing a set of milestones. The milestones are key outcomes of each phase and allow the next phase to be commenced. The final milestone shown is the landscape strategic plan. The planning process continues beyond this milestone into the stages of monitoring, evaluation and adaptation as necessary. Throughout the entire process there is continual adaptive feedback to earlier stages. Continual and cyclical revisiting of earlier stages is necessary due to changing scientific information, political pressures and changing community values. The three main phases and their associated stages are described below.

1. Understand how a landscape is valued

What is it that people value about a landscape? The generic values obtained from a landscape were listed earlier in the document. These included sufficient water, clean water, income, biodiversity, cultural values (aesthetic, recreational and spiritual) and resilience. These are representative of categories of value — each category contains a much more detailed set. Collectively, these values contribute to overall social wellbeing as derived from natural resources. The stages of determining landscape values include:

- Identifying the stakeholders (those residing both within and outside the landscape) that will be affected by a change to the landscape resources. These people will guide the selection of values.
- Developing a vision for the landscape. Often this involves drafting a vision statement. However, a vision can also be expressed visually (eg. through sketches, paintings or computer models). A well-drafted vision statement captures the primary aspirations held by stakeholders for the landscape and engenders interest and support for the final strategic plan.
- Translating the vision into broad objectives. These are general objectives for the landscape that broadly and comprehensively cover matters of importance to stakeholder groups. An example of such objectives is provided in Figure 16.
- Translating the broad objectives into more specific objectives. For example, a biodiversity objective may be broken down into a set of specific objectives for the preservation of specific habitats in particular locations. Likewise, an objective for profitability of land uses may be broken down into all the factors that drive profitability, such as soil health, irrigation water-use efficiency and precision farming.
- Translating specific objectives into measurable targets, criteria and indicators. A target is a set level measured against some objective that a plan seeks to reach. A criterion is a continually varying scale measuring the degree of objective-attainment by proposed landscape options before they are implemented. An indicator is identical to a criterion, however measures objective-attainment of landscape options after implementation and is used for monitoring.

Three milestones are attained through the first phase of the landscape-planning model. Firstly, a list of landscape attributes that are valued by the community is compiled. In some cases, this list may attach qualitative or quantitative measures of importance to each valued attribute. Secondly, a set of objectives, generally broken up into parent and sub-objectives, is produced. These objectives can be used to guide landscape-planning activities. Thirdly, a set of measurable criteria, targets and indicators is established.

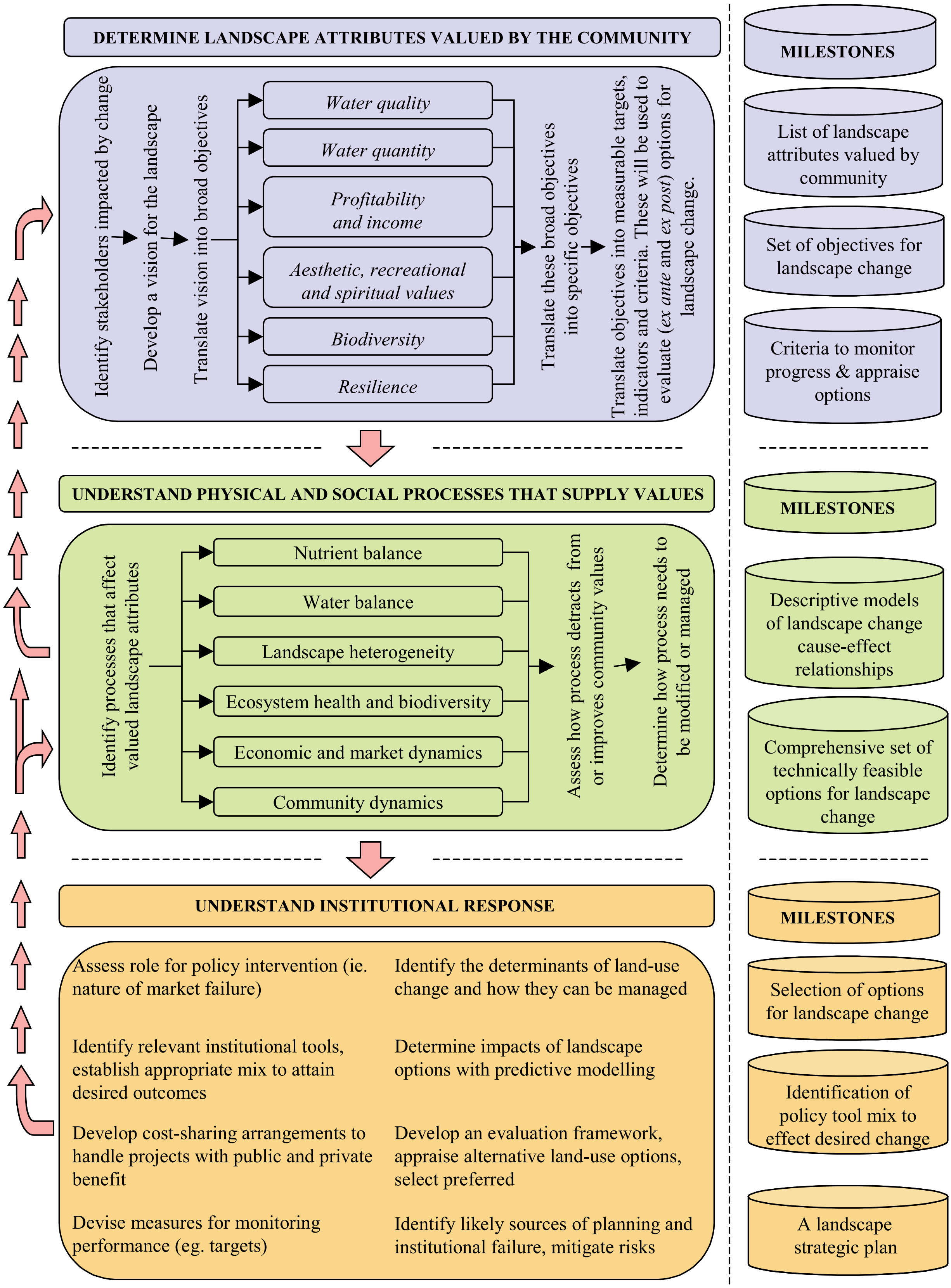

Figure 16. The procedural landscape-planning model

These will be used, either *ex-post* or *ex-ante*, to assess the degree of objective attainment.

2. Understand the physical and social landscape processes that supply those values

The values people derive from a landscape will be dependent on a set of fundamental physical and social processes. These processes can be altered from their current status to provide increased amounts and security of the attributes people value. For example, deep-rooted perennial vegetation with greater groundcover can be planted to reduce erosion rates and decrease sediment run-off into streams. The set of physical and social landscape processes includes: water balance; nutrient balance and erosion; landscape heterogeneity; ecosystem health and biodiversity, economic and market dynamics; and community dynamics. The stages involved in understanding these processes include:

- Identifying the processes that affect valued landscape attributes. For example, nutrient cycling and erosion have significant impacts on clean water — an attribute likely to be of value to the community. A list of the major processes likely to be relevant in most catchments is supplied in Figure 16.
- Assessing how each process detracts from or contributes to landscape attributes valued by the community. This involves developing an understanding of the scientific principles driving the landscape process. For example, much research into groundwater flow systems was needed to understand the fundamental forces causing salinity. Understanding supply curves, demand curves and elasticities can allow predictions of how commodity price changes will lead to changes in areas of land allocated to different land uses.
- Determining how the process needs to be modified or managed. At this stage, only physical changes to the system are considered, ignoring their social, political or economic feasibility. How does the natural, cultural or economic system need to be altered in order to sustain or deliver more of the attributes valued by the community? Usually the system can be altered in many different ways to supply commensurate levels of valued attributes.

Two milestones are attained through the second phase of the landscape-planning model. Firstly, a scientific understanding is gained that can explain how physical and social systems respond to external stimuli. This allows the construction of descriptive models that show how the process operates.

3. Understand the institutional response required to ensure correct functioning of landscape processes

Once a scientific understanding of the consequences of changing landscape processes is established, it is possible to develop a targeted institutional response. This will typically require resolution of the conceptual issues shown in the third phase of the landscape-planning model (Figure 16). This generalised set of institutional concepts will be relevant to most landscape-planning problems.

Perspectives on ways forward

The conceptual framework for planned landscape change can be approached from many different perspectives. Some of the major research fields and management styles that will contribute to planned landscape change in Australia are tabulated below:

Improving production systems: research and development	Innovations in science and technology are continually providing farmers with production systems capable of improved environmental and/or economic performance. Considerable jumps in yields of crops, horticultural and grazing activities over the past century have allowed Australian agriculture to remain internationally competitive. In addition to productivity improvements, research is increasingly turning towards the environmental performance of farming systems. For example, new farming systems that approximate the recharge rates of native vegetation are being tested and applied.
Understanding ecosystem services	This perspective stresses opportunities to use natural processes to deliver outcomes, like flood control, fertilisation and water purification at lower cost than conventional approaches.
Enhancing farmer attitudes, awareness and learning	With continual changes in technology, markets, institutions and best practice information requirements of farmers are likely to become increasingly complex. Helping farmers to learn about improved techniques of land management and become aware of environmental issues will be an ongoing requirement for landscape planning.

Improving and applying economic instruments	The cost of repairing Australia's degraded landscapes is overwhelming, and is likely to exceed the capacity of public funds alone. Developing economic instruments, such as tradable property rights and environmental certification, provides an option for attaining improved landscape health through the market. The development, trial and application of such instruments forms a critical component of effecting desired change.
Strengthening catchment planning institutions and processes	Integrated catchment planning has existed in various forms throughout Australia for some time. There is still much to be learnt about the institutional arrangements and processes for improved catchment planning. For example, how should the complex interplay between top-down and bottom-up approaches be managed? Taking a whole-of-catchment perspective to direct land-use change over time towards improved environmental, economic and social outcomes will help build healthy landscapes.
Understanding catchment-scale processes	Current knowledge of hydrological, geological, ecological, lithological and economic processes at the landscape scale is limited. This limitation places constraints on our ability to predict the future consequences of land-use change. A major component of planned landscape change will involve the development of improved models to understand landscape processes.
Researching and developing alternative industries	Options for productive use of degraded land (eg. salt-tolerant crops) and developing alternative non-agricultural industries (eg. tourism) will help landscapes meet economic requirements. In some cases, this may provide more cost-effective responses than correcting underlying land degradation problems.
Understanding Australia's cultural and historical attachment to landscapes	An area of growing research and community interest is Australia's cultural relationship with its landscapes. How have Australian perceptions of landscape value and significance changed over time? What are the implications of this cultural change for land management policy and research? Understanding these factors will be pivotal to developing landscape plans that deliver community aspirations.

No single perspective will provide the entire solution. The challenge for planning is to integrate the perspectives and assist governments in making difficult choices. Lastly, we stress that each perspective depends on all other perspectives. The engineering perspective, for example, supports the farming perspective and these two are linked only through the catchment perspective.

River gums along a billabong of the Murrumbidgee River, New South Wales. © CSIRO

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