

# **Ecosystem Services and Australian Natural Resource Management (NRM) Futures**

**Paper to the Natural Resource Policies and Programs  
Committee (NRPPC) and the  
Natural Resource Management Standing Committee  
(NRMSC)**

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August 2007



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ISBN 9780642553874

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### **Acknowledgements**

The Australian Government Department of the Environment, Water, Heritage and the Arts has collated and edited this paper for the Natural Resource Management Standing Committee. While reasonable efforts have been made to ensure that the contents of this paper are factually correct, the Australian Government and members of the Natural Resource Management Standing Committee (or the governments that the committee members represent) do not accept responsibility for the accuracy or completeness of the contents, and shall not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance on, the contents of this paper.

The paper was developed by the Ecosystem Services Working Group of the Natural Resource Policies and Programs Committee, comprising Steven Cork, Australian Government Department of the Environment, Water, Heritage and the Arts; Gary Stoneham, Victorian Department of Sustainability and the Environment; Kevin Love, Victorian Department of Sustainability and the Environment and Peter Alexander (South Australia Department for the Environment and Heritage). Important input was also provided by Kate Gainer, Richard Thackway and Kim Lowe.

Cork Steven, Stoneham Gary, Lowe Kim (Ecosystem Services Working Group of the Natural Resource Policies and Programs Committee) 2007. *Ecosystem services and Australian natural resource management (NRM) futures*: Paper to the Natural Resource Policies and Programs Committee (NRPPC) and the Natural Resource Management Standing Committee (NRMSC). Australian Government Department of the Environment, Water, Heritage and the Arts: Canberra, Australia.

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# 1 Executive summary

## 1.1 Whole-of-government policy objectives with respect to ecosystem assets and services

The ecosystem services concept has relevance to all policies and programs that flow from the National Strategy for Ecologically Sustainable Development (1992), especially the Natural Heritage Trust and National Action Plan for Salinity and Water Quality. This is not to say, however, that the ecosystem services concept offers solutions to all of the challenges posed by these policies and programs (see, for example, the discussion about stewardship programs in Section 8.1).

The ecosystem services concept reduces the complexity of natural systems to a manageable (comprehensible) number of services that people get from ecosystems as a way to focus on human dependence on the environment and to engage stakeholders and the community in dialogue about what services are needed where, when and by whom.

- The concept *is* part of society's response to ecologically sustainable development (ESD) – it *is not* an alternative.
- It *is* a way of adding value to well established approaches in economics and ecology – it *is not* a replacement. It provides a meaningful way of community members and stakeholders contributing transparently to land use planning.
- It *is* a way of framing and communicating planning and policy issues – it *is not* a new discipline or set of techniques.

The ecosystem services concept has been used successfully in Australia and internationally as a way to focus on natural resource management (NRM) priorities at catchment, regional, national and global scales and to link and report on the relationship between the environment and human well-being.

## 1.2 Origins and use of the ecosystem services concept

Economists and ecologists have been working together for several decades to find ways to explain the dependence of humans on the natural environment to a broad audience. In recent years progress has been made through refined language and better data on how ecological and economic processes interconnect for the benefit of society. These concepts are not new but are now entering mainstream thinking thanks to clearer expression. **They are central to future environmental policy, whether they use the name ecosystem services or a variety of other names.** The concepts have their roots in ecology and economics.

The concept of ecosystem services has been adopted worldwide by leaders in thinking about ESD including the World Bank, the World Resources Institute, the United Nations initiated 2005 Millennium Ecosystem Assessment, Goldman Sachs and the Heinz Foundation. It has been adopted by these organisations because other frameworks for integrating economics and ecology have not captured the central role and benefits of ecosystem-based management in a way that a broad audience can

relate to. The concept reinforces the interdependency of environmental management and human well-being.

There has been considerable debate about the relationship between ecosystem functions, ecosystem services and biodiversity. Understanding is adequate for broad management objectives to be set within a framework relating ecosystem function to human needs and for progress against those objectives to be assessed. In general a greater diversity of functional types leads to greater productivity, although in the short term systems can be highly productive with low biodiversity. Genetic, species and functional diversity are all important for providing ecosystem services, but the right combinations of functions are also important. Maintaining a diversity of functional types is thought to confer resilience on ecosystems. **Protecting as much biodiversity as possible is a wise strategy for managing risks associated with medium-term and long-term climate change and other environmental changes and for keeping future management options open.**

Several case studies in which the ecosystem services concept has been applied are analysed in Section 5.

### **The ecosystem services concept in practice in the states**

Victoria, NSW, South Australia and Queensland have responded to requests for input on application of the ecosystem services concept in their jurisdictions.

In Victoria, the ecosystem services concept is central to thinking about NRM particularly in engaging the community and stakeholders in project, program and strategy development. Ecosystem services thinking is used to communicate market-based approaches to meeting conservation objectives (e.g. Bush Tender and EcoTender). These approaches have evolved from a focus on single ecosystem services to a focus on multiple, bundled services.

In NSW, the ecosystem services concept is also fundamental to several NRM policies. The market-based Environmental Services Scheme is an explicit application of the ecosystem services concept.

Policies and practices in South Australia are consistent with the ecosystem services concept. The 'no species loss' strategy in that state identifies some opportunities to align with ecosystem services thinking and may assist in defining duty of care and assessing the status of ecosystem services.

At least one major study in south-eastern Queensland has adopted an ecosystem services framework as it's focus.

### **1.3 An operational definition of the ecosystem services concept for use in developing and implementing policy**

There is broad agreement worldwide on the definition of ecosystem services. The simple definition of the Millennium Ecosystem Assessment is ideal:

*...ecosystem services are the benefits people obtain from ecosystems.*

It is important to note that the ecosystem services concept is not fundamentally about market-based instruments, although market-based instruments have been applied very successfully to protecting ecosystem services by addressing one of the greatest threats to them: market failure (also referred to later as "missing markets").

Those who pioneered the development of the ecosystem services concept intended it to include the **full range of services**: those that involve tangible products, such as food, fibre, clean air and fresh water; indirect services like pest control, regulation of flow rates in waterways, maintenance of genetic diversity, and stabilisation of soils; and intangible services such as providing cultural, intellectual and recreational stimulation and satisfaction.

There is inconsistent interpretation of the concept among agencies and interest groups, some focusing only on marketable services and others focusing only on non-marketable services. This creates confusion, which can be avoided by being specific about the services of interest under the umbrella of ecosystem services. **Also, some people use the term 'ecosystem services' to refer to services provided by land managers to people rather than services provided by ecosystems.**

It is useful to define an "ecosystem services approach" as well as defining ecosystem services.

An **ecosystem services approach** is one that seeks to integrate the ecological, social and economic dimensions of NRM (including conservation as well as production objectives) by:

- explicitly identifying and classifying the benefits that people derive from ecosystems, including market and non-market, use and non-use, tangible and intangible benefits
- describing and communicating these benefits in concepts and language that stakeholders and the public can understand
- posing and trying to answer a set of critical questions for sustainable management of ecosystems and human welfare, including:
  - Which services are provided by which ecosystems?
  - Who benefits from different services? How? What are the future needs of humans for these services?
  - What are the impacts of humans on different ecosystem services?
  - What is the role of biota and other natural assets?
  - How do different ecosystem services interact with one another?
  - What are the critical levels of ecosystem services for human welfare and survival?
  - What are the possibilities and implications of technological substitution for ecosystem services?

Other approaches do some of this, but none do it all. An ecosystem services approach seeks to draw on these other approaches rather than replace them.

#### **1.4 Use of the ecosystem services concept in natural resource management policy and program development**

The ecosystem services concept assists in many phases of the policy cycle, especially:

- identifying issues in terms of what humans need and value and which humans are being affected by what ecosystem processes
- identifying priorities for action and devising interventions with a focus on human welfare outcomes
- monitoring outcomes (although indicators usually are not for the ecosystem services themselves but for assets and processes underpinning them)
- assisting dialogue about public versus private goods and services, and what products and services could be the focus of incentives.

The key challenge that the ecosystem services concept poses for policy makers and planners is to consider the full range of services rather than focusing on one or a few that are convenient while ignoring possible perverse interactions with those services that are ignored. This is how the concept adds detail and value to the broader concept of ESD. **This is not to say, however, that policy should not focus on individual ecosystem services or ecosystem assets once the overarching concept has been applied – in fact that individual focus might be inevitable.**

The debate about duty of care and, more recently, stewardship has focused on maintaining characteristics of land that may not have direct benefit to the landholder. In the past, this debate focused largely on soil attributes and stability; it has moved to vegetation more recently. Economics has contributed an interpretive framework with the concept of total economic value, which includes direct and indirect values and market and non-market values. **Ecosystem services language has elaborated on the concept of total economic value to explicitly focus on what services people *perceive* they are getting from the land.**

Duty of care is about defining that part of environmental management that is the responsibility of the landholder. In the academic literature, and in practice in other parts of the world, stewardship arrangements are about what society might want to pay for. The crux of this debate is that there is usually a grey area of mixed public and private benefits in the middle and the boundary is hard to define. The ecosystem services concept does not solve this problem but contributes to broader and more inclusive dialogue about the issues. It should be noted that stewardship has not yet been defined by Australian governments, so it is difficult to discuss in detail how the ecosystem services concept can contribute to the discussion.

Although some view stewardship in terms of paying for certain ecosystem services, this might be impractical because all ecosystem services require ecosystem

functionality that contributes to both private and public benefit. Therefore, stewardship programs might need to focus on specific inputs and outcomes rather than on ecosystem services as a whole.

Some of these challenges have played out in debate overseas about ‘multifunctionality’. This is discussed in Section 9.1.

## 1.5 Comparison with other viable approaches

At its heart, the ecosystem services concept is about the multiple services provided by the environment. Most other multiple-use concepts recognise that a range of services is possible but do not attempt to identify those services comprehensively. The ecosystem services concept, as developed by its leading proponents, requires attention to the full suite of services, either individually or in aggregates, and to the tradeoffs among those services and between those services and potential technological substitutes. This makes the concept very useful for bringing diverse interest groups together to identify and discuss common and separate interests.

Some economists ask what is new about the ecosystem services concept, arguing that economics is already addressing all of the issues for which the concept was developed. This attitude comes from the misconception that the ecosystem service concept seeks to replace some aspects of environmental economics. The misconception has been resolved by groups such as the World Bank and the Millennium Ecosystem Assessment and several state governments in Australia, but highlights the potential for the concept to be misunderstood and misused.

One major misinterpretation of the ecosystem services concept is that it is equivalent to market-based instruments. While ecosystem services thinking focuses on services and beneficiaries, it encourages consideration of a range of institutional and societal responses to identifying what services are needed, where and when they are needed, and how to maintain the flow of services. Market-based instruments often share common language with ecosystem services approaches and use the concept as a framework for identifying mechanisms to protect as many services as possible, but market-based instruments are not inevitable outcomes of an ecosystem services approach.

## 1.6 Barriers to using the concept effectively

While the concept has the potential to bring together groups that have traditionally been in conflict or had divergent views, it can also drive conservationists and agriculturalists apart if not carefully and thoughtfully applied. For example, some conservation-oriented individuals and groups fear that the intrinsic value of biodiversity will be forgotten among the many utilitarian values that are included in lists of ecosystem services or that stewardship payments will only apply to utilitarian values.

**These concerns can be addressed, as was done in the Millennium Ecosystem Assessment, by recognising that:**

1. the central reason for talking about ecosystem services is to encourage the full suite of use and non-use values to be considered together; and
2. biodiversity underpins all ecosystem services and although some services can be delivered in the short term by simplified ecosystems, these ecosystems have less resilience than complex ecosystems and greater potential to either fail or require increasing inputs to keep delivering services over the long term.

## 1.7 Measuring ecosystem services

While many countries have a set of indicators for assessing the state of the natural environment, few have systems explicitly based on ecosystem services. This is, however, changing rapidly.

The Millennium Ecosystem Assessment employed a range of environmental attributes as indicators of the state of ecosystem services. **The value of an ecosystem services approach is to provide a framework that relates the state of environmental, social and economic assets to human welfare.**

It is still difficult to measure ecosystem services directly. It may not even be advisable, because services are defined in terms of people's perceptions of what they want or need and those perceptions and/or needs may change whereas the assets that provide the services will retain their intrinsic importance. The approaches being taken in Victoria and NSW, for example, use an ecosystem services conceptual framework but focus on the state of underlying assets in relation to baselines or benchmarks for these assets.

In terms of understanding the relationship between biodiversity and ecosystem services and measuring how well that relationship is working, there have been some exciting developments. Some researchers have attempted to characterise ecosystem services by the component populations, species, functional groups (guilds), food webs or habitat types that collectively produce them. These have been termed 'ecosystem service providers' or 'service providing units'. **Ecosystem service providers are defined at different levels within ecological hierarchies depending on the type of service being provided and the geographic scale over which the service provider operates and its efficiency can be estimated** (see Appendix D.6).

## 1.8 Recommendations and next steps

In considering future approaches to NRM in Australia, the Australian and state governments would benefit from having a considered position on how to approach the concept of ecosystem services, because it is now routinely incorporated in leading thinking and action with respect to sustainable land management worldwide.

The concept progresses the broader sustainability agenda through a structured approach to valuing the many services society expects from the environment. It has recently been used as the basis for a global assessment of ecosystems and their links to human well-being.

This paper demonstrates that the concept and language of ecosystem services offer substantial benefits for framing and communicating environmental policy and

programs. There are, however, pitfalls, especially as interpretations and applications can and do differ among interest groups. Agreement among jurisdictions on at least the broad definition of ecosystem services and what an ecosystem services approach entails would eliminate much of the unhelpful confusion.

An ecosystem services approach can provide governments with a credible framework to support the design, implementation, evaluation and communication of environment and NRM policies and programs. It should complement – not replace – existing approaches.

## 2 Introduction

### 2.1 Genesis of this project

The Natural Resource Management Ministerial Council (NRMMC) agreed at NRMMC9 (October 2005, Resolution 8A) to ‘... *direct Standing Committee to look at development of ecosystem services at a national level, adopting experiences gained through State/Territory based NRM programs*’, cognisant that this directive may require forming a new task group to develop a national approach towards ecosystem services.

The Natural Resource Policies and Programs Committee (NRPPC) produced the following actions at NRPPC8 (February 2006):

- *NRPPC recognises that developing a national approach towards ecosystem services is a designated NRMMC priority area. However, NRPPC agreed that further preliminary work was required to define the task for NRPPC’s consideration. The NRPPC could then decide whether to delegate to an existing sub-group or create a new group.*
- *NRPPC requested Kevin Love, Peter Alexander, Gary Stoneham and Steven Cork to draft terms of reference and report by NRPPC9 (May).*

At NRPPC9 (May 2006) draft terms of reference were presented, debated and modified in line with alternative terms of reference tabled by the Australian Government. The actions were:

- *NRPPC requested Kevin Love, Peter Alexander, Gary Stoneham and Steven Cork to build on the NRPPC-agreed direction for this working group and prepare a paper that would input to the Future NRM Directions workshop (July).*
- *NRPPC agreed to the alternative Terms of Reference as drafted by the Australian Government, with the insertion of point (5) from the original version, amended as follows:*

*(1) Identify the whole-of-government policy objectives across all tenures, to define, manage and measure ecosystem assets and services.....etc.*

*(2) Outline the origins and use of the ecosystem services concept as a framework for defining, categorising and valuing the public and private benefits to humans from the environment...*

*...and so on, without amendment to the remaining seven points.*

The agreed terms of reference are given in Section 3.

Progress on this task has been slow due to competing commitments for all members of the working group and difficulty getting feedback from busy staff in the jurisdictions.

At NRPPC11:

- *NRPPC noted progress in framing a paper on ecosystem services for future NRMSC consideration. NRPPC agreed to seek comment on the draft paper Ecosystem Services and Australian NRM Futures ... from jurisdictions.*
- *NRPPC agreed to a restricted 'under embargo' circulation of the draft paper ... to expert industry/science persons for comment.*
- *NRPPC agreed to schedule Ecosystem Services for a presentation and further discussion at NRPPC13, in Hobart on 25 May 2007.*

## **2.2 The underpinning questions**

As the excerpts from NRMSC and NRPPC meetings above, and the terms of reference in Section 3, illustrate, the questions underpinning this project are many and varied. Some are about definitions and measurement, some are about policy application and some are about the relationships between ecosystem services thinking and other, more traditional, ways of thinking about the interactions between humans and the natural environment.

Perhaps the most fundamental question that the ecosystem services concept tries to address is:

- How can natural services be utilised, conserved and incorporated into sustainable planning for the benefit of the present generation and generations to come?

Much of the interest in the ecosystem services concept in Australia and internationally is generated by the possibility that this concept may make a new and useful contribution to addressing this question.

Thinking in terms of benefits to people from nature is already embedded in communication and policy about environmental and NRM issues in Australia, and in the disciplines of ecology and economics from which policy derives much of its technical input. When looking at the benefits of applying the ecosystem services concept, the question really being asked is whether explicitly adopting an ecosystem services approach provides a more complete or rational framework for decision making about environmental and natural resource management practices than other frameworks which are currently used or could be used.

## **2.3 What is an 'ecosystem services approach'?**

As this paper unfolds, definitions and applications of the ecosystem services approach will be discussed and analysed critically. There will be consideration of how an ecosystem services approach compares with other approaches and the strengths and weaknesses of such approaches. More detail will be given about what an ecosystem services approach entails (see Section 7) - put simply, however, it seeks to use ecosystem services thinking to consider the full range of ecological, social and

environmental benefits from the environment to people by addressing a set of key questions.

Other approaches do some of this, but none do it all. An ecosystem services approach seeks to draw on these other approaches rather than replace them.

### 3 Terms of reference

The following terms of reference were approved at NRPPC9.

1. Identify the whole-of-government policy objectives across all tenures, to define, manage and measure ecosystem assets and services, including consideration of:
  - state and national strategic goals – particularly in issue or threat-based strategies like salinity, weeds and pest animals
  - economic efficiency – define the cause of market failure and the role of state and federal governments
  - scientific capacity – define current scientific capabilities for measuring ecosystem services
  - international conventions and obligations – define the international obligations and conventions relevant to the provision of ecosystem services including:
    - a. WTO [World Trade Organization] and other international conventions relevant to the interaction between ecosystem service provision and commodity markets
    - b. environmental and conservation obligations
  - social implications – identify social issues relevant to ecosystem service provision.
2. Outline the origins and use of the ecosystem services concept as a framework for defining, categorising and valuing the benefits to humans from the environment.
3. Report on the ways in which jurisdictions are currently using the ecosystem services concept in developing and implementing natural resource management policies and programs.
4. Based on the findings of 1 and 2 above, develop an operational definition of the ecosystem services concept for use in the development and implementation of policy.
5. Identify ways in which the ecosystem services concept can be beneficially used in natural resource management policy and program development, exploring the advantages and disadvantages of its use.
6. Compare the use of the ecosystem services concept with the use of viable alternative approaches in natural resource management policy and program development.

7. For those areas in which it will be of benefit to use the concept of ecosystem services, identify what, if any, barriers exist to the effective use of the concept and propose ways of overcoming these barriers.
8. Identify current means of measuring ecosystem services and the current capability to make such measurements.
9. Make overall recommendations as to the practicality and benefits of adopting the ecosystem services concept in natural resource management policy and program development/implementation and outline next steps to be taken.

## 4 Whole-of-government policy objectives

### Terms of reference Item 1

Identify the whole-of-government policy objectives across all tenures, to define, manage and measure ecosystem assets and services, including consideration of:

- state and national strategic goals – particularly in issue or threat-based strategies like salinity, weeds and pest animals
- economic efficiency – define the cause of market failure and the role of state and federal governments
- scientific capacity – define current scientific capabilities for measuring ecosystem services
- international conventions and obligations – define the international obligations and conventions relevant to the provision of ecosystem services including:
  - a. WTO [World Trade Organization] and other international conventions relevant to the interaction between ecosystem service provision and commodity markets
  - b. environmental and conservation obligations
- social implications – identify social issues relevant to ecosystem service provision.

Some elements of Item 1 are dealt with in detail elsewhere in this paper. This section focuses on national strategic goals, and international conventions and obligations.

### 4.1 National strategic goals

#### 4.1.1 Current policy approaches to sustainable use of resources

The concepts of ecologically sustainable development (ESD) and ecologically sustainable resource use have been integral to Australian policy thinking since the early 1990s.

The National Strategy for Ecologically Sustainable Development, signed by all levels of government in 1992, describes ESD as:

*development which aims to meet the needs of Australians today, while conserving our ecosystems for the benefit of future generations... using those environmental resources which form the basis of our economy in a way which maintains and, where possible, improves their range, variety and quality. At*

*the same time ... [utilising] those resources to develop industry and generate employment.*

The words we have underlined in the above quote are a partial definition of ecosystem services (i.e. benefits to people from ecosystems). Thus, there is no doubt that Australian governments and NRM policy makers and managers should be focusing on the benefits to people from the natural environment. The really challenging questions are whether it is possible or desirable to:

- identify the set of benefits that are important to Australians in a clear, explicit and agreed way
- estimate how much of each benefit is needed now and into the future, by whom and where
- measure these benefits (e.g. as part of monitoring programs or to assess return on environmental investments) and, if so, against what targets
- use the terminology of ‘ecosystem services’ which has developed from collaborations of the world’s leading scientists, economists and policy makers around the world and is now the focus of major environment programs on most other continents of the world.

The suite of Australian Government environmental and NRM policies and programs, including the *Environment Protection and Biodiversity Conservation Act 1999*, Natural Heritage Trust, National Action Plan for Salinity and Water Quality, and national agreements on a range of environmental issues have evolved under the banner of the National Strategy for Ecologically Sustainable Development and Australian Government–state–local government agreements on their respective roles and responsibilities in relation to the environment.

These documents sometimes contain the specific words ‘ecosystem services’ or ‘environmental services’ but, if not, they almost always use similar terms like ‘ecosystem values’, ‘ecosystem health’ and ‘ecosystem function’. For example, the Framework for Future Natural Resource Management Programmes, endorsed by the Natural Resource Management Ministerial Council in November 2006<sup>1</sup>, states:

*Australia’s environmental and productive natural resources are among its most precious assets. These resources provide the basis for the productive and ecological services that are fundamental to economic and community life and for the maintenance of a sustainable environment in urban and rural Australia and in Australia’s marine areas.*

Thus, current policy documents are full of language acknowledging the importance of managing ecosystems so they are ‘functional’ and ‘valuable’, but rarely is ecosystem function or value defined explicitly. The ecosystem services concept has been

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<sup>1</sup><http://www.nrm.gov.au/publications/frameworks/pubs/future-programmes.pdf>

developed to explicitly link ecosystem function with human welfare and to define what services are required to meet human needs and desires (MA 2003, 2005a).

#### 4.1.2 Future developments in environmental policy

Australian governments have received a clear indication over the past few years about the directions in which the Australian public would like to see environmental policy move in the future.

The Steering Committee report to Australian governments on the public response to the discussion paper "Managing Natural Resources in Rural Australia for a Sustainable Future: A discussion paper for developing a national policy" following public consultation in 1999–2000 (National Natural Resource Management Policy Statement Steering Committee 2000) made the following observations:

*In addition, a significant number of responses from a range of organisations and groups noted that the discussion paper did not focus sufficiently on biodiversity issues, both in terms of its inherent value and the services that ecosystems provide.*

*A clear message to emerge from the public was the importance of the social aspects of natural resource management (as well as economic and environmental) and the need to stress the people factor (such as an individual's values and aspirations) that will make a national policy effective.*

There have been 10 recent national evaluations of Australian environmental policy (<http://www.nrm.gov.au/me/evaluation/index.html>). Many recommend greater attention to assessing return on investment from environmental programs, including better measures of what return on investment means. The recent Corish ([www.daff.gov.au/\\_data/assets/pdf\\_file/0005/56363/corish-response.pdf](http://www.daff.gov.au/_data/assets/pdf_file/0005/56363/corish-response.pdf)) and Keogh (<http://www.nrm.gov.au/publications/books/pubs/regional-delivery.pdf>) reports both emphasise that many land managers want to see better measures of public and private benefits from land management and to be acknowledged and rewarded for maintenance of at least some of the public benefits. A major obstacle to making policy reforms in this area is the absence of an agreed approach to categorising public and private benefits from the environment – something that the ecosystem services concept offers.

National objectives and outcomes for regional NRM planning (<http://www.nrm.gov.au/funding/principles/national.html>) are:

1. Promote sustainable resource use, particularly sustainable agriculture
2. Protect and improve the condition of land, water (including ground water) and vegetation resources that provide the **ecosystem services** that support sustainable resource use industries
3. Improve water quality and environmental condition in surface and ground water systems including wetlands and estuaries while maintaining the economic and social values derived from water use
4. Protect our coastal catchments, ecosystems and the marine environment

5. Reverse the decline in the extent and quality of native vegetation and maintain and restore habitat for flora and fauna
6. Protect and manage places and values of national environmental significance, including threatened species and communities, listed migratory species, Ramsar wetlands of international importance, world heritage areas and national heritage places
7. Promote Indigenous community participation in planning and delivery of regional NRM outcomes

Table 1 illustrates a typical approach to ecosystem services in current national NRM policy. The acknowledgement that ecosystem services are important is common throughout policy documents but advice on how to identify, categorise and measure these services is poorly developed.

**Table 1**  
**Information from the Australian Government, Natural Resource Management, National Objectives website (<http://www.nrm.gov.au/funding/principles/national.html>) illustrating the kinds of investments or activities the Australian Government supports through regional natural resource management strategies.**

Scope of regional plans	Examples of protection and improvement actions:
Identify key land resource assets	Improve awareness and understanding of land and water degradation
Identify key processes threatening land, water and vegetation resources or impacting on the provision of ecosystem services	Encourage the adoption of measures to address resource degradation and improve management, distinguishing between measures that provide primarily public benefit and those that provide private benefit
Protect and improve the condition of land, water and vegetation resources	<p>Improve mechanisms for communicating information on best practice management of soils and vegetation, including improved technical advice and agricultural extension services</p> <p>Apply best practice guidelines in resource development, having regard to local and state regulations</p> <p>Develop and implement best practice land, water and vegetation management guidelines at a property level</p> <p>Implement actions at catchment level that enhance integration of surface and ground water management.</p>

The 2005 reviews of the National Action Plan for Salinity and Water Quality and Natural Heritage Trust stage 2 biodiversity and sustainable agriculture programs highlight issues in the delivery of conservation and NRM policy (Griffin NRM Pty Ltd and URS Australia Ltd 2006; RM Consulting Group et al. 2006).

The biodiversity review found that regional organisations are aware that to develop and adopt best practice NRM systems, they must base their strategies on a sound understanding of the natural resource base in their region and the production systems it supports. There was, however, a perceived lack of 'strong, long-term, consistent

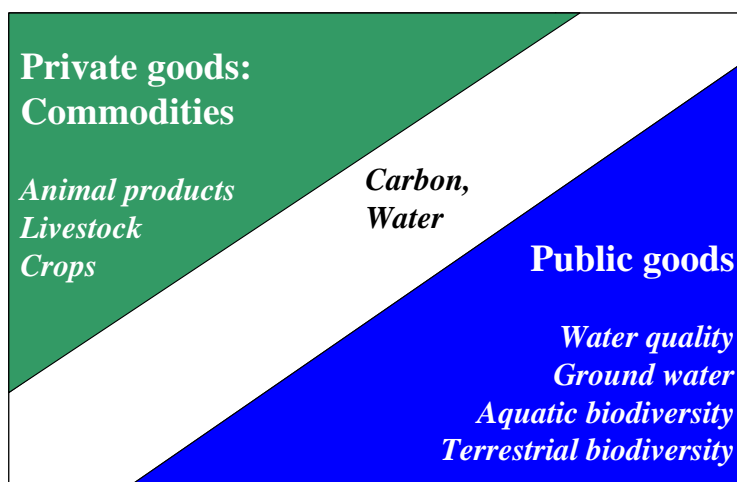
whole-of-government policy and legislation to achieve key national biodiversity targets'. This indicates that there is a problem in the signals landholders are receiving about how biodiversity should be managed, and more broadly, which environmental outcomes are more and less important and why.

The sustainable agriculture review highlighted the perceived competition between production and biodiversity objectives. This included a perception that biodiversity conservation outcomes were a higher priority under the Natural Heritage Trust than sustainable agriculture.

These and other reviews illustrate the need to develop a framework that relates biodiversity to production and broader aspects of human welfare. The ecosystem services approach provides one such framework, although there are others, which are discussed in Section 9.

These reviews identified other issues for future NRM policy, including the need to integrate biodiversity with other objectives, develop better data to assess progress towards sustainability goals, clarify public versus private responsibility, and find a better balance between protection and rehabilitation of natural environments without providing private benefits from investment of public money.

## 4.2 Economic efficiency and market failure



**Figure 1**

An economics view of ecosystem goods (ecosystem services can be seen as the maintenance and/or delivery of these goods). The white diagonal represents an area that is not clearly public or private

Economists recognise three broad classes of goods and services arising from the natural environment.

**Private goods where markets have evolved** – Natural resources such as land, water and air can be employed to produce commodities including crops and livestock products. These goods and services are private goods in that they can be bought and

sold in established markets. These markets have evolved autonomously and it is widely understood that they efficiently discover prices and allocate effort and resources between the alternative production opportunities.

**Private goods where markets have been (or can be) created** – A second class of goods and services generated from the way natural resources are employed includes carbon, water, fish stocks etc. Markets have not evolved for these ecosystem services but markets can be created if government caps access to these resources (at the sustainable yield level), allocates property rights and then allows markets to sort out who gets to use these resources. Australia's water market is a good example of an artificial market where the sustainable yield is defined, property rights are defined, trading rules are designed and then a market is employed (the water market) to allow private firms to trade in water entitlements. Through government intervention a market has been created for irrigation water in the Murray–Darling Basin. The Hunter River Salinity Scheme is another example of a well-designed cap and trade market.

**Public goods** – The third class of ecosystem services is shown in the lower right of the diagram. These goods and services include terrestrial and aquatic biodiversity, water quality, and ground water. These are public goods – they are not able to be owned by individuals. The economy lacks institutions that efficiently allocate investment to the production of ecosystem services that are public goods. Recent developments in economic theory and field pilot projects suggest that markets can be created for ecosystem services that are public goods by auctioning conservation contracts (e.g. BushTender).

Potential roles of state/territory and Australian government in addressing these issues are discussed in Sections 6, 8 and 12.

### **4.3 Current scientific ability to measure ecosystem services**

This topic is covered in Section 11.

### **4.4 International conventions and obligations relevant to providing ecosystem services**

#### **4.4.1 Conservation obligations**

Australia is party to a number of international agreements and conventions relating to biodiversity and sustainable management of natural resources (see <http://www.environment.gov.au/commitments/index.html#involvement> and <http://www.environment.gov.au/biodiversity/international/index.html>). *The National Strategy for the Conservation of Australia's Biological Diversity* is the chief vehicle for meeting obligations under these conventions. This strategy aims to conserve Australia's own biological diversity and to contribute to the conservation and ecologically sustainable use of biological diversity on a global scale. The strategy is currently being revised and thought is being given to how to incorporate broader aspects of the relationship between biodiversity and human activities into the strategy.

#### 4.4.2 Trade implications of ecosystem services and similar approaches

In Europe and parts of Asia, the term ‘multifunctionality’ has been used in much the same contexts as ‘ecosystem services’. As the name implies, multifunctionality is used to recognise the non-commodity (non-market) benefits that come from agricultural landscapes (OECD 2001). These include the same non-market benefits recognised in the ecosystem services classifications discussed later in this paper (Section 5).

Issues surrounding multifunctionality are discussed in Section 9.1. These issues include the association of the concept of multifunctionality with subsidisation of agriculture.

As a result, Boisvert and Blandford (2006) have recommended that, for policy purposes, a workable definition of multifunctionality must be restricted to non-commodity outputs of agriculture that satisfy two conditions:

- they are jointly produced with commodity outputs
- they provide social value (and impose social costs) not reflected in markets.

This definition brings into focus a problem that also arises when relating ecosystem services to economic classifications of value (see Section 9.2). Whereas both concepts – multifunctionality and ecosystem services – should logically include the full range of *functions*, *benefits* and/or *services* from landscapes or ecosystems, some authors have found the need to restrict the definition of multifunctionality to fit policy or political needs. The same is sometimes done with ecosystem services. This can be confusing and interfere with communication of the concepts that multifunctionality and the ecosystem services concept are intended to address (see Section 5).

#### 4.5 Social issues relevant to providing ecosystem services

As discussed in Section 5, the ecosystem services concept deals with the connections between biodiversity, the natural environment and human welfare. For this reason, ecosystem services are intimately involved in most aspects of resilient, healthy and prosperous societies. In terms of policy development, the ecosystem services concept offers the possibility of explicitly connecting environmental and social policy (see Sections 5 and 8).

## 5 Origin and use of the ecosystem services concept

### Terms of reference Item 2

Outline the origins and use of the ecosystem services concept as a framework for defining, categorising and valuing the benefits to humans from the environment.

### 5.1 Origin

Whether it be called ‘ecosystem services’ or some other term, the idea that nature and natural processes support human life and well-being has always been at the heart of NRM.

Humans have evolved with ecosystems, relying on them for food, shelter, medicines and a range of other resources. For some, the focus on nature from a ‘services’ or ‘benefits’ point of view is unduly human-centric, especially when this relationship gets translated into economic language and concepts.

Those whose primary focus is on conservation of other species fear that a focus on ecosystem services will devalue the importance of conservation. But viewed from another direction, we can argue that if other species have no value other than their existence value then humans faced with shortage of food, money, shelter or other basic needs could be forgiven for regarding protection of natural ecosystems as a luxury they cannot afford.

On the other hand, explaining the relationship between humans and nature as an essential one for the survival and well-being of our species adds enormously to the value of protecting other species.

The concept of ecosystem services emerged through decades of interactions among many of the world’s leading ecologists and economists searching for a way to simply communicate the dependence of humans on ecosystems. Names like ‘public services of the global ecosystem’ gave way to ‘nature’s services’ and ‘ecosystem services’ (Box 1:).

There has been debate about the nuances of these names – for example, some have argued that ecosystem services are those that require ecosystem-scale processes that deliver more than the sum of what individual species can provide. ‘Environmental services’ is often used as a synonym, although some are concerned that this term loses the focus on ecosystem-scale processes.

The focus on ecosystem ‘services’ attempts to make at least four major points:

1. There is a need for a simple and understandable explanation of the relationship between humans and nature that enables people to make reasoned decisions about environmental management in relation to other aspects of their lives.
2. Daily life for humans is about the exchange of goods and services. A service arises when resources of one sort or another—e.g. materials, time, talent—are

transformed into other forms that have some value or benefit to someone. Some services are about producing physical products or goods, e.g. bread, books, televisions. Some are not physical but still are tangible, e.g. training, education, entertainment. Others are intangible, e.g. emotional support, intellectual stimulation, provision of a sense of place, friendship.

3. By framing the relationship between humans and nature in terms of resources, goods and services (e.g. as in Figure 2) that meet definable physical and emotional human needs we have a robust, purposeful and open basis for discussing priorities, actions and tradeoffs in environmental decision making.
4. While these ideas already exist in some form within ecology and economics, they are not readily accessible to broad audiences and there have been few attempts to comprehensively classify natural resources and natural processes in ways that link them in plain language to human needs.

**Box 1: Some steps in the evolution of the term ‘ecosystem services’**

From Mooney & Ehrlich (1997)

- Environmental services (SCEP 1970)
- Public service functions of the global environment (Holdren & Ehrlich 1974)
- Public services of the global ecosystem (Ehrlich et al. 1977)
- Nature’s services (Westman 1977)
- Ecosystem services (Ehrlich & Ehrlich 1981)
- Nature’s services (Daily 1997)

The language and the concepts have now been adopted by governments, international organisations, business groups, interest groups and academics around the world, including the World Bank, United Nations, Millennium Ecosystem Assessment, World Business Council on Sustainable Development and Goldman Sachs (MA 2003, 2005a).

As discussed in Section 5.2 below and later in this paper (Sections 6, 8, 11 and 12), frameworks and language for identifying and classifying ecosystem services potentially play a key role in defining environmental challenges, supporting development of policies and programs to address the challenges, and assessing progress towards social, economic and environmental goals.

## 5.2 Definitions

Most groups that have worked on ecosystem services have adopted their own definition of ecosystem services that suits the context of their project or program. These definitions are usually variants on the most widely accepted definition:

*Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life. They maintain biodiversity and the production of ecosystem goods, such as seafood, forage, timber, biomass fuels, natural fibre, and many pharmaceuticals, industrial products, and their precursors... In addition to the production of goods, ecosystem services are the actual life-support functions,*

*such as cleansing, recycling, and renewal, and they confer many intangible aesthetic and cultural benefits as well. (Daily 1997:3)*

**Box 2: Report on Goldman Sachs' new environmental policy<sup>2</sup>, illustrating how ecosystem services have become a focus for businesses trying to contribute to environmental sustainability**

*Goldman Sachs' new green policy targets climate, 'ecosystems services'*

<http://www.greenbiz.com>/GreenBiz.com 23 November 2005 – Global investment bank Goldman Sachs has adopted a comprehensive environmental policy, acknowledging the scientific consensus on climate change and calling for urgent action by public policy makers and federal regulators to reduce greenhouse gas emissions.

The policy is also the first in the financial sector to acknowledge the degradation of global 'ecosystems services' addressed in the [United Nations' Millennium Ecosystem Assessment](#). Ecosystem services include the provision of water and food, control of pests and pathogens, renewal of fertile soil, control of floods, and more. The Millennium Ecosystem Assessment's findings that two-thirds of these services are being degraded present real challenges as well as opportunities for business.

Goldman Sachs will establish and fund a Centre for Environmental Markets in partnership with academia and civil society. The centre will engage in research to develop public policy options for establishing markets around climate change, biodiversity conservation and ecosystem services. Recognizing that climate change cannot successfully be addressed through voluntary action alone, the firm has also committed to promote regulatory solutions for reducing greenhouse gas emissions.

While this definition is helpful, the word 'natural' is often interpreted too narrowly. For example, NRM programs operate in ecosystems that contain farms, towns, landscapes, fishing, extractive industries and so on, and all of these ecosystems are still capable of producing ecosystem services. The intention of the word 'natural' in Daily's definition is simply to denote ecosystems containing species that are assembled in landscapes rather than, for example, in vats in a laboratory (although one could argue that the services provided by yeast in baking and brewing come from an ecosystem service because yeast evolved in systems of naturally occurring species).

The Millennium Ecosystem Assessment, which involved over 1,300 of the world's leading ecologists, economists and environmental policy makers, adopted an ecosystem services approach for its global assessment of condition and trends in ecosystems:

*An ecosystem is a dynamic complex of plant, animal and micro-organism communities and the non-living environment interacting as a functional unit. Humans are an integral part of ecosystems...*

*Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational,*

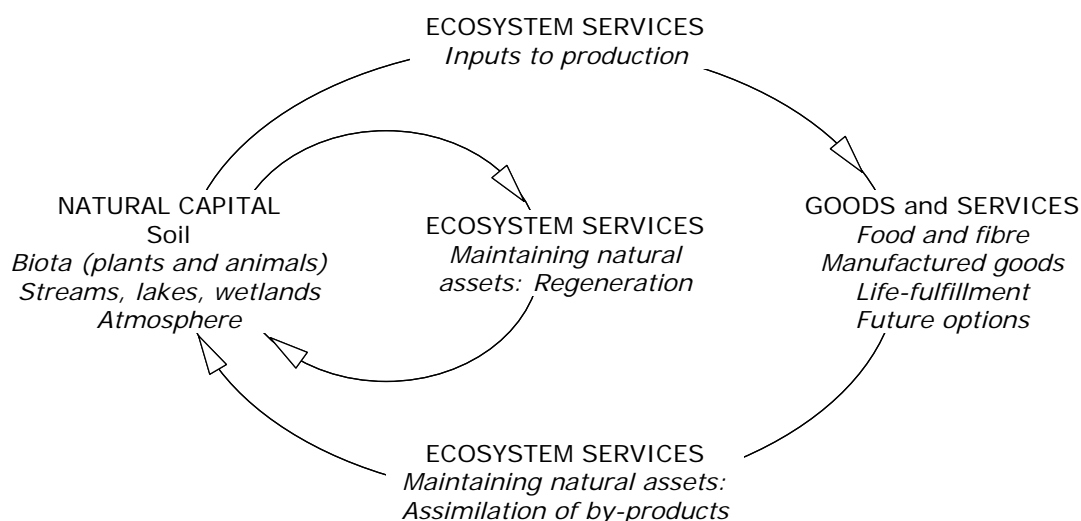
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<sup>2</sup> On the World Business Council for Sustainability website at <http://www.wbcsd.org/plugins/DocSearch/details.asp?type=DocDet&ObjectId=MTczNTQ>

*and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth. (MA 2003:49)*

The words underlined in the quote above are a simplified version of Daily's definition of ecosystem services and free of the connotations of the word 'natural'.

The confusion that sometimes arises over definitions of ecosystem services arises from different interpretations of these definitions. Interpretations and misinterpretations are discussed in Section 5.6.



**Figure 2**  
**A conceptual framework defining ecosystem services in terms of three types of transformations: (1) transformations of natural assets into products valued economically and in other ways by people in a catchment; (2) transformations of the by-products of Transformation 1 ecosystem services back into natural assets; (3) internal transformations among natural assets to maintain those assets**

From Abel et al. (2003)

### 5.3 Conceptual frameworks

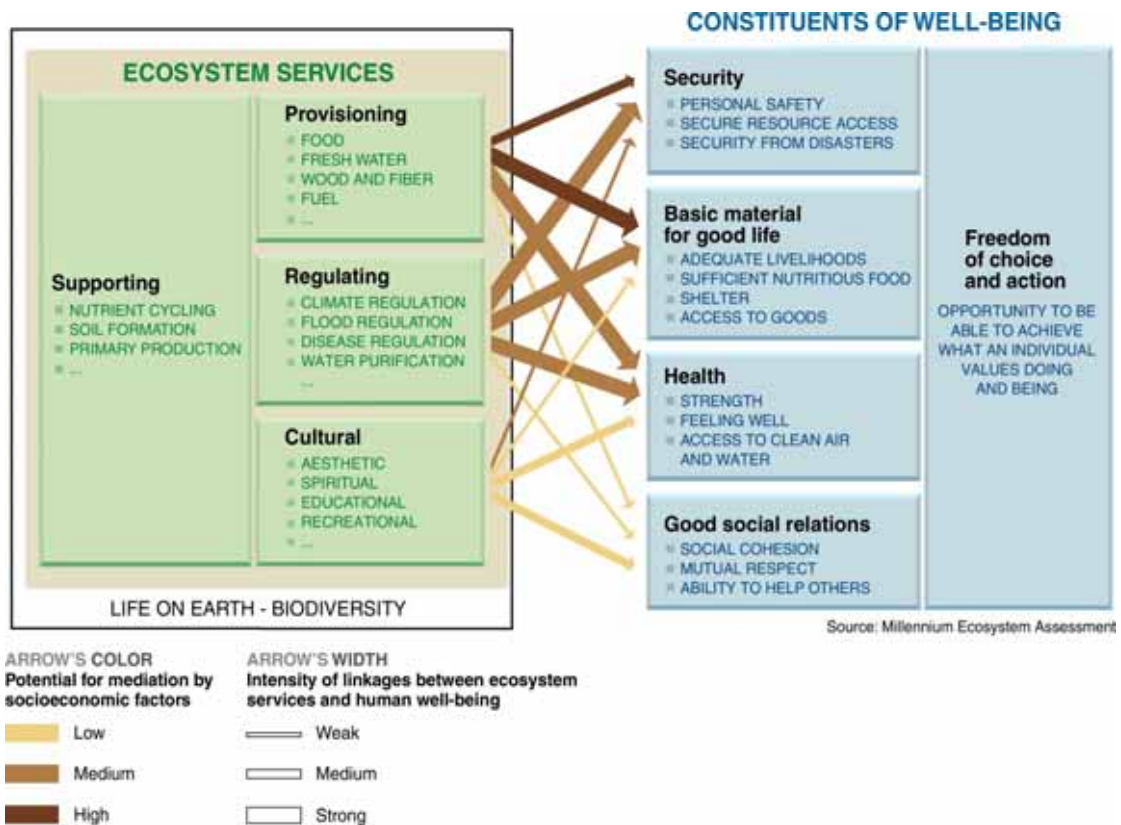
The term 'ecosystem services' embodies a conceptual framework that likens the relationship between humans and the environment to the transactions between customers and service providers in daily life. This borrows from the economic concept of services, which is based on transformations of resources from one form to another (Figure 2).

Thus, at one level, the term 'ecosystem services' is a communication device that seeks to provide a comprehensive list of the benefits from the environment (Figure 2, Figure 3 and Table 2) in everyday language.

### 5.4 Classifications of ecosystem services

There are a range of physical and cultural functions that are provided by ecosystem services. The recent Millennium Ecosystem Assessment adopted an ecosystem

services approach (Figure 3) as the framework for global assessment of the world's ecosystems and the implications for human welfare. This report identified the supporting, provisioning, regulating and cultural utility functions of ecosystem services in supporting 'life on earth'. A similar classification developed by Daily (1999) classified ecosystem services into (a) the production of goods, (b) regeneration processes, (c) stabilising processes, (d) life-fulfilling functions and (e) preservation of options (Table 2).



**Figure 3**  
The classification of ecosystem services used by the Millennium Ecosystem Assessment

From MA (2005a)

Virtually all ecosystem services projects and programs have developed their own take on these classifications to take account of the ways in which people express their needs and aspirations. Thus, the ecosystem services projects in the Goulburn Broken Catchment (Victoria) and the Gwydir Catchment (NSW) developed ecosystem services classifications based on input from stakeholders (Binning et al. 2001; Cork et al. 2001; <http://www.ecoman.une.edu.au/gesp/index.html>).

Appendix A gives detailed examples from De Groot et al. (2002) and others, and outlines an approach based on the relationship between ecosystem services, ecosystem functions and functional groups of organisms (Swift et al. 2004).

Individually tailored classifications are a major strength of the ecosystem services approach but they can also give rise to some odd services or some lack of consistency in approach. If the Australian Government were to adopt the ecosystem services

approach as a framework for programs such as land stewardship, it would need to consider tailoring a classification to fit its policy environment.

**Table 2**  
**A classification and examples of ecosystem services**

Adapted from Daily (1999)

Major category	Sub-categories and examples
Production of goods	Food: Terrestrial animal and plant products, forage, seafood, spices Pharmaceuticals: Medicines, precursors to synthetic drugs 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: The basis for the production of other goods
Regeneration processes	Cycling and filtration processes: Detoxification and decomposition of wastes, renewal of soil fertility, purification of air and water Translocation processes: Dispersal of seeds necessary for revegetation, pollination of crops and native vegetation
Stabilising processes	Coastal and river channel stability, compensation and substitution of one species for another when environments vary, control of the majority of potential pest species, moderation of weather extremes (such as temperature and wind), partial stabilisation of climate, regulation of the hydrological cycle (mitigation of floods, droughts, salinity)
Life-fulfilling Functions	Aesthetic beauty, cultural, intellectual, and spiritual inspiration, existence value, scientific discovery, serenity
Preservation of options	Maintenance of ecological components and systems needed for the future, supply of goods and services awaiting discovery

## 5.5 Key questions for research, management and policy

The most comprehensive assessment of the ecosystem services concept's potential role in policy was made by President Clinton's Committee of Advisors for Science and Technology (PCAST 1998), which identified a set of key questions that the concept forces policy makers and managers to address:

- Which services are provided from which ecosystems?
- Who benefits from different services? How? What are the future needs of humans for these services?
- What are the impacts of humans on different ecosystem services?
- What is the role of biota and other natural assets?
- How do different ecosystem services interact with one another?

- What are the critical levels of ecosystem services for human welfare and survival?
- What are the possibilities and implications of technological substitution for ecosystem services?

## 5.6 Interpretations and misinterpretations

The ways in which ecosystem services language and ideas are used will, and should, vary among applications. This use should not be tightly constrained because part of the strength of the concept is that it allows different people to express what they perceive to be the services they derive from ecosystems in their own language.

There have been, however, perverse differences in interpretation, within the common broad definition of ecosystem services, which have caused confusion and even conflict between interest groups.

Some confusion has emerged from different interpretations of the relationship between total economic value and ecosystem services (see Section 9.2 for a detailed discussion of the relationship between ecosystem services and economics). One such interpretation equates ecosystem services with indirect use values (e.g. carbon sequestration and erosion control) (OECD 1999). While this narrow interpretation is a minority view in the published literature, it is nevertheless used widely. One example is in Australia where some representatives of agricultural lobby groups have used ecosystem services language to argue for payments to farmers for services such as carbon sequestration, water filtration and erosion control. This is controversial as many believe that major components of these services should be within the farmer's duty of care to the environment and therefore should not be paid for with public funds.

A second minority interpretation is the one discussed in Section 9, which recommends restricting use of the term 'multifunctionality' to non-commodity (non-market) outputs of agriculture. This is the exact opposite of the minority view expressed above and is equally unhelpful.

Thirdly, there is the issue of restricting use of the term to NRM only. Strictly speaking, the concept of ecosystem services encompasses all aspects of an ecosystem, whether related to production or to 'intangible' values such as cultural values. The concept is as relevant to management of air quality issues as it is to soil quality.

Finally, some people have used the term ecosystem services to refer to services provided by land managers to people rather than services provided by ecosystems to people.

Adherence to the original intention of the ecosystem services concept – to consider the full suite of environmental services in one framework – avoids the confusion and potential conflict illustrated above. However, for some applications it will be necessary to avoid loose use of the term ecosystem services and to be specific about the particular services that are the subject of, for example, stewardship programs.

## 5.7 Biodiversity, ecosystem services and resilience

### 5.7.1 Where does biodiversity fit in ecosystem services classifications?

In some schemes for classifying ecosystem services, maintenance of biodiversity or habitat for biodiversity is seen as one service (for example, see Table 14). The argument for this is that protecting other species is something that humans desire and value and that the internal processes that maintain ecosystems therefore provide a valuable service to humans.

For some people and organisations, especially those whose primary focus is biodiversity conservation, the idea that maintenance of biodiversity is lost among 15 to 20 other ecosystem services is unacceptable. After much debate, the Millennium Ecosystem Assessment decided not to include maintenance of biodiversity as an ecosystem service but to recognise it as the underpinning for all other ecosystem services (MA 2005a; Figure 3).

This difference of interpretation with respect to biodiversity can lead to unhelpful polarisation of debate. For example, arguing for protection of biodiversity because biodiversity is needed to provide all ecosystem services opens up the question of whether all biodiversity is required to provide all ecosystem services. On the other hand, arguing that protection of biodiversity is important because humans have cultural and ethical reasons for valuing all other life forms is a legitimate expression of an ecosystem service that could be said to take precedence over most or all other services. In reality, it is most unhelpful to treat these two arguments separately or as opposing viewpoints.

### 5.7.2 Relationship between biodiversity and ecosystem services

Appendix D contains detailed discussion about the relationship between biodiversity and ecosystem services. This relationship can be summarised as follows:

- There has been considerable debate about the relationship between ecosystem function, ecosystem services and biodiversity.
- Understanding is adequate for broad management objectives to be set within a framework relating ecosystem function to human needs (i.e. a stewardship framework) and for progress against those objectives to be assessed.
- In general a greater diversity of functional types leads to greater productivity, although in the short term systems can be highly productive with low biodiversity.
- Genetic, species and functional diversity are all important for providing the ecosystem service; the right combinations of functions are also important.
- Maintaining a diversity of functional types is thought to confer resilience on ecosystems.
- Protecting as much biodiversity as possible is a wise strategy for managing risks associated with medium-term and long-term climate and other environmental change and for keeping future management options open.

## 5.8 Applications I: Studies of one to a few ecosystem services

Up to now, most research into ecosystem services has focused on establishing their worth by comparing costs and benefits of one or a few ecosystem services with their technological substitutes.

### 5.8.1 Water services

The case of New York City's water supply is perhaps the most well known study of an ecosystem service – water filtration (Chichilnisky & Heal 1998; Heal 2000). This study demonstrated that even with very little ecological information (NRC 2000) a lot of public money could be saved by managing watersheds better rather than building water filtration plants. It called into question the strategies of many cities around the world that depend on technology for providing clean water and vindicated the many others that still rely on natural water purification mechanisms (Reid 2001).

In a study of Melbourne's water catchment, recommendations for timber harvesting regimes were based partly on avoiding or minimising the costs of decreased water or timber yields under a range of scenarios (Read Sturgess & Associates 1992).

To assess the capacity and benefits of water flow regulation by ecosystems in Xingshan County, Hubei Province, China, Guo et al. (2000) used a process-based simulation model to estimate the capacity of water flow regulation by terrestrial ecosystems (especially forests). The model took into account a range of ecosystem processes, including canopy interception, litter absorption, and soil/ground water conservation. The capacity of water flow regulation was estimated to differ substantially among the 90 types of vegetation-soil-slope complexes in the watersheds. The simulation model estimated that water flow regulation by forested ecosystems allowed the Gezhouba hydroelectric power plant to generate an economic value 0.42 times the annual income from forestry in the county in 1994. The model suggested that income may reach 2.2 times the annual income from forestry when the Three Gorges Hydroelectric Power Plant begins to operate.

The use of water by humans and ecosystems in general provides a good example of the need for an approach that considers and communicates the full suite of services from ecosystems. When the use of water by natural ecosystems, production systems, industry and urban centres is properly assessed, there is no excess capacity. The water that many people think is simply flowing away unused is supporting ecosystems that provide the range of services listed in previous sections (Rockström et al. 1999). Therefore, as demand for more food or more water for other production and industrial uses increases, other services provided by ecosystems will have to be traded off.

### 5.8.2 Ecosystem services from soil

A lower-bound estimate of the contribution of natural nitrogen fertilisation to global crop production can be obtained using average estimates of net primary production and the nitrogen concentration in the crops produced (Daily, Matson & Vitousek 1997). The economic value of this contribution can be estimated as the cost of fertiliser to replace the naturally fixed nitrogen (US\$45 billion per year globally), taking into account that nitrogen from fertilisers is used much less efficiently than naturally fixed nitrogen (Daily, Matson and Vitousek 1997). A value for the

contribution to production of all land plants can be estimated similarly (US\$320 billion per year). If, however, we want to estimate changes in delivery of fertilising services, we must take account of the effects of changed management on many influencing variables, including hydrological processes (surface and subsurface water flows), erosion, tillage and harvesting regimes, fire, climate and the many variables that in turn affect them.

The cost of replacing the support and nutrient translocating services of soil itself have been estimated at over US\$900,000/ha (Daily, Matson & Vitousek 1997).

### **5.8.3 Pollination**

About 92 per cent of plants worldwide are pollinated by animals, and in about half of these, reproduction is determined more by the numbers of pollinators visiting the plants than by weather, soil fertility, diseases, parasites or animals that eat their flowers (Nabhan & Buchmann 1997). There are more than 1,200 vertebrate species and between 100,000 and 200,000 invertebrate species involved in pollination of flowering plants (Nabhan & Buchmann 1997), yet most crops in the USA and Australia are pollinated mainly by introduced honey bees (Gill 1989; Nabhan & Buchmann 1997).

The value of honey bees to agriculture in the USA is estimated to be US\$2–8 billion annually, based on estimates of increased seed and fruit production due to bees alone and changes in commodity prices with supply (Nabhan & Buchmann 1997). An estimate for Australia is A\$0.6-1.2 billion million (Gill 1989).

Concern has been raised about this heavy reliance on one pollinator species. A 'pollination crisis' has been predicted in the USA due to a major decline in honey bees caused by diseases and mite infestations (Watanabe 1994; Nabhan & Buchmann 1997). It is estimated that other pollinators could take up US\$4–7 billion of the service provided by honey bees in the USA if they and their habitats were present in sufficient amounts. But there are serious questions about that potential being realised given observed declines in pollination rates and seed set in a range of crops and native plants associated with urbanisation, land clearing and use of agricultural chemicals (Nabhan & Buchmann 1997).

A study of bees in California (Kremen et al. 2004; Kremen & Ostfeld 2005) is a perfect example of the many studies of one or a few ecosystem services. It showed that proximity to native vegetation enhances pollination services in cropping areas. When dealing with single ecosystem services there is a much greater chance of being able to control variables and draw unequivocal conclusions than when attempting to deal with suites of services.

### **5.8.4 Natural regulation of potential weed and pest populations**

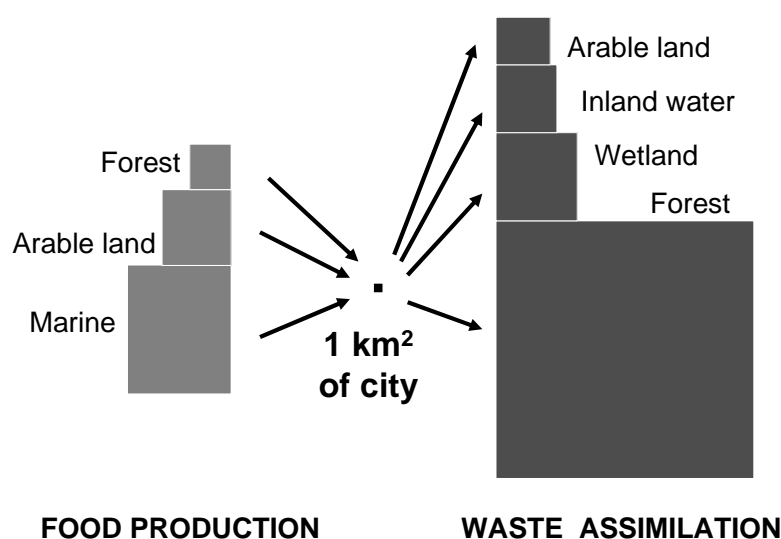
Much has been written about the natural regulation services provided by insects, spiders, birds, mammals and other animal species living in natural ecosystems (e.g. De Bach 1974; Ford 1991; Teng et al. 1994; Daily, Alexander et al. 1997; Naylor & Ehrlich, 1997; Pimentel et al. 1997; Heong & Escalada 1998; Wilby et al. 2005).

Recent evidence suggests that improved management of plankton-eating crustaceans and fish, together with management of nutrient flows into waterways, is likely to

improve control of algal outbreaks substantially (Matveev 1998). This is an example of a pest regulation service by natural ecosystems that is likely to be more cost effective than engineering and chemical alternatives.

### 5.8.5 Waste assimilation around the Baltic Sea

Studies of cities around the Baltic Sea (Folke et al. 1997) suggest that on average around 1,000 km<sup>2</sup> of forests, arable land, wetlands, and inland and marine waters are required to provide natural resources and assimilate carbon, nitrogen and phosphorus wastes per km<sup>2</sup> of city. Over 80 per cent of the area was required for assimilation of carbon and other wastes. Extrapolating the analyses to the 744 largest cities in the world, it was estimated that the world's need for carbon sequestration already outstrips capacity substantially (Folke et al. 1997).



**Figure 4**  
Scaled representation of the areas of different ecosystem types required to provide food and assimilate waste for one square kilometre of a city on the Baltic Sea

Adapted from Folke et al. (1997)

## 5.9 Applications II: Studies of suites of ecosystem services

While studies of one or a few ecosystem services, such as those reviewed above, have made important contributions to understanding how ecosystems deliver services and to elucidating the nature of technological substitutions for ecosystem services, there often is a need for an approach that considers the full suite of services in at least a qualitative sense. The challenge in moving to this level of assessment – which is after all what an ecosystem services approach challenges researchers, managers and policy makers to do – is that the relationships between biodiversity, ecological functions, ecosystem services and human well-being are poorly understood for many services.

Broadly speaking, two overlapping approaches have been taken to dealing with this challenge:

- use of qualitative or semi-quantitative approaches that use expert and local knowledge to rank ecosystem services for further study according to how important and critical they are
- attempts to gather the necessary quantitative information and develop integrated models of environmental, social and economic processes to predict the ecosystem services outcomes of policy and management options.

Examples of these approaches are given below.

### **5.9.1 Ecosystem services in the Goulburn Broken catchment, Australia**

A project conducted by Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) in the Goulburn Broken catchment in south-eastern Australia considered the ecosystem services provided by a whole watershed (Binning et al. 2001; Cork et al. 2001; [www.ecosystemsproject.org](http://www.ecosystemsproject.org); Cork et al. 2002; Abel et al. 2003; Cork & Proctor 2005). The aims of the project included: increasing awareness and understanding of ecosystem services among members of society; exploring the value of ecosystem services (in economic and other terms) to people in relation to real decisions and challenges; and investigating new mechanisms and institutional arrangements for recognising and making better use of these values. A framework for analysing ecosystem services at a range of scales was developed in partnership with stakeholders.

The approach had the following elements:

- a semi-quantitative inventory of what ecosystem services were present, how they were being used, and what was happening to them under current land use regimes
- identification of major decision scenarios for the future
- quantitative and qualitative economic, social and ecological assessments of decisions and exploration of new options
- analysis of institutional arrangements and exploration of new mechanisms for gaining greater value from ecosystem services.

The initial semi-quantitative inventory was requested by the policy makers among the stakeholder group because they were in the process of developing a new strategic plan and needed guidance before the results of the more detailed research and modelling of the later stages of the project would be available. An economic, social and biophysical profile for the catchment was derived from Australian Bureau of Statistics data and an input–output analysis of the catchment. Qualitative assessments of interactions between ecosystem services and land uses were derived from expert judgments by staff from CSIRO, other research institutions, government land management agencies, industry, and other stakeholders (Binning et al. 2001; Shelton et al. 2001). Participants were asked to identify what goods and services of value came from the catchment's ecosystems and to judge the impacts of marginal changes in the ecosystem services or land uses.

Interactions between ecosystem services and land uses were judged to be high priority for future investigation if either: (i) a marginal change in the service is likely to have a substantial impact on delivery of valued products from the land use; or (ii) a marginal change in the land use is likely to impact negatively on the ecosystem service (Table 3).

This was essentially a process to engage a wide range of stakeholders in thinking about the catchment's values and challenges and to identify where the project managers should focus more detailed quantitative analyses. The participants' reasoning was documented to provide hypotheses that could be assessed and tested experimentally if necessary. In addition a set of issues papers was commissioned from experts in various fields of ecology to link existing knowledge and theory with the set of ecosystem services identified by stakeholders and with the reasoning behind the assessments (Binning et al. 2001; [www.ecosystemsproject.org](http://www.ecosystemsproject.org)).

Twelve major ecosystem services were identified and assessed against 12 groupings of land uses and industries (Table 3). Some ecosystem services (e.g. pollination) are very important to a wide range of land uses but only appeared to be of high priority for one or a few land uses. Other services, like waste absorption and maintenance of soil health, appeared to be a high priority for most land uses.

The inventory process also identified issues facing the catchment in the next 10–50 years and beyond. These included:

- re-establishing part of the floodplain of the lower Goulburn River by removing levee banks
- developing alternative strategies for managing vegetation across the catchment
- developing options for enhancing cultural values and growing the tourism and recreation industries in the upper catchment
- developing some industries with possible offsets on other land uses
- managing combinations of land uses to enhance value to communities at a catchment scale.

The research challenges that the above issues pose include:

- exploring the costs and benefits of ecosystem services (such as water filtration, flood control, maintenance of soil fertility, and natural pest control) compared with technological alternatives (such as water filtration facilities, levee banks and application of fertilisers and pesticides)
- assessing non-market values (e.g. aesthetic, cultural and biodiversity values)
- assessing economic returns from public investment in land use change under current institutional arrangements (compared with possible improvements like development of markets for some ecosystem services)

- exploring ways to consider whole ecological–social systems and interactions among ecosystem services and land use options.

**Table 3**  
**Semi-quantitative inventory of ecosystem services in the Goulburn Broken catchment in Australia**

Ecosystem services (rows) judged to be of high importance (indicated by dark shading) to various land uses (columns) in the Goulburn Broken catchment. Key to column headings (land uses): 1 – Dairying, on farm; 2 - Fruit and grapes; 3 – Vegetables; 4 – Grazing; 5 – Crops; 6 – Intensive animals; 7 – Forestry; 8 – Food processing; 9 – Housing; 10 – Water production; 11 – Recreation; 12 – Areas of cultural/future options

Services	Land uses											
	1	2	3	4	5	6	7	8	9	10	11	12
Pollination												
Life fulfillment												
Regulation of climate												
Pest control												
Provision of genetic resources												
Maintenance of habitat												
Provision of shade and shelter												
Maintenance of soil health												
Maintenance of healthy waterways												
Water filtration and erosion control												
Regulation of rivers and ground water												
Waste absorption and breakdown												

Following the inventory, biophysical research and modelling addressed many of these issues and challenges but focused on elements for which data were available or could be obtained (Abel et al. 2003). Economic valuation techniques were used for services that were amenable (including input–output analysis, traditional benefit–cost analysis, and various approaches to assessing non-market values). A multi-criteria decision framework was also used to organise the economic and other assessments (Proctor & Dreschler 2003, 2006).

**5.9.2 Ranking the full suite of ecosystem services in wetlands**

Another situation that often calls for coarse overall assessment of ecosystem services is evaluating the roles of whole ecosystems such as wetlands and the implications of replacing those roles with technological alternatives. The example in **Error! Not a valid bookmark self-reference.** was used by the authors (Barbier et al. 1997) to illustrate the importance of ranking the full suite of ecosystem services in a wetland

system as a way to both determine which services to examine further and to compare different wetlands.

**Table 4**  
**Use of wetland characteristics in Petexbatun, Guatemala**

From Barbier et al. (1997). Key: \* = low importance; \*\* = medium; \*\*\* = high

<b>Economic values</b>	<b>Direct</b>	<b>Indirect</b>	<b>Non-use</b>
Components/assets			
1. Forest resources	***		
2. Wildlife resources	*		
3. Fisheries	**		
4. Forage resources	**		
5. Agricultural resources	**		
6. Water supply	***		
Functions/services			
1. Ground water recharge		*	
2. Flood and flow control		***	
3. Shoreline/bank stabilisation		***	
4. Sediment retention		***	
5. Nutrient retention		*/**	
6. External support		***	
7. Recreation/tourism		*	
8. Water transport		***	
Diversity/attributes			
1. Biological diversity	**	**	**
2. Uniqueness/cultural heritage			*

### 5.9.3 Farm-level holistic assessment

The Response-Inducing Sustainability Evaluation (RISE) model was developed to evaluate how sustainable single farms are within a system-oriented framework that allows consideration of multiple farms and landscapes (Häni et al. 2003). The model uses sophisticated data analysis but is intended to be easily understandable to farmers and to offer them advice, education and planning support.

The model covers ecological, economic and social factors by defining 12 indicators – for energy, water, soil, biodiversity, emission potential, plant protection, waste and residues, cash flow, farm income, investments, local economy and social situation (Table 5). Drawing on the Pressure-State-Response environmental assessment model, RISE includes for each indicator a ‘state’ variable (current condition) and a ‘driving force’ variable (measure of the estimated pressure the farming system places on the specific indicator) determined from direct measures of a number of parameters by trained practitioners working with farmers. Each indicator’s degree of sustainability is defined as ‘state minus driving force’. In addition, a strength/weakness profile is determined for: (1) the stability of the social, economic and ecological framework; (2) the farmer’s risk awareness and risk management measures; (3) grey energy in machines, buildings and external inputs; and (4) animal health and welfare.

**Table 5**  
**Variables included in the RISE model**

From Häni et al. (2003)

<sup>1</sup> D = driving force; <sup>2</sup> S = state; <sup>3</sup> FL = farmland; <sup>4</sup> CP = crop period; <sup>5</sup> MRI = minimum regional income; <sup>6</sup> FTE = full time equivalent

<b>Indicator</b>	<b>D1/S2</b>	<b>Basis of data</b>	<b>Units</b>
Energy	D	Energy usage	ha FL3
		Environmental impact (global warming, air pollution etc.)	Farm
	S	Energy consumption per workforce (FTE6) Degree of self sufficiency for energy consumption	Farm Farm
Water	D	Water consumption	ha FL
	S	Stability of water source	Farm
Soil	D	Soil contamination through fertilisers and pesticides	ha FL
		Effect on the soil by farm machinery	ha FL
Biodiversity	S	State of soil: nutrients, carbon, pH, moisture, salinity, erosion	ha FL
		Zones of ecological compensation (ZEC's): surface of ZEC's; compliance with the law	ha FL
	D	Size of plots (only those without high biodiversity)	ha FL
Emission potential	S	Surface with high biodiversity	ha FL
	D	Input of nitrogen (N) and phosphorus (P)	ha FL
Plant protection	S	N & P balance (supply and demand)	Farm
		Storage of farm manure	Farm
Plant protection	D	Crop rotation	CP4
		Quantity of active ingredients	ha FL
	S	Risk potential of pesticides used	ha FL
		Plant protection system	Farm
Wastes and residues	D	Education, equipment control, observance of waiting periods, existence of buffer zones	Farm
		Wastes produced	Farm
		On-farm wastes disposal	Farm
Cash flow	S	Off-farm wastes disposal and/or recycling	Farm
		Depreciation, amortisation and loss as % of capital	Farm
Farm income	D	Return on assets	Farm
	S	Number of FTE6 multiplied by MRI5, as % of sales	Farm
Investments	D	Farm income, as % of previous measure (absolute value)	Farm
		Condition of buildings, equipment, permanent crops	Farm
Local economy	S	Equity ratio	Farm
		Maintenance and investments as % of total capital	Farm
		Sales in relation to a regional benchmark	ha FL
Social situation	D	Relative size and compensation level of local workforce	Farm
		Lowest salary paid as % of MRI	Farm
	S	Relation between average FTE compensation on the farm and MRI	Farm
Social situation	D	Relation between lowest FTE compensation and farm income per FTE	Farm
		S	Assessment of the social situation of family workers and employees

RISE has been tested and used to evaluate very different farms in Brazil, Canada, China and Switzerland.

RISE appears to be a unique attempt to combine the elements of many approaches to modelling suites of ecosystem services. It looks promising as a way to address many of the communication issues associated with achieving the benefits of an ecosystem services approach.

5.9.4 The ARIES project

ARIES (Assessment and Research Infrastructure for Ecosystem Services) is a project by the Ecoinformatics Collaboratory at the University of Vermont in the USA (Figure 5).

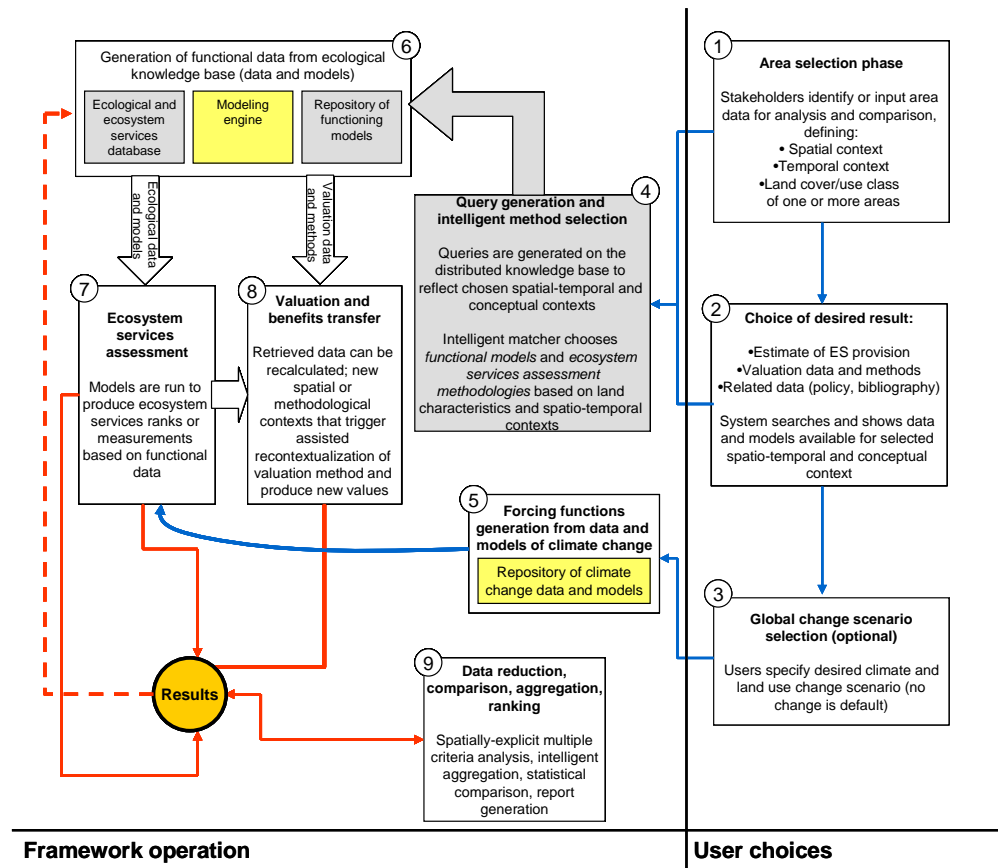


Figure 5  
The ARIES framework

Reproduced, with permission from the Grund Institute for Ecological Economics at the University of Vermont, USA (<http://ecoinformatics.uvm.edu/projects/the-aries-framework.html>)

The project aims to: (1) quantify the economic value of ecosystem services as a vehicle for ensuring social recognition and acceptance of public management of ecosystems; and (2) better integrate ecosystem services into decision making for national and international treaties, policies, and conservation programs. The four elements of the project are:

- an integrated, web-accessible information technology framework to support ecosystem services assessment, projection, and economic valuation
- a task force to define protocols for economic valuation of ecosystem services
- a task force to create protocols for ecological assessment of ecosystem services.
- a dissemination task force to ensure widespread acceptance of the ecosystem services approach.

MIMES (Multiscale Integrated Modelling of Ecosystem Services) is a more advanced approach to making multiscale models of ecosystem services accessible to a wide audience. It is being developed by the same group (see <http://www.uvm.edu/giee/mimespage/>).

### 5.9.5 Integrated modelling of a mountain fynbos system in South Africa

Higgins et al. (1997) developed a dynamic ecological economic model of ecosystem services provided by the mountain fynbos ecosystems of South Africa (Table 6).

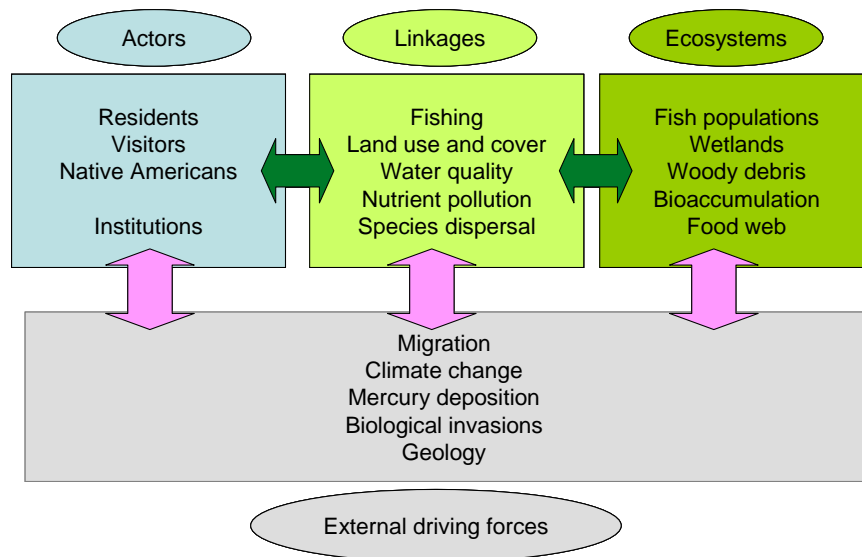
**Table 6**  
**Components of the quantitative model used to investigate the benefits of alternative land uses for mountain fynbos ecosystems in South Africa**

From Higgins et al. (1997)

Sub-models	Components
Hydrological sub-model	Rainfall
	Evapotranspiration
	Riverflow
	Biomass
Plants sub-model	Vegetation age
	Area of alien plants
	Area of native plants
	Number of native species
	Number of endemic species
	Harvestable wildflowers
Fire sub-model	Fire
Management sub-model	Fire control
	Alien clearing
	Wildflower quota
	Visitor numbers
Economic valuation sub-model	Water production
	Genetic storage
	Endemic species
	Wildflower harvest
	Ecotourist visitation
	Management costs

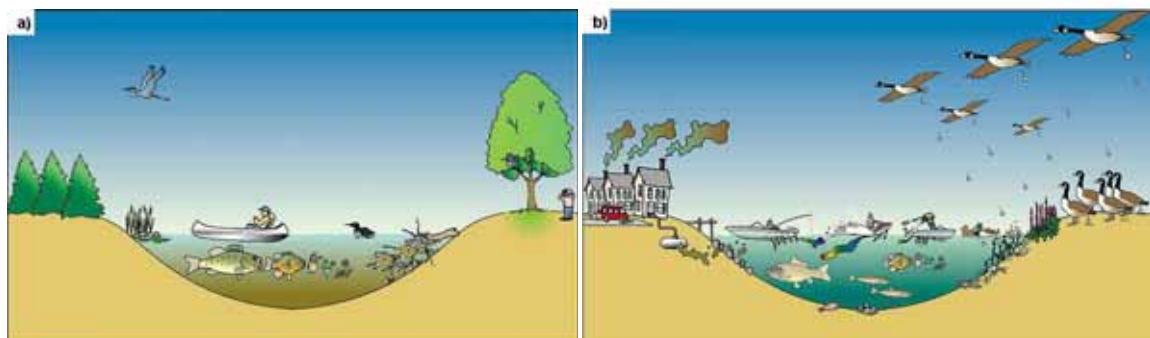
The researchers considered these ecosystems to be threatened by invading alien plants and wanted to assess the relative costs and benefits of increasing funding for management of these invasions. The model comprised five interactive sub-models of hydrology, fire behaviour, plant ecology, management regimes and economic valuation. The model was applied to a set of scenarios that differed with respect to fire management, alien plants, wildflower harvesting, and controlling hikers and ecotourists. For each scenario, two levels of economic benefit (high and low) were considered for wildflower harvesting, hiking and ecotourist visitation, water production, and future use of genetic resources stored in endemic plants. The model also addressed direct and indirect costs of implementing the management scenarios. The purpose of the high and low valuations was to encompass uncertainty associated with estimating values. It was concluded that water production and genetic storage were the most valuable ecosystem services and that the costs of clearing alien plants would be a tiny proportion of the overall value of the ecosystem services protected.

The approach used by Higgins et al. (1997) is an example of a module-based rapid modelling approach that has been employed by the research group to develop models of ecosystem services interactively with stakeholders in a number of studies (Villa, 2001; Villa et al. 2002; <http://esd.uvm.edu/>).



**Figure 6**  
Key attributes and drivers of Wisconsin's Northern Highlands Lake District

Redrawn, with permission, from the study by Peterson et al. (2003)



**Figure 7**  
Pictorial representation of two extreme scenarios for ecosystem services of lakes in northern Wisconsin

Reproduced, with permission, from Peterson et al. (2003)

### 5.9.6 The Future of the Lakes study

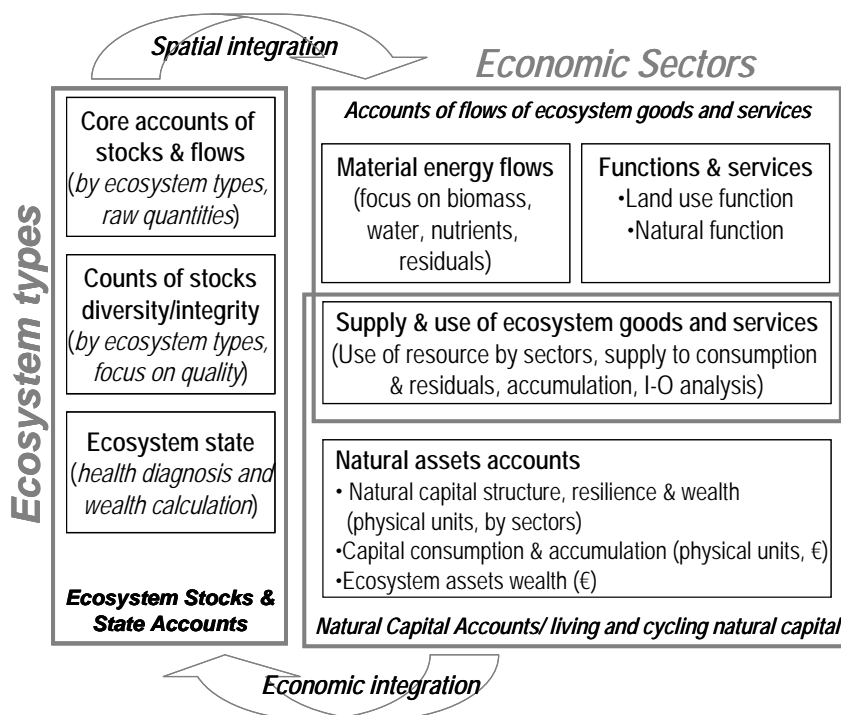
A novel combination of ecosystem services analysis and scenario planning can be seen in the science–community collaborative study of lakes in northern Wisconsin, USA (Peterson et al. 2003).

Approaches like this could be useful in bridging the gap between science and community thinking about the future. A similar approach in the Millennium Ecosystem Assessment is discussed later in this section. Figure 6 and Figure 7 illustrate the thinking behind the Wisconsin scenarios (in which ecological processes

are prominent) and the way in which the scenarios were communicated using evocative pictures illustrating impacts on human well being via ecosystem services.

### 5.9.7 European Environment Agency: Land and Ecosystem Accounting Framework

The European Environment Agency (EEA) has embarked on a process of land accounting that will ‘organise all the separate pieces of environmental information and data we have according to their specific geographical location and distribution’ in order to ‘see what is happening in a specific place and its surroundings’. These data include satellite mapping of land use over time (Lange & Weber 2007).



**Figure 8**  
The European Environment Agency's Land and Ecosystem Accounting Framework

From Lange & Weber (2007)

The rationale behind this process is that it is safer to calculate how well nature would be able to withstand changes than to try to detect how close a natural system is to reaching so called ‘tipping points’ or thresholds.

In the longer term the EEA aims to produce an assessment of Europe's ecosystems in 2012. This assessment will emphasise the contribution of ecosystems to human well-being in terms of goods and services.

The Land and Ecosystem Accounting Framework provides a tool for understanding the links between the ecosystem goods and services that are vital for human well-being and the underlying processes that generate them, in line with the ‘ecosystem approach’ recommended by the Millennium Ecosystem Assessment.

The EEA's Land and Ecosystem Accounts consist of three components: land cover accounts, land use and ecosystem accounts, and economic accounts (including other socioeconomic data) (Figure 8). The components are linked by classifications of

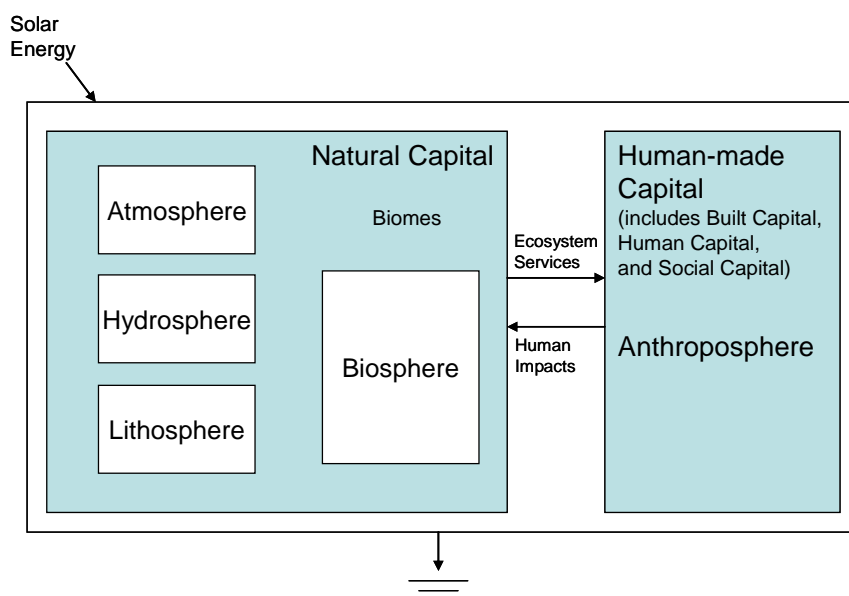
natural systems, of the economic system, and by common spatial and temporal references.

### 5.10 Applications III: Global applications of the ecosystem services concept

#### 5.10.1 A global metamodel

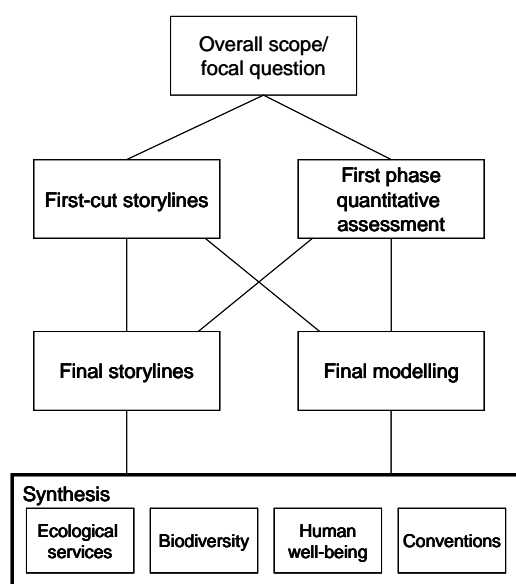
At a much larger scale, Boumans et al. (2002) developed a metamodel of the biosphere (GUMBO) to simulate the integrated earth system and assess the dynamics and values of ecosystem services (Figure 9). GUMBO is a synthesis and simplification of several existing dynamic global models in both the natural and social sciences. It includes modules to simulate carbon, water, and nutrient fluxes through the atmosphere, lithosphere, hydrosphere, and biosphere of the global system. Social and economic dynamics are simulated within the anthroposphere. These five spheres are linked across 11 biomes. The dynamics of 11 major ecosystem goods and services for each of the biomes are simulated and evaluated.

The value of global ecosystem services was estimated to be about 4.5 times the value of gross world product (GWP) in the year 2000 using this approach, which is even greater than the controversial estimate by the same team in 1997 (see Costanza 1998 and the other papers in issue 25 of *Ecological Economics*, which is devoted to a discussion of valuing the world's ecosystem services).



**Figure 9**  
A global unified metamodel of the biosphere, anthroposphere and ecosystem services (GUMBO)

Adapted from Boumans et al. (2002)



**Figure 10**  
**Approach to combining quantitative models and qualitative scenario planning in the Millennium Ecosystem Assessment**

From Alcamo et al. (2005)

### 5.10.2 Global scenarios for ecosystem services

The approach taken by the Millennium Ecosystem Assessment to assessing the past and present state of the world’s ecosystem services is discussed in Section 11.2.2. The Scenarios Working Group of the Millennium Ecosystem Assessment combined a selection of quantitative global models with qualitative scenario planning to explore plausible future dynamics of the relationships between human activities, ecosystem services and human welfare (MA 2005b; Alcamo et al. 2005; Cork et al. 2006; Figure 10; Table 7; Table 8).

**Table 7**  
**Models used to explore impacts of future scenarios on ecosystem services and human welfare in the Millennium Ecosystem Assessment**

From Alcamo et al. (2005)

<b>Ecosystem service</b>	<b>Indicator</b>	<b>Model used to calculate indicator</b>
<i>Direct drivers of ecosystem change</i>		
Climate change	Temperature change, precipitation change	IMAGE <sup>1</sup>
Changes in land use and land cover	Areas per land cover and land use type	IMAGE
Technology adaptation and use	Water use efficiency, energy efficiency, area and numbers growth, crop yield growth, and changes in livestock carcass weight	IMPACT <sup>2</sup> , IMAGE, WaterGAP <sup>3</sup>
<i>Exogenous inputs</i>		
Air pollution emissions	Fertiliser use, irrigation, wage rates	IMPACT, IMAGE
	Sulfur and NOx emissions	AIM <sup>4</sup> , IMAGE
<i>Provisioning services</i>		
Food	Total meat, fish, and crop production; consumption; trade, food prices	IMPACT
Food	Potential food production, crop area, pasture area, and biofuels area	IMAGE, AIM
Fish	Stock	Ecopath/Ecosim <sup>5</sup>
Fuel wood	Biofuel supply	IMAGE, AIM
Fresh water	Annual renewable water resources, water withdrawals and consumption, return flows	WaterGAP, AIM
<i>Regulating services</i>		
Climate regulation	Net carbon flux	IMAGE
Erosion	Erosion risk	IMAGE
<i>Supporting services</i>		
Primary production	Primary production	IMAGE, AIM
Food security	Calorie availability, food prices, Numbers of malnourished pre-school children in developing countries	IMPACT
Water security	Water stress	WaterGAP, AIM
<i>Input to biodiversity calculations</i>		
Terrestrial biodiversity	Land use area, climate change, nitrogen and sulfur deposition	IMAGE
Aquatic biodiversity	River discharge, climate change	WaterGAP, IMAGE

<sup>1</sup> The IMAGE 2.2 global change model of the National Institute of Public Health and the Environment in the Netherlands, which computes climate and global land cover on a grid scale and several other indicators of global change.

<sup>2</sup> The IMPACT model of the International Food Policy Research Institute in the USA, which computes food supply, demand, trade, and international food prices for countries and regions (Rosegrant et al. 2001).

<sup>3</sup> The WaterGAP model of the University of Kassel in Germany, which computes global water use and availability on a watershed scale (Alcamo et al. 2003a, 2003b).

<sup>4</sup> The AIM global change integrated model of the National Institute for Environment Studies in Japan, which computes land cover and other indicators of global change worldwide, with an emphasis on Asia (Kainuma et al. 2002).

<sup>5</sup> The Ecopath with Ecosim model of the University of British Columbia in Canada, which computes dynamic changes in selected marine ecosystems as a function of fishing efforts (Pauly et al. 2003).

**Table 8**  
**Outcomes of the Millennium Ecosystem Assessment scenarios for ecosystem services in 2050 compared with 2000**

From MA (2005b)

	Global Orchestration		Order from Strength		Adapting Mosaic		TechnoGarden	
	Industrial countries <sup>a</sup>	Developing countries <sup>a</sup>	Industrial countries <sup>a</sup>	Developing countries <sup>a</sup>	Industrial countries <sup>a</sup>	Developing countries <sup>a</sup>	Industrial countries <sup>a</sup>	Developing countries <sup>a</sup>
<b>Provisioning services</b>								
Food (extent to which demand is met)	↑	↑	↔	↓	↔	↓	↑	↑
Fuel	↑	↑	↑	↑	↑	↑	↑	↑
Genetic resources	↔	↔	↓	↓	↑	↑	↔	↑
Biochemicals/ pharmaceutical discoveries	↓	↑	↓	↓	↔	↔	↑	↑
Ornamental resources	↔	↔	↔	↓	↑	↑	↔	↔
Fresh water	↑	↑	↔	↓	↑	↓	↑	↔
<b>Regulating services</b>								
Air quality regulation	↔	↔	↔	↓	↔	↔	↑	↑
Climate regulation	↔	↔	↓	↓	↔	↔	↑	↑
Water regulation	↔	↓	↓	↓	↑	↑	↔	↑
Erosion control	↔	↓	↓	↓	↑	↑	↔	↑
Water purification	↔	↓	↓	↓	↑	↑	↔	↑
Disease control: human	↔	↑	↔	↓	↔	↑	↑	↑
Disease control: pests	↔	↓	↓	↓	↑	↑	↔	↔
Pollination	↓	↓	↓	↓	↔	↔	↓	↓
Storm protection	↔	↓	↔	↓	↑	↑	↑	↔
<b>Cultural services</b>								
Spiritual/religious values	↔	↔	↔	↓	↑	↑	↓	↓
Aesthetic values	↔	↔	↔	↓	↑	↑	↔	↔
Recreation and ecotourism	↓	↑	↓	↑	↓	↓	↑	↑
Cultural diversity	↓	↓	↓	↓	↑	↑	↓	↓
Knowledge systems (diversity and memory)	↔	↓	↓	↓	↑	↑	↔	↔

Note: For provisioning services, enhancement is defined as mean increased production of the service through changes in area over which the service is provided (e.g. spread of agriculture) or increased production per unit area. Production is judged to be degraded if the current use exceeds sustainable levels. For regulating services, enhancement refers to a change in the service that leads to greater benefits for people (e.g. the service of disease regulation could be improved by eradication of a vector known to transmit a disease to people). Degradation of regulating services means a reduction in the benefits obtained from the service, either through a change in the service (e.g. mangrove loss reducing the storm protection benefits of an ecosystem) or through human pressures on the service exceeding its limits (e.g. excessive pollution exceeding the capability of ecosystems to maintain water quality). For cultural services, degradation refers to a change in the ecosystem features that decreases the cultural (recreational, aesthetic, spiritual etc.) benefits provided by the ecosystem, while enhancement refers to a change that increases them.

<sup>a</sup> These categories refer to the countries at the beginning of the scenario; some countries may change categories during the course of the 50 years.

## 6 Application of the ecosystem services approach by state governments

### Terms of reference Item 3

Report on the ways in which jurisdictions are currently using the ecosystem services concept in developing and implementing natural resource management policies and programs.

### 6.1 New South Wales

The following information and comments were provided by Don Hayman, NSW Department of Primary Industries.

#### 6.1.1 Application of ecosystem services approaches in NSW

Forests NSW already manages forests for ecosystem services and provision of ecosystem services to ‘the market’ (Box 3).

There are also potential benefits to agriculture in the development of ecosystem services incentive schemes and income diversification opportunities for farmers and smallholders that the Department of Primary Industries should support and contribute to.

Relevant policies, strategies and plans for managing ecosystem services in NSW include:

- NSW Invasive Species Plan
- NSW Salinity Strategy
- NSW Environmental Services Scheme (Box 3)

#### 6.1.2 Comments on the ecosystem services concept

The following comments are an edited version of those provided, as some of the comments were provided for feedback to authors only.

In discussing the concepts of biodiversity and resilience it could be argued that this is related to functionally ‘unique’ species rather than necessarily ‘rare’ species. The paper examines the concept that greater functional diversity leads to greater productivity and this confers ecosystem resilience. However, reference to the need to ‘protect’ biodiversity risks perpetuating, by lack of discussion, the concept that ‘protection’ will necessarily enhance biodiversity when there is substantial evidence that disturbed ecosystems are often the most diverse.

While the precautionary principle is generally accepted as a wise management approach the limitations currently inferred by protection of biodiversity (i.e. absence of active/adaptive management) must be acknowledged, e.g. exclusion of fire.

**Box 3: NSW Environmental Services Scheme**

([http://www.forest.nsw.gov.au/env\\_services/ess/default.asp](http://www.forest.nsw.gov.au/env_services/ess/default.asp))

The overall aim of the scheme is to identify the environmental benefits provided by changed land use activities to enable them to be valued by the community. Eventually, the goal is to create a market for trading these environmental services.

The scheme was implemented in six steps:

1. Identifying the types of environmental services that would be examined
2. Determining the best ways to measure a range of environmental services
3. Developing and implementing a cost-effective competitive process for selecting trial participants
4. Making contractual arrangements for engaging selected participants
5. Establishing systems for monitoring the production of environmental services from land use changes and contract compliance
6. Evaluating the benefits and costs to the farm business of land use changes for environmental services

Six environmental services were selected:

1. Carbon sequestration: related to greenhouse gases and air quality
2. Terrestrial biodiversity benefits: related to improvements in the value of vegetation as habitat for other life forms
3. Salinity benefits: related to improvements in stream water salinity
4. Soil benefits: related to retention of soil on the property
5. Water quality: related to retention of nutrients on the property
6. Acid sulfate soil benefits: related to reduction in the production and export of acid products from acid sulfate soil regions.

Indices were established for each of the selected environmental services which express the quantity of service produced in clearly understood units, e.g. tonnes of sediment retained. Toolkits were developed to estimate these indices for each property and land use change. The toolkits<sup>3</sup> were based on existing, or in some cases, newly developed, biophysical models.

The relationship between policy and political cycles is often a barrier to the development and implementation of policy and practices appropriate to ecosystem

<sup>3</sup> For examples, see:

*Biodiversity*: Oliver, I., Ede, A., Hawes, W., and Grieve, A. (2005).

The NSW Environmental Services Scheme: Results for the biodiversity benefits index, lessons learned, and the way forward, *Ecological Management & Restoration* **6**, 197–205

*Carbon sequestration predictor*: Montagu, K.D., Cowie, A.L., Rawson, A., Wilson, B.R. and George, B.H. (2003).

'Carbon Sequestration Predictor for land use change in inland areas of NSW – background, user notes, assumptions and preliminary model testing'. State Forests NSW Research and Development Division Technical Paper No. 68. Available at [http://www.forest.nsw.gov.au/env\\_services/ess/files/help\\_file.pdf](http://www.forest.nsw.gov.au/env_services/ess/files/help_file.pdf)

*Salinity*: Herron N., Peterson, P., (2003).

A simplified GIS-based approach to prioritise salinity investment at the property-scale. In 'Proceedings MODSIM 2003 International Congress on Modelling and Simulation', 14-17 July 2003, Townsville.

Modelling and Simulation Society of Australia and New Zealand. Available at: [http://http://www.dnr.nsw.gov.au/salinity/science/pdf/herron\\_peterson\\_2003.pdf](http://http://www.dnr.nsw.gov.au/salinity/science/pdf/herron_peterson_2003.pdf)

timeframes, e.g. a forest with a 100 year or more lifecycle, and to the development of markets and management for ecosystem services.

Other issues that are important to consider are: development of financial instruments; addressing design challenges; removing barriers associated with investing in ecosystem services such as high up-front costs, long periods with limited returns on investment, and the high risk due to long timeframes and uncertainty (e.g. associated with climate change).

There needs to be greater recognition that social preferences change and are influenced by interest groups and targeted campaigns. Social opinion changes faster than ecosystems.

The private enterprise sector is innovative and more readily adaptable than governments. For example, the business sector responded quickly to the 'environmental accountability' agenda and now leads voluntary sustainability reporting, because business sees the competitive advantage in such reporting. Managing to sustain natural and social capital in order to generate economic wealth is a concept that business quickly adopted and adapted to. In general, and relative to government, private enterprise is innovative and adaptable, relatively efficient, increasingly (globally) powerful and can provide insight into socioeconomic drivers. Private enterprise is not affected by 'portfolio barriers' or 'voter preference' issues.

The role of private enterprise groups (e.g. the World Business Council for Sustainable Development) in contributing to the development of a national framework for ecosystem services should be considered in developing a national approach to ecosystem services.

Determining who bears the cost of and who benefits from providing or managing ecosystem services is a significant issue that is already a barrier to successful ecosystem service markets e.g. water.

An example of addressing stewardship or duty of care is forest certification<sup>4</sup> through which forest managers address key issues that may not relate directly to the provision of products (e.g. timber) but which are considered essential for the sustainability of the forest ecosystem for which they are responsible. Markets already exist for certified timber.

## 6.2 South Australia

The following comments were collated across agencies in South Australia by Bill Davies (Department of Water, Land and Biodiversity Conservation). They have been edited to a limited extent as some were intended as feedback to the authors only and some clarification was needed in places.

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<sup>4</sup> Forest certification is an independent assessment of an organisation's forest management activities and operations set against predetermined criteria.

In general, South Australia's *No Species Loss* strategy identifies some opportunities to align with Ecosystem Services and may assist in defining the duty of care, assessment of status of ecosystem services etc.

### 6.2.1 Ecosystem services and policy making

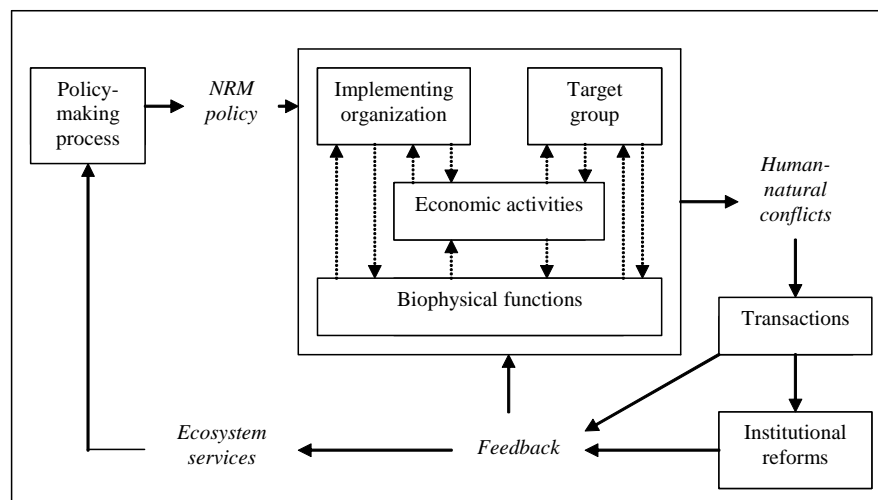
As a part of society's response to ecologically sustainable development, the concept of ecosystem services is a way of framing and communicating planning and policy issues. Some ideas that should be highlighted include:

- Some environmental benefits do not get recognised in formal markets.
- Markets are missing for ecosystem services (see Section 4.2).
- The process of valuing ecosystem services can inform the policy debate and lead to better decision making.

While the concepts and ideas of ecosystem services are not new, how to introduce them into mainstream thinking and future environmental policy is a big challenge.

Potential roles of ecosystem services in the policy process would include:

- helping to identify priorities for action and devise interventions
- encouraging development of indicators that reflect key assets and processes underpinning ecosystem services
- helping to engage a broad range of people and facilitate dialogue about key issues.



**Figure 11**  
A model of ecosystem services and the policy implementation process

The model presented in the diagram was developed by Dr Tian Shi, Corporate Strategy and Policy Branch, Primary Industries and Resources South Australia.

Sustainable NRM requires a clear understanding of the way people and their institutions interact with ecosystems. Ecosystem changes are generally the combined effects of natural dynamics and a multitude of economic decisions.

Therefore, the sociological and political bases of economic activity must be understood as well as the biophysical. Figure 11 illustrates the interactions between ecosystem services and the policy implementation process.

In addition, the precautionary principle needs to be stressed in policy making:

- It is unwise to sacrifice biodiversity simply because of uncertainty about its impacts on ecosystem properties and services.
- Protecting as much biodiversity as possible is a wise strategy for managing risks and for keeping future management options open.

#### **6.2.2 Policy issues associated with ecosystem services**

- a mix of policy tools is needed that harness the synergies between educational, regulatory and economic incentives
- regional targets and caps should be set for the use of ecosystem resources
- more effective on-ground delivery is needed and more understanding of policy
- policy should be realistic: detailed management prescriptions and monitoring are not possible for all ecosystem services.

#### **6.2.3 Other issues needing to be addressed by government or other sectors with respect to ecosystem services**

- Acknowledge the economic value of ecosystem goods and services and address the missing information about demand for ecosystem services.
- The ‘public good’ nature of many ecosystem benefits make it impossible to define tradable property rights; therefore society needs to sort out which ecosystem functions are the responsibility of landowners and managers and which society should contribute to.
- Large-scale markets for ecosystem services will only emerge once markets are backed by government restrictions on resource use and access; therefore it is essential to address legal and political constraints in establishing new markets for ecosystem services.
- Government needs to engage relevant stakeholders and develop innovative mechanisms that secure greater non-government participation.

### **6.3 Victoria**

Comments in this section were provided by Alistair Phillips and Gary Stoneham, Department of Sustainability and Environment, Victoria.

### 6.3.1 Economic architecture for the efficient provision of ecosystem services

An important strand of activity drawing on ecosystem services thinking has been to design economic systems that bring the production of ecosystem services into the decision space of firms by changing incentive structures in the economy. Designing economic architecture that provides rewards for efficient production of ecosystem services has been the underlying objective of programs such as the Market-Based Instruments Pilot Program (see Appendix C).

Like all economic problems, there are two fundamental issues that need to be resolved: a) What is the optimum mix of goods and services (including ecosystem services) that is needed (the demand-side problem); and b) Which agencies (private firms, government, NGOs etc.) should produce these goods and services. In this respect, the objectives of public policy on ecosystem services is the same as any for other sector of the economy – to meet the preferences of society whilst imposing as little drain on our national wealth as possible. Unfortunately, the economy lacks the basic economic infrastructure needed to achieve this objective. There are two main problems:

**Missing information on social preferences** – we do not have clear signals about the collective willingness of society to pay for additional units of ecosystem services (demand side). This aspect of the environment generally, but ecosystem services specifically is problematic.

**Missing institutions/markets to ensure efficient supply of ecosystem services** - markets for ecosystem services are missing such that even if demand could be determined, it is not possible to efficiently procure ecosystem services (supply side). Rapid advances have been made on the supply side of the environment/ecosystem service problem. New institutions have been designed, trialled and evaluated that encourage efficient supply of ecosystem services. These include: *tradeable emission permits* (sometimes called cap and trade) for ecosystem services that are private goods; *auctions of conservation contracts*, such as BushTender for ecosystem services that are public goods; and the creation of *offset markets*. These mechanisms aim to employ competition to discover and reward low-cost producers of ecosystem services. Well designed competitive process for generating ecosystem services are generally beneficial because this minimises the drain on national resources leaving capacity in the economy to produce other goods and services such as health, education, defence etc. The use of competitive processes will also avoid accusations that such programs are implicit subsidies for farmers. Moreover, a new methodology has emerged, called mechanism design, that allows economists to test and refine these new institutions in the laboratory before they are released into the economy.

Appendix C describes the key features of a pilot in Victoria. In the pilot, landholders were exposed to a ‘complete’ set of markets for ecosystem services including a tradeable permit for carbon (ecosystem services that is a private good) and an auction of conservation contracts for ecosystem services that are public goods (biodiversity, salinity control, water quality and stream flow benefits) in addition to the commodity markets in which they already operate. The pilot changed the institutional setting in which landholders operate by creating incentives for efficient production of ecosystem services. This involves tradeoffs between commodity production and ecosystem service production.

## 6.4 Queensland

The following information and comments were provided by Simone Maynard (SEQ Catchments), Andrew Davidson (SEQ Catchments) and David James (University of Sunshine Coast).

### 6.4.1 Background

In 2006 a project was initiated by SEQ Catchments under NHT funding (now in collaboration with the Office of Urban Management and the University Sunshine Coast), aimed at developing an *agreed framework* for defining and assessing the ecosystem services of South East Queensland (SEQ). The SEQ Ecosystem Services Project was established in response to Management Action Targets identified in the Integrated Natural Resource Management Plan for SEQ and Desired Regional Outcomes under the SEQ Regional Plan 2005 – 2026;

Management Action Target: CES 1 – Ecosystem Services; *Prepare a report that identifies the ecosystem services provided by SEQ natural assets and a framework for incorporating these values in the implementation of NRM* (NRMSEQ 2005).

Desired Regional Outcome 5: Rural Futures, Policy 5.2.3; *Maintain the capacity of the region's environmental resources to supply ecosystem services* (OUM 2006).

### 6.4.2 Policy and management context

It is recognised that the concept of ecosystem services can potentially be applied in a number of policy, planning and management contexts within the SEQ Region e.g. education, incentives, payment for the provision of services (stewardship payments), statutory or strategic planning and regulation. The specific policy, planning or management context will determine how and to what level of detail ecosystem services need to be considered. There is general consensus that the focus of assessments within this Project must be practical and that the framework should also be capable of flexible application by different agencies in various contexts and on various geographic scales. The *current* management context for ecosystem services in SEQ includes:

- Prioritising funding (including possible stewardship payments) to maintain or improve provision of services and natural resource management (SEQ Catchments).
- Possible incorporation of the mapping of ecosystem services into the review of the SEQ Regional Plan (OUM).
- Possible incorporation of the mapping of ecosystem services into Local Government planning.
- Identifying priority locations for environmental offset provision.
- Assessing, monitoring and reporting on the current and (where possible) historic and potential future provision of ecosystem services.
- Providing information to decision makers on the monetary value of ecosystem services (where relevant and feasible).

### 6.4.3 The ecosystem services approach in SEQ

The SEQ Ecosystem Services Project has involved active participation by representatives of Queensland Government agencies, Local Governments, conservation organisations, agricultural organisations and technical personnel from research organisations in the SEQ Region. Through a series of Think Tanks and Stakeholder Workshops, general agreement has emerged among participants about the overall format of an appropriate framework for defining and assessing the ecosystem services in SEQ. It has been agreed the SEQ Ecosystem Services Framework should be based largely on the United Nations Millennium Ecosystem Assessment (MA) schema.

Steps towards developing the framework for SEQ have included:

1. The development of a common definition and terminology for ecosystem services to provide consistency of approach throughout the SEQ Region.
  - The SEQ Ecosystem Services Project has adopted the MA (2005) definition; *Ecosystem services* are the 'benefits people obtain from ecosystems' (MA 2005).
  - The SEQ Ecosystem Services Project has adopted 3 'service categories' from the MA; Regulating Services, Provisioning Services and Cultural Services.
  - 28 ecosystem services (both market and non-market) have been identified in total and compartmentalised under the three categories of services.
2. Establishing the position of 'biodiversity' within the framework; defining the importance of biodiversity to the delivery of ecosystem services.
  - An 'Ecologist Workshop' was held to develop a set of principles and identify any underlying assumptions relating to biodiversity and the development/application of the ecosystem services framework.
3. The development of a list of biomes (Ecosystem Categories) within the SEQ Region in accordance with the MA Reporting Categories.
  - The MA Reporting Categories were refined to 'biome' level. Broad vegetation groups or groups of Regional Ecosystems have generally been used as a surrogate for 'biome'.
4. The identification of ecosystem functions (and processes) occurring in each of these biomes.
  - The SEQ Ecosystem Services Project has adapted the definition of ecosystem function from De Groot (2002). *Ecosystem functions are the biological, geochemical and physical processes and components that take place or occur within an ecosystem.*

- 19 ecosystem functions have been identified and described. The list of functions and associated processes has been adapted from De Groot (2006) and I. Beitz (2005).
- The SEQ Ecosystem Services Project has adopted 4 ‘function categories’; Regulating Functions, Provisioning Functions, Cultural Functions and Supporting Functions.

Thus far, a series of maps has been constructed from relevant GIS layers to identify where these particular biomes are located in the SEQ Region. Another series of maps have also been developed to indicate the spatial distribution of ecosystem functions within the SEQ region. The combination of these two data sets and the resulting maps provide a spatial representation of where the ecosystem services are provided and which particular biomes (ecosystems) are providing these services. It is important to note however, that due to the public good and diffuse nature of many ecosystem services, these maps are not necessarily representative of where the services or their benefits (‘constituents of well-being’) are being received.

To build on these spatial data sets and to prioritise different geographic areas on the basis of the ecosystem services they generate, an Expert Panel Workshop was held. A ‘Biophysical Working Group’ was formed, as one activity within the workshop. The aim of this Working Group was to produce weighted spatial representations of the provision of ecosystem services throughout the SEQ Region.

The MA framework identifies various benefits received by the global community from ecosystem services, namely; *Constituents of Well-being*. The MA makes it clear that ecosystems are to be valued and prioritised in terms of the benefits they yield. For this reason a second working group within the Expert Panel Workshop was formed, termed the ‘Benefits Working Group’. The main task for these participants was to identify the different kinds of benefits (constituents of well-being) that can be attributed to different ecosystem services. The group was asked to consider what these benefits might be specifically for the SEQ Region. The group was also asked to consider ways in which the values or relative importance of these constituents of well-being might be determined and offer recommendations on the appropriateness and feasibility of various methods through which weights may be derived that indicate the relative importance of these benefits.

The anticipated output was essentially a *snapshot* of what currently exists in terms of ecosystem services within the SEQ region, or at least considered technical advice on how this information may be sourced and assembled. Generally, the aim of the Expert Panel was to develop the general framework already established into a more operational form. The first Expert Panel Workshop was held on the 15<sup>th</sup> June 2007.

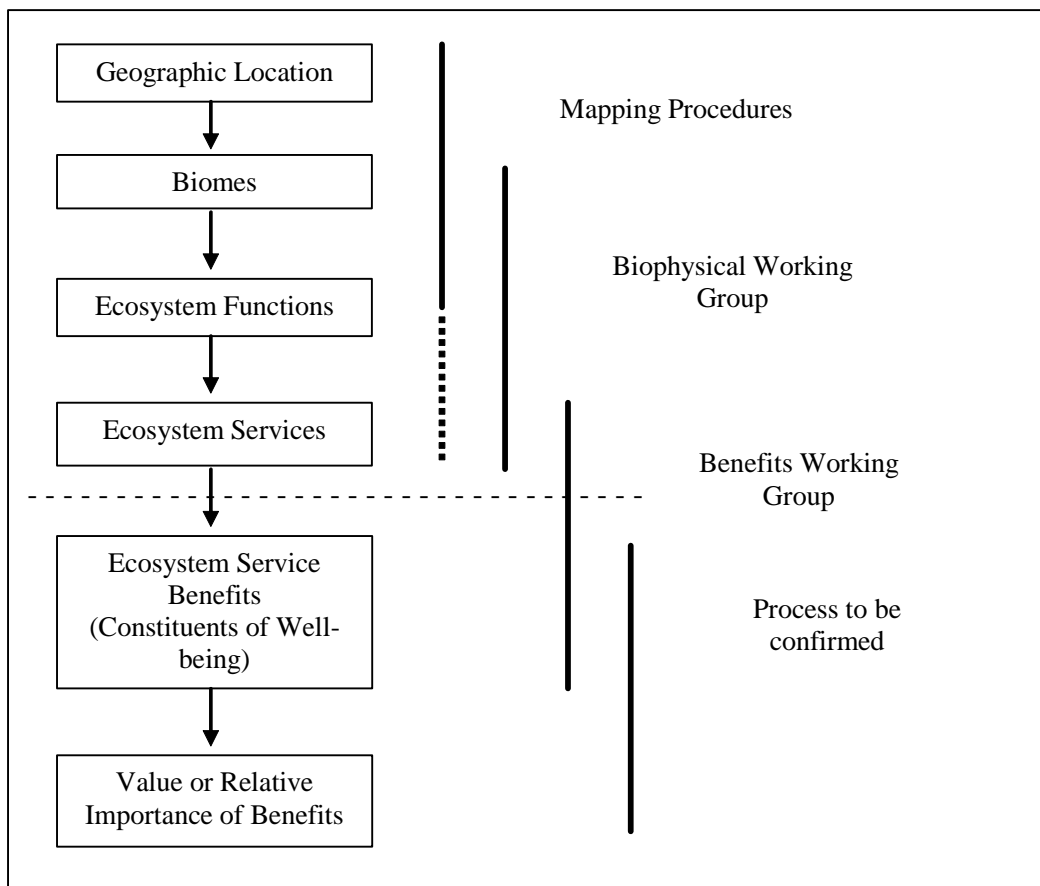
Feedback from the Expert Panels and other participants involved in the Project have been given serious consideration by Steering Group members and amendments to the list of ecosystem functions and services used in the Panels have been made. A second Expert Panel on the 29<sup>th</sup> November has therefore been proposed to reassess the links between biomes, ecosystem functions and ecosystem services. The link between ecosystem services and constituents of well-being will be assessed at a later date.

**6.4.4. Role of the technical framework**

It should be clearly understood that the framework for SEQ, as it evolves, is intended to be used as a decision *support* tool, not a decision *making* tool. The general aim of the framework is to allow different stakeholders to apply the framework in different ways, depending on the decision context and using whatever information (including value judgments relating to benefits weights) they consider to be relevant. The process for deriving weights (as opposed to the mathematical formulae used to calculate them) depends very much on institutional arrangements and consultative or participatory mechanisms involving relevant stakeholders. The first step is for all stakeholders to agree on the structure of the general framework and to ensure that all data, assumptions and value judgments in any application are completely transparent.

**6.4.5. Where to from here**

The power and success of the Project to date can be attributed to the tireless contribution of resources and expertise by the individual participants and agencies involved in the workshops.



**Figure 12**  
**Key components and interconnections of the SEQ Ecosystem Services Framework**

Each step in the development of the framework is handled in a ‘Think Tank’ exercise, comprising of an open forum of SEQ stakeholders who ground truth and develop each step of the process as it evolves. What has become very plain however, is that

assessing ecosystem services and their benefits across the SEQ community will involve multi-disciplinary inputs from an even wider range of stakeholders. At this stage, there have been some discussions on conducting a form of 'Citizen Senate' towards the end of year, to evaluate the value and importance of the benefits (constituents of well-being) delivered to the SEQ community from the various ecosystem services they receive.

Conceptually, the key components of the framework so far developed, as well as the tasks yet to be carried out, are shown in Figure 12. Components below the dotted horizontal and vertical line are yet to be completed in the development of the framework.

Accordingly, in developing 'the agreed framework for ecosystem services' in SEQ, key technical issues addressed and being addressed by participants include the following:

- How to *quantify and estimate the supply* of ecosystem services in SEQ.
- How to define what is meant by *maintaining a given level* of ecosystem services in SEQ.
- How to assess the *values or relative importance* of ecosystem services in SEQ.
- How to assess *tradeoffs* among different ecosystem functions and/or ecosystem services in SEQ.
- How to assess the *potential impacts* of development scenarios or projected human activities on ecosystem services in SEQ.
- How to identify the need for and benefits of *measures designed to restore and/or enhance* the provision of ecosystem services in SEQ.
- How to *prioritise different locations* or geographic areas within the SEQ region according to the ecosystem services they generate.

There are many issues in considering the *application* of an ecosystem services approach to natural resource management and decision making and these have yet to be fully discussed and resolved in the context of the SEQ Ecosystem Services Framework. Further developmental work is currently being planned.

## 7 An operational definition of ecosystem services

### Terms of reference Item 4

Based on the findings of [Items] 1 and 2 above, develop an operational definition of the ecosystem services concept for use in the development and implementation of policy.

As discussed in Section 5.2, most definitions of ecosystem services are similar at a high level, i.e. ecosystem services are benefits to people from nature. Below this level, however, the interpretations are sufficiently different to drive wedges between conservation and production interests and between government departments.

The narrow interpretations – that ecosystem services are either marketable or non-marketable values but not both – are untenable given the origins of the concept. ‘Ecosystem services’ has been used loosely as shorthand for interests and agendas that would be better made explicit.

#### Box 4: Description of an ecosystem services approach

An **ecosystem services approach** is one that seeks to integrate the ecological, social and economic dimensions of NRM (including conservation as well as production objectives) by:

- explicitly identifying and classifying the benefits that people derive from ecosystems, including market and non-market, use and non-use, tangible and intangible benefits
- describing and communicating these benefits in concepts and language that stakeholders and the public can understand
- posing and trying to answer a set of critical questions for sustainable management of ecosystems and human welfare, including:
  - Which services are provided by which ecosystems?
  - Who benefits from different services? How? What are the future needs of humans for these services?
  - What are the impacts of humans on different ecosystem services?
  - What is the role of biota and other natural assets?
  - How do different ecosystem services interact with one another?
  - What are the critical levels of ecosystem services for human welfare and survival?
  - What are the possibilities and implications of technological substitution for ecosystem services?

**We recommend that Australian governments adopt the broad interpretation – that ecosystem services are all benefits from nature, including marketable and non-marketable, tangible and intangible, use and non-use values.**

**In addition, it is useful to define what an ecosystem services approach entails (Box 4).**

Within this definition, specific programs and projects should identify the specific services or groups of services that they focus on. For example, a land stewardship program should not state its objective as ‘paying for protection of ecosystem services’, but should identify which services, or even which aspects of certain services, it targets.

To facilitate communication both among governments and between governments and the public, it would be useful for Australian governments to agree on a high level list of ecosystem services that acknowledges the diversity of ecosystem services but allows flexibility for renaming services to suit specific programs or projects. Classifications like that used by the Millennium Ecosystem Assessment (Figure 3) would be suitable.

The main purpose of agreeing on such a classification would be to avoid confusion from narrow interpretations, such as those discussed in Section 5.6, and to encourage programs and projects dealing with partial sets of ecosystem services to be specific about the services they are focusing on rather than using the generic terminology in an unclear way.

An issue that will inevitably arise is how biodiversity is dealt with under the classification (see Section 5.7.1). In resolving this issue, it will be important to be very open and clear about the different objectives of different interest groups, because much of the disagreement about the place of biodiversity arises because of misunderstanding of these objectives. An interpretation that should suit most needs is:

- Protecting other species is something that is fundamentally important to Australian society for ethical, moral and cultural reasons.
- There will remain differences of opinion about whether the value of biodiversity should be given special status above other values or should be traded off against other values using a common metric such as economic value, but this is a deep philosophical issue that goes wider than ecosystem services or NRM and any classification of ecosystem services should seek to accommodate the difference rather than try to resolve it completely.
- At another level, diversity of function among genes, species, ecosystems and landscapes underpins provision of all ecosystem services and in light of the information currently available, a wise strategy is to maintain as much of this diversity as possible.

As a major strength of ecosystem services approaches is the customised identification and classification of services for specific programs or projects, we recommend that programs and projects are encouraged to develop their own list of specific ecosystem services, under the umbrella of the high level classification, for the specific purposes

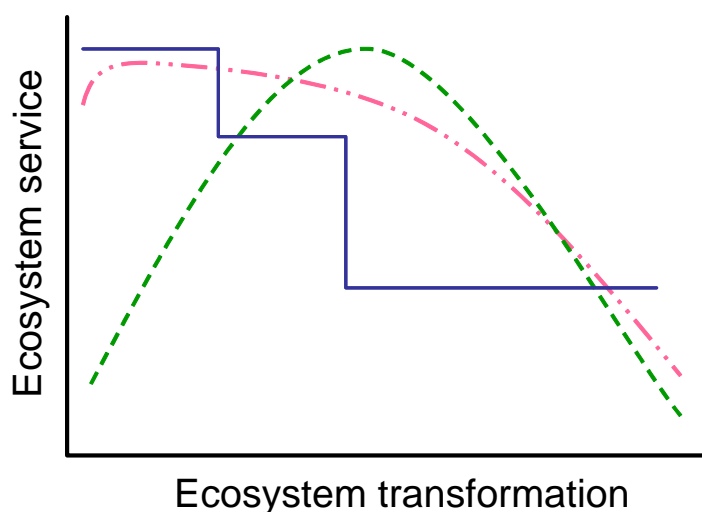
that are needed. This is a relatively easy thing to do once objectives of a program are identified but it is not useful to identify a specific list before these objectives are determined. The examples given in Appendix A provide possibilities. Readers should also see the work of Ken Wallace of the Western Australian Department of Environment and Conservation, who proposed a different classification from those of Daily (1997) or the Millennium Ecosystem Assessment (MA 2005a) that addresses perceived redundancies in previous approaches (Wallace 2007).

## 8 The significance of ecosystem services for policy

### Terms of reference Item 5

Identify ways in which the ecosystem services concept can be beneficially used in natural resource management policy and program development, exploring the advantages and disadvantages of its use.

There are many challenges for sustainable NRM policy (see Appendix B). The ecosystem services approach does not solve these problems but it can contribute to more open and constructive dialogue about them because a greater range of stakeholders potentially understand and identify with the challenges and therefore are more likely to accept some ownership and responsibility for solutions. Starting with a comprehensive list of ecosystem processes, services and the human needs they meet also prompts dialogue about whole social and economic systems, which is more likely to lead to enduring solutions although it can be a problem for policy makers who want to restrict the scope of the problem to stay within their portfolio responsibilities.



**Figure 13**

**Hypothetical relationships between ecosystem transformation (natural to intensive land use by humans from left to right on the horizontal axis) and delivery of ecosystem services. The curves represent different services**

Examples of policy approaches which have been discussed in tandem with thinking about ecosystem services include:

- community consensus-based decision making, which allows regional- or catchment-level participation in discussion around the possibilities for balancing production of ecosystem services in an area

- conventional benefit-cost analysis of alternative land management practices, which requires valuation of ecosystem services (including non-market services) for the purpose of comparison
- creation of markets for ecosystem services to rectify undersupply of those services
- regulation which is coupled with supply of ecosystem services, for example ‘cap and trade’ systems designed to prevent overuse of ecosystem services and direct resources to the highest value use.

Clearly, as policy approaches these examples can exist in isolation from the idea of ecosystem services. The critical contribution of ecosystem services to each is that (fully adopted) ecosystem services thinking makes transparent the interactions between a number of ecosystem services and provides a framework within which to analyse the tradeoffs and multiple benefits built into different options.

Thinking about plausible ways in which delivery of different ecosystem services could change as ecosystems change illustrates some of the other key policy challenges with respect to ecosystem services (Figure 13). Different services might change as land use intensifies by gradually decreasing, increasing, increasing and then decreasing or in a step-wise fashion. The challenges for policy makers include:

- Policy makers need to consider a range of levels of land use intensification along the horizontal axis in Figure 13. For example, an area includes mixed cropping and grazing in a variegated landscape of paddocks, remnant vegetation roadside corridors, stream and creek systems, roads and scattered human settlements. Which of these are sustainable? (Note that this is a normative proposition that requires deciding on a level on the vertical axis below which we should not fall. How to do this is another challenge.)
- For those services that are non-sustainable there are two overlapping policy options: (1) policies that engender behavioural changes that wish to reconfigure the spatial landscape within the intensification level to deliver more sustainable service delivery; or (2) policies that engender behavioural changes that wish to shift the level of intensification (usually to the left of the graph), to lift the level of critical services overall.
- What are the suite of policy approaches (mechanisms for behavioural change at individual and/or organisational levels) that allow choices between (1) and (2) or some combination?
- How do we deal with different scales of space and time (property–catchment–region, years–decades–millennia etc) within the ecosystem services approach?

These are all very important policy questions and an ecosystem services approach does not, at this time, provide answers. However, this is not the fault of ecosystem services approaches – these problems exist regardless of whether an ecosystem services approach is employed or not. **Adopting an ecosystem services approach gives more hope of leading us towards answers to these questions, however, because it requires us to ask what the services are that people value, how they**

**change with land management, and how much of each service people need in particular situations, scales and times.**

The experience of applying ecosystem services approaches in Victoria and NSW shows how useful the broad concept can be in communicating the rationale for environmental management policies to the public and to potential investors. The success of this communication, however, requires a consistent message about what ecosystem services are and which ones are the focus of a particular program. In both NSW and Victoria, the broad umbrella of the ecosystem services approach has been used and under that umbrella, specific programs have focused on salinity, habitat, wetlands and carbon.

As discussed in Sections 5.3 and 9.2, an agreed ecosystem services framework does not replace traditional economic and ecological approaches to identifying values to be targeted for NRM investment – but it adds some detail to what those values are and expresses them in plain language. The examples of ecosystem services frameworks discussed throughout this paper, including the Millennium Ecosystem Assessment, the Ecosystem Services project in the Goulburn Broken Catchment, BushTender and EcoTender in Victoria, and the Environmental Services Scheme in NSW, show how providing a clear conceptual framework has encouraged participation by communities, landowners and industries in investment, self regulation and self reporting of progress towards better environmental management. As these are key components of the Natural Heritage Trust stage 3, cooperative application of ecosystem services approaches across jurisdictions has much to offer.

**Box 5: Rationale for applying ecosystem services thinking in NRM policy in Victoria** (Gary Stoneham, DSE, Victoria)

The objectives of public policy in NRM are the same as in any other sector of the economy – to meet the preferences of society whilst imposing as little drain on the economy as possible.

Because most people have minimal understanding of the benefits they obtain, or could obtain, from different approaches to NRM, their demands are not clear and might or might not reflect their best interests.

The problem can be reduced to a second-best framework by assuming that funds allocated to the environment, such as through the National Action Plan for Salinity and Water Quality and Natural Heritage Trust, provide the only tangible signal of demand. The *second-best* efficiency objective then is to efficiently procure ecosystem services within a given budget or environmental objective.

Efficient procurement of ecosystem services depends on being able to identify those landholders who can supply ecosystem services at low cost. Markets perform this efficiently for commodities but markets are missing for ecosystem services.

For ecosystem services that are private goods (e.g., carbon and water quantity) competition can be harnessed through cap and trade programs. A carbon market operates in the European Union but not in Australia. These institutions (institutions in social sciences are a wide range of social processes and structures) cap resource use/emissions at a sustainable level, define property rights and allow trade in rights. This approach generates price signals that guide investors toward efficient management of these resources/emissions. The presence of competitive markets solves the problem of incentives for efficient production of commodities and utility maximisation for consumers. Cap and trade approaches, like the water market, are efficient. There has been significant progress made in the use and acceptance of this approach. Examples include: the Hunter River Salinity Trading Scheme, water market and Sulphur Dioxide Trading Scheme (USA)

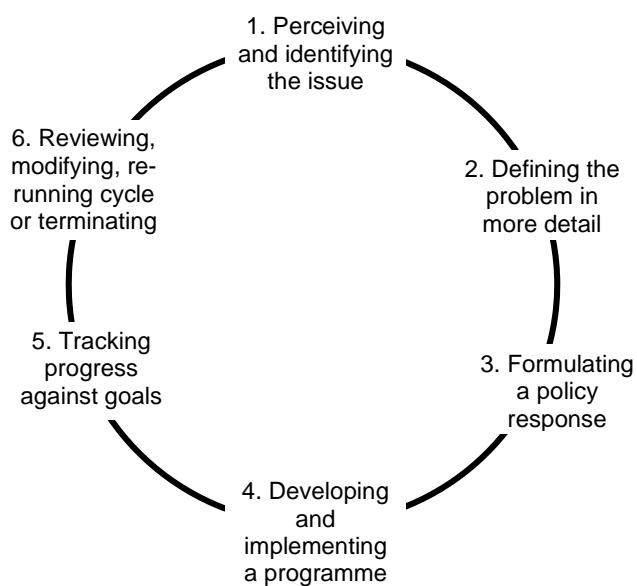
The ecosystem services concept should not be seen as a solution to all NRM policy challenges but an ecosystem services approach can aid dialogue in many instances. For example:

- The effectiveness of community decision making depends on the quality of information available to participants and potentially their willingness to compromise. An ecosystem services approach often suffers from lack of appropriate information but it can aid dialogue about what information is needed and why.
- It is difficult to incorporate consideration of future generations' 'preferences' and interests in planning, but an ecosystem services approach raises questions about the nature of future needs, who needs what and how much might be needed.
- Catchment-based planning assumes that a system is closed, whereas the decisions in one region or catchment will often impact on or depend upon conditions outside that region/catchment.
- Conventional benefit-cost analysis does not deal well with 'ethical' issues such as fair distribution or intergenerational equity. The validity of valuation techniques for non-market services, particularly intangible services such as 'aesthetics', is highly contestable. Many people consider the 'utilitarian' nature of benefit-cost analysis inappropriate for making decisions about environmental assets with 'intrinsic' value. An ecosystem services approach does not resolve these issues – in fact it can bring them to the fore – but it does provide a basis for dialogue about what the values are that are being contested. Often this debate occurs without such a framework so the potential for miscommunication is large.
- It can be difficult to create a market for an ecosystem service as many services are generated from ecosystem processes that occur over many properties, even catchments, and are not exclusively owned. In practice, market-based approaches to NRM focus on specific assets like carbon<sup>5</sup> or biodiversity habitat or processes like transpiration but an ecosystem services approach helps to explain why these assets have been chosen.

If we consider a generic policy cycle (Figure 14), recognising that policy does not always evolve in such an organised way, ecosystem services approaches can be seen to contribute in a range of ways at different stages (Table 9).

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<sup>5</sup> Carbon can be seen as an asset in that, under current policies and attitudes, society wants to accumulate carbon in trees to reduce atmospheric carbon. The more carbon accumulated in trees the bigger the asset and the better the outcome.



**Figure 14**  
A generic policy cycle

**Table 9**  
Potential contribution of ecosystem services language and concepts to the policy cycle

Policy phase	Role of ecosystem services language and concept
Perceiving and identifying the issue	Ecosystem services language and concepts were developed to help frame the debate about environment/economic tradeoffs in ways that a broader range of participants could understand and engage with. The ecosystem services approach uses the language of everyday business – the giving and receiving of services.
Defining the problem in detail	Economics is about identifying supply and demand relationships but it does not always articulate the role of the environment in detail. There has been discussion about whether the economy is a sub-set of the environment or vice versa, and recently environmental and ecological economics have subdivided values into use and non-use, market and non-market to recognise that some environmental benefits are not taken into account in formal markets. Ecosystem services approaches have moved this debate forward by developing frameworks that comprehensively describe all known benefits provided by ecosystems in simple language that allows beneficiaries to recognise themselves. This has engaged a broader range of people in considering the roles of different individuals and groups in maintaining or exploiting ecosystems and has laid the foundations for considering market-based instruments as policy tools.
Formulating a policy response	The language of ecosystem services has increased public interest in, and understanding of, the reliance of humans on ecosystems, the different roles of human activities in giving to and taking from ecosystem processes, and the potential economic and other benefits from better environmental management. This has prepared the way for consideration of policies that attempt to define what humans need from ecosystems and how to meet those needs. One policy response is to address the ‘missing market’ problem that arises because many of the benefits that emerge from ecosystems are wholly or partly public property and therefore do

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		not get traded in markets and do not have acknowledged monetary value. Market-based instruments come from old and new economic theory. They are not synonymous with ecosystem services but ecosystem services frameworks provide a convenient way to explain why market-based instruments are being applied and what the benefits are that are being protected using these instruments. However, a critical requirement for market-based approaches is to be able to measure outputs and outcomes. Usually this requires measuring the underlying ecological processes rather than ecosystem services themselves.
Developing and implementing a program	and	As indicated above, market-based instruments are only one of many possible policy responses to the issue of how to manage ecosystems to meet human needs. In the past there has been a tendency to devise programs that address individual environmental issues without considering the larger ecosystem and landscape contexts or the human needs that environmental management implicitly is trying to meet. Ecosystem services frameworks have challenged policy makers and land managers to consider the full range of benefits and their interactions in terms of what humans need to sustain their lives. This has linked social and biophysical sciences as frameworks for defining human social needs with frameworks for identifying physical needs and allowed comparison of the relative merits of technological substitutes versus ecosystem services. Some of the main issues holding back the development of the next generation of major environmental programs have been limitations on our ability to quantify human needs and to predict and measure environmental responses to interventions.
Tracking progress against goals		Projects like the Millennium Ecosystem Assessment have employed ecosystem services frameworks and have refined ways to measure and report change in ecosystems and the services they deliver. Approaches like the Environmental Benefits Index, based on Habitat Hectares, in Victoria and the <a href="#">Vegetation Assets, States and Transitions (VAST) framework</a> in the Bureau of Rural Sciences are improving our ability to measure progress towards ecosystem services goals and therefore encourage the development of new approaches to purposeful land management, including land stewardship schemes.
Reviewing, modifying, re-running cycle or terminating		Many, if not most, environmental policies in Australia have been terminated not because they have achieved their objectives but because policy or public interest changed. This is partly because it has not been clear how much environmental protection was enough. An ecosystem services approach, which couples human needs with the environmental benefits that meet those needs, provides an important conceptual basis for deciding when programs have met their social, economic and environmental objectives. In this way ecosystem services frameworks offer a way to integrate social, economic and environmental issues.

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## 8.1 Stewardship and duty of care

A specific issue that is topical at the moment is land stewardship arrangements, especially the possibility of paying landowners for changes to land management. An ecosystem services approach can help define what is needed from the land in terms of meeting human needs (including our need to protect other species) and what natural assets and processes need to be managed to meet these needs. This can, of course, be done without reference to ecosystem services but ecosystem services language has

been found to be useful in keeping the dialogue focused on needs and how to meet them.

Furthermore, an ecosystem services approach focuses discussion on how much of any service is needed, who needs it, who the beneficiaries are, and who currently bears the costs. This then supports discussion about roles and responsibilities, including duty of care. Again, all of this can be done using the language of economics and ecology but few stakeholders will be able to engage with or understand what is being discussed. In many cases the solution to these challenges cannot be determined analytically but requires social consensus, which requires that all stakeholders can engage.

**There is great power in being able to argue that a program is designed to meet an identified set of human needs by an identified set of environmental and social actions and that progress can be measured in terms of how well those needs are being met.**

To reiterate, an ecosystem services approach is not a silver bullet that solves all problems, but it does facilitate dialogue about key issues.

The debate about duty of care and, more recently, stewardship has focused on maintaining characteristics of land that may not have direct benefit to the land manager or landowner. In the past this debate has focused largely on soil attributes and stability; more recently the focus has moved to vegetation cover and type. Economics has contributed the concept of total economic value, which includes direct and indirect values and market and non-market values (Figure 15). Ecosystem services language has elaborated on this concept to more explicitly focus on what benefits people *perceive* they are getting from the land.

Duty of care is about defining that part of environmental management that is the responsibility of the landowner (usually considered in terms of best practice). In some of the academic literature and in some parts of the world, stewardship payments are about what society might want to pay for over and above best practice (Gatzweiler 2006). The crux of this debate is that, while it is easy to define matters that are clearly duty of care and matters that are clearly not duty of care, there are many matters that fall between these extremes that are not clearly one or the other and the boundary is hard to define. Ecosystem services approaches do not solve this problem but they contribute to broader and more inclusive dialogue. It should be noted that Australian governments have not agreed on a definition of stewardship so it is difficult to discuss in more detail how an ecosystem services approach can contribute.

Although some people try to characterise the stewardship debate in terms of paying for certain ecosystem services, this is impractical because all ecosystem services require ecosystem functionality that contributes to both private and public good. Therefore, we still need to sort out which ecosystem functions are the responsibility of landowners and managers and which society should contribute to.

## 9 Comparison with alternative approaches

### Terms of reference Item 6

Compare the use of the ecosystem services concept with the use of viable alternative approaches in natural resource management policy and program development.

There is a number of other approaches that seek to explain the relationship between humans and ecosystems. These include the concepts of ecological footprint (e.g., Global Footprint Network and the University of Sydney 2005), GAIA (e.g. Lovelock 2006), industrial metabolism (Ayres & Simonis 1994), and others (e.g. Boyden 2004).

Ecological footprint focuses on the demands that humans place on the environment and their impacts. Like the ecosystem services concept, it is a powerful communication device that can contribute to strategic planning for NRM but it tends to be more technical and less transparent and adaptable to the perceptions of different groups than ecosystem services. It is thus less suitable for engaging the public in dialogue about NRM, although many individuals within the public might prefer the footprint metaphor to an ecosystem services one. An ideal approach to engaging the public would include both ecological footprint and ecosystem services concepts.

Allied to the ecological footprint approach are various approaches that analyse the "metabolism" of human societies in terms of what resources they use, where they get them from, and what waste products they return to the environment (e.g. Foran et al. 2005). Some of these approaches also analyse stocks and flows of resources, including intangible resources like social capital and measures of human welfare. Such approaches provide important information that can be considered in dialogue around ecosystem services.

The concept of GAIA proposes that the world functions essentially as a single organism and that all activities of humans and other species have an impact on the whole organism. This is also a powerful communication device and is at the heart of many sophisticated models of earth systems. When engaging the public in dialogue, this concept resonated with many but is probably too academic for many.

The two alternative approaches that most overlap with, and get confused with, ecosystem services are multifunctionality and the concept of total economic value, which are discussed in more detail below.

### 9.1 Multifunctionality

In Europe and parts of Asia, the term 'multifunctionality' has been used in much the same context as 'ecosystem services'. Multifunctionality is used to recognise the non-commodity (non-market) benefits that come from agricultural landscapes (OECD 2001). These include the same non-market benefits recognised in the ecosystem services classifications discussed in Section 7.

According to Huang et al. (2006) the concept of multifunctionality was first introduced by the Organisation for Economic Co-operation and Development (OECD) in 1992 and was discussed at the 1992 Earth Summit in Rio in the context of potential environmental benefits from agricultural activities. Multifunctionality was identified as an element of 'non-trade concerns' in Article 20 of the Agreement on Agriculture in the World Trade Organization (WTO) Uruguay Round (Anderson 2000). The Food and Agriculture Organization (FAO 1999) reviewed the multifunctional characteristics of agriculture.

The terminology of multifunctionality refers to 'non-trade concerns' or 'non-commodity externalities', which include agricultural contributions to long-term food security, environmental protection, and the maintenance of rural traditions and communities (Huang et al. 2006). A typical list of functions for rice paddies includes: flood mitigation, water resource fostering, soil erosion prevention, reduction of land subsidence, water purification, processing organic waste, soil purification, micro-climate modification, refreshing the atmosphere, conserving biodiversity, beautification of landscapes, promotion of health and recreation, and participatory learning and education about cultures, tradition and religion (Aizaki et al. 2006; Huang et al. 2006; Levine et al. 2006; Matsuno et al. 2006). Clearly, these are the same as ecosystem services.

To a much greater extent than the ecosystem services concept, the concept of multifunctionality has become associated with discussion about subsidising agriculture (Normile & Bohman 2002). As a condition for joining the WTO in 2001, for example, the Taiwanese government was required to reduce its use of price support for domestic agriculture (Huang et al. 2006). Similar debates are current in Korea, Japan and Indonesia with respect to rice (Agus et al. 2006; Kim et al. 2006; Matsuno et al. 2006). Government intervention is seen by many governments as necessary to correct the failure of markets to encourage production of non-food benefits from agricultural landscapes but this is sometimes not consistent with directives from international trade bodies (DeVries 2000). Rice in particular is a crop that means much more than food to Asian countries, playing an important role in socioeconomic development of rural communities and conservation of natural resources and the environment (Matsuno et al. 2006). The perception of the contribution made by rice cultivation practices and paddy irrigation often differs among people because society places widely different values on uses of water and land (Molden et al. 2002).

Two of the major challenges facing agricultural policy around the world are: (1) addressing the failure of markets to adequately protect public goods and services; and (2) achieving desired income distribution between farmers and the rest of society (Blandford & Boisvert 2005). Concern about payments for multifunctionality (or ecosystem services) arise particularly if it appears that these approaches are being used to achieve redistribution of income domestically at the expense of other countries (i.e. through unfair trading prices). Solutions to this dilemma include restricting the concept of multifunctionality to non-commodity outputs involving technical externalities or public goods and for which market failure and the misallocation of resources are important (e.g. amenity values and agricultural pollution) and identifying different types of domestic policy measures to address

distributional issues (Lichtenberg 2004; Blandford & Boisvert 2005; Chang et al. 2005; Boisvert & Blandford 2006; Chang & Boisvert 2006).

As a result, Boisvert and Blandford have recommended that, for policy purposes, a workable definition of multifunctionality must be restricted to non-commodity outputs of agriculture that satisfy two conditions:

- they are jointly produced with commodity outputs
- they provide social value (impose social costs) not reflected in markets.

This definition brings into focus a problem that also arises with respect to relating ecosystem services to economic classifications of value (see Section 9.2). Whereas both multifunctionality and ecosystem services should logically include the full range of functions, benefits or services from landscapes or ecosystems, some authors have found the need to restrict the definition of both multifunctionality and ecosystem services to fit policy or political needs. This can be confusing and interfere with communication of the ideas that ecosystem services approaches are intended to address.

## 9.2 Economic classifications of value

Economics defines and classifies value in various ways that we will not go into comprehensively here.

The concept of total economic value (Figure 15) emerged from environmental economics as a framework for acknowledging the full range of values the environment provides (Pearce & Moran 1994). The concept of ecosystem services emerged from the same sort of thinking that generated total economic value. The ecosystem services concept attempts to conceptualise this thinking in a different way that its proponents believe is understandable to a wider range of people. An ecosystem services approach also goes further in detailing the links between benefits or services and the underpinning ecological processes and functions that generate them. The ecosystem services concept also does not exclusively focus on economic measures of value, although often it is economics methods that are employed to assess values and trends in ecosystem services (however see, for example, Appendix D.6, for an example of an approach that measures the state of ecosystem services without necessarily referring to economic value).

Total economic value distinguishes between use values and non-use values (Barbier et al. 1997). Use values involve some human 'interaction' with the resource whereas non-use values do not. Non-use values rely merely on the continued existence of an environmental resource and are unrelated to use. Use values can be either direct or indirect (Figure 15).

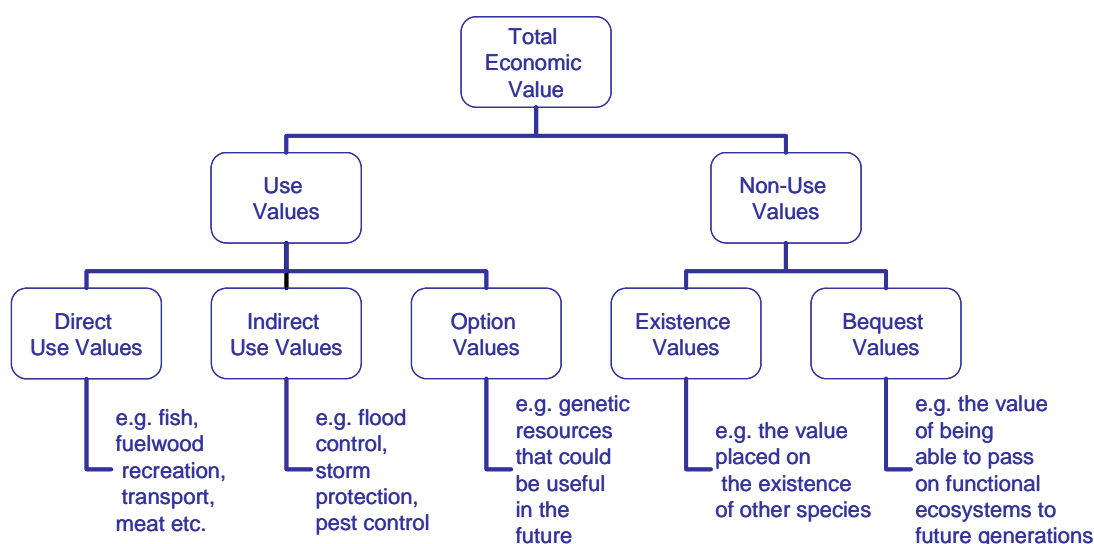
Direct use values are more likely to have market value. Indirect use values, on the other hand, are difficult to quantify and are generally ignored in management decisions. For example, production of food is a direct use value for which money is exchanged in markets, whereas the nutrient cycling performed by soil organisms indirectly supports agricultural production but this contribution is unmarketed and

goes financially unrewarded. With respect to wetlands, Barbier et al. (1997) make the following observations:

*...storm protection and shoreline stabilization functions may have indirect use value through reducing property damages, yet often coastal or riverine wetland systems are drained in order to build still more waterfront property. Mangrove systems are known to be breeding grounds and nurseries for shrimp and fish that are essential for coastal and marine fisheries, yet these important habitats are currently being converted rapidly in many regions for aquaculture, particularly shrimp ponds. Natural floodplains may recharge ground water used for dryland agriculture, grazing livestock and domestic or even industrial use, yet many of these floodplains are threatened by dams and other barrages diverting water for upstream irrigation and water supply.*

There are two ways in which people may value natural resources without using them either directly or indirectly. Existence value is the ‘intrinsic’ value of natural resources that arises simply due to their existence. It is the value that leads people to want to see other species like giant pandas, for example, protected, even if these people never see the species. Bequest value is what leads people to support policies and actions that protect natural resources for future generations to use. Option values are values that are not currently used but have potential to be used in the future.

A range of methods has been developed to estimate the value of non-marketed benefits from the environment (Bingham et al. 1995; Barbier et al. 1997). It remains an issue, however, that different sectors of society have different values for biodiversity and ecosystem services (Swift et al. 2004). Approaches to assessing the ecological aspects of ecosystem services, independent from associated economic valuation, are therefore a useful complement to economic frameworks.



**Figure 15**  
The concept of total economic value

After Barbier et al. (1997) and OECD (2002)

The list of examples usually given to illustrate total economic value (e.g. Figure 15) includes ecosystem services; a comprehensive list of ecosystem services such as those in Table 2 and Appendix A could easily be mapped to categories of total economic value and there would be ecosystem services in all categories.

Some confusion has emerged, however, from different interpretations of the relationship between total economic value and ecosystem services by some authors. One such interpretation equates ecosystem services with indirect use values (e.g. carbon sequestration and erosion control) (OECD 1999). While this narrow interpretation is a minority view among the published literature, it is nevertheless used widely, including in Australia.

A second minority interpretation is the one already discussed in Section 9.1, which recommends restricting the use of the term multifunctionality to non-commodity (non-market) outputs of agriculture.

## 10 Barriers to using the ecosystem services concept

### Terms of reference Item 7

For those areas in which it will be of benefit to use the concept of ecosystem services, identify what, if any, barriers exist to the effective use of the concept and propose ways of overcoming these barriers.

At its heart, the ecosystem services concept is about multiple values. Most other multiple-use frameworks recognise that a range of benefits is possible but do not attempt to identify and list those benefits comprehensively; they usually focus on just a few. The ecosystem services concept, as developed by its leading proponents, requires attention to the full suite of services, either individually or in aggregates, and to the tradeoffs among those services and between those services and potential technological substitutes. This makes the concept a very useful one for bringing diverse interest groups together to identify and discuss common and separate interests within one framework.

The concept of ecosystem services has been developed and tested over several decades by some of the world's leading ecologists and economists. It was developed specifically to bring together economic and ecological thinking and production and conservation thinking. It has immense credibility as demonstrated by it becoming the heart of the framework developed by the Millennium Ecosystem Assessment to do its global assessment of the state of the world's ecosystems over the past five years. This project involved over 1,300 of the world's leading scientists, economists and policy analysts.

Despite the long gestation of the concept, some people think the classification schemes currently available contain inconsistencies (e.g. they mix ends with means). This can be confusing to people who crave a high level of consistency in classifications. This weakness can be fixed by revisiting the framework where that is necessary (e.g. Wallace 2007) or tailoring it to specific projects.

Some economists ask what is new about the concept, arguing that economics is already addressing all of the issues for which the ecosystem services concept was developed. This attitude comes from the misconception that the ecosystem services concept seeks to replace economics, which is not true. Nevertheless, this is a significant issue because neoclassical economics is still the dominant paradigm in decision making in many levels of government and business, and care needs to be taken to find harmony between ecosystem services language and economic language. This is not an insurmountable challenge, as several of the architects of ecosystem services thinking have been advisors to heads of government before and after their involvement with this way of thinking. But it highlights the potential for the ecosystem services concept to be misunderstood and misused.

Another way in which the concept gets misused is when the name is used as a way to bring credibility to a project or policy that does not seek to consider the full range of

services. 'Ecosystem services' is often used as code for 'we are considering the environment' but in many cases this is not justified.

While the ecosystem services concept has the potential to bring together groups that have traditionally been in conflict or had divergent views, such as conservationists and agriculturalists, it can also drive them apart if not carefully and thoughtfully applied. For example, some conservation-oriented individuals and groups fear that the intrinsic value of biodiversity will be forgotten among the many utilitarian values that are included in lists of ecosystem services or that stewardship payments will be made only for utilitarian values.

These concerns can, however, be addressed, as was done in the Millennium Ecosystem Assessment, by recognising that:

- the central reason for talking about ecosystem services is to encourage the full suite of use and non-use values to be considered together
- biodiversity underpins all ecosystem services and although some services can be delivered in the short term by simplified ecosystems, such ecosystems have less resilience and greater potential to fail in the long term.

## 11 Measuring ecosystem services

### Terms of reference Item 8

Identify current means of measuring ecosystem services and the current capability to make such measurements.

### 11.1 Measuring and modelling ecosystem services

A number of attempts have been made in Australia and around the world to measure and/or model the quantity and distribution of ecosystem services associated with the way people utilise our natural resource base. Invariably, this involves modelling biophysical processes and estimating causal relationships between action and outcome.

There have been many projects over several decades that have attempted to describe the benefits to people from Australian ecosystems in a cogent framework. The first high-profile project to use the term ‘ecosystem services’ was the Ecosystem Services Project run by CSIRO, The Myer Foundation & Land and Water Australia (Binning et al. 2001; Abel et al. 2003; [www.ecosystemservicesproject.org](http://www.ecosystemservicesproject.org); see also Section 5.9.1 and Table 3). This project initially adopted a rapid approach to assessing which ecosystem services were important for which land uses in the Goulburn Broken catchment of Victoria, based on a combination of published information and expert judgement (Table 3).

The approach was successful in engaging a wide range of people from different sectors of the local community and government and became the framework for a revision of the catchment’s strategic plan (Goulburn Broken Catchment Management Authority 2003). Variations on the approach were also applied in the Gwydir catchment of NSW (<http://www.ecoman.une.edu.au/gesp/index.html>) and in Atherton, Queensland (Blanch et al. 2006). The initial rapid assessment was followed by a more detailed attempt to model possible economic, environmental and social outcomes in relation to a set of scenarios for the future of the catchment (Abel et al. 2003). While this phase of the project also yielded valuable insights, it was hindered by lack of information on several key ecosystem processes.

Ecosystem services are not comprehensively considered in policy and legislation because they were not understood and there was little awareness of them when most of our existing legislation and policies were developed (Salzman 2005). Now that awareness is growing, the next barrier to ecosystem services being incorporated in policy and legislation is the ability to measure them and to assess changes in services that occur due to interventions. For example, effective policy and legislation regarding water quality was only really achieved once water quality could be measured (Salzman 1997).

There has been a range of attempts to address this issue. For example, metrics have been developed for measuring carbon and the quality of habitat to encourage markets for carbon sequestration and biodiversity conservation. The main research effort with respect to other ecosystem services has been focused on case studies where

measurements of the importance of individual ecosystem services are relatively easy to make. For example, there have been many studies looking at the implications of pollination rates on crop production and the economic benefits of pest control by native insects and birds. But while in theory the relationship between plants and water filtration in catchments is simple, it is much harder to predict or measure impacts that can be attributed directly to changes in native vegetation.

If we want to consider the whole suite of ecosystem services at the whole ecosystem, landscape or catchment scale, the challenges are even greater. Cause and effect are connected through complex transformation processes, and the processes delivering each ecosystem service are interrelated.

Attempts have been made to develop models that allow prediction of outcomes in terms of bundles of ecosystem services. These models are hampered by limited information on many processes. Researchers have used expert judgement models (Binning et al. 2001), semi-quantitative models assembled with local input using modules that represent a standard set of ecosystem processes (Higgins et al. 1997), models based on a mixture of detailed quantitative models and rule sets (Abel et al. 2003), and very detailed quantitative models based on hydrology and its impacts on vegetation (Beverly et al. 2003). The approach developed in Victoria has been the most comprehensive, with models and metrics linked directly to decision making and market-based instruments. Initially, only habitat for biodiversity was targeted but the latest approach (EcoTender) targets bundles of services that allow incentives to be applied for a much larger suite of ecosystem services.

## **11.2 Ecosystem services-based indicators of environmental change**

### **11.2.1 Choosing indicators**

The issue of choosing indicators for assessing environmental impacts or progress towards environmental objectives is a complex one. The matters that need to be considered include:

- how the relationship between land management and the environment is conceptualised
- what aspects of the potential impact are relevant
- what environmental outcomes are being sought
- what magnitude of change is relevant and over what timeframe

Environmental indicators are physical, chemical, biological or socioeconomic measures that represent key elements of a complex ecosystem or environmental issue. In most cases indicators are used as part of programs for monitoring change over time and, as such, must be capable of measurement with appropriate precision and accuracy and at appropriate spatial scales to detect the amount of change that is relevant to the purpose.

An environmental indicator should be embedded in a well-developed interpretive framework so that the set of indicators can be related to one another and combined to provide a holistic view of the linked human–environment system of interest.

One framework that has been popular for some time in a number of countries for reporting the state of the environment is the Pressure-State-Response model. This model requires: indicators that describe pressures exerted on biological diversity and ecosystem functions; indicators of the condition or state of the environment; and indicators of responses to the pressures, or to changes in the condition or state, which include policy, management and research responses.

In a typical set of environmental indicators (DEST 1994) each indicator should:

- serve as a robust indicator of environmental change
- reflect a fundamental or highly valued aspect of the environment
- be at a spatial scale appropriate for the environmental issues of interest
- provide an early warning of potential problems
- be capable of being monitored to provide statistically verifiable and reproducible data that show trends over time and, preferably, apply to a broad range of environmental regions
- be scientifically credible
- be easy to understand
- be monitored regularly with relative ease
- be cost-effective
- have relevance to policy and management needs
- contribute to monitoring of progress towards objectives and commitments
- where possible and appropriate, facilitate community involvement
- where possible and appropriate, use existing commercial and managerial indicators
- where possible and appropriate, be consistent and comparable with other countries' and state and territory indicators.

The last point is particularly challenging, as pressures to develop indicators rapidly and to take advantage of local interests and expertise commonly result in low levels of commonality across jurisdictions within a country let alone internationally.

**Table 10**  
**Indicators of biological diversity taken from 20 state of the environment reports**

From Saunders et al. (1998)

Indicator of	No. of reports that use each indicator
<b>Pressure</b>	
Vegetation clearance, fragmentation, conversion	10
Threatening processes (other than clearance)	8
Introduced species or genes	6
Grazing	5
<b>State</b>	
Conservation status of species	16
Extent of protected areas	12
Distribution and abundance of species	9
Extent of intact or unmodified plant/animal communities	6
Changes in distribution and abundance	6
Distribution and abundance of introduced species	5
Size and shape of protected areas	5

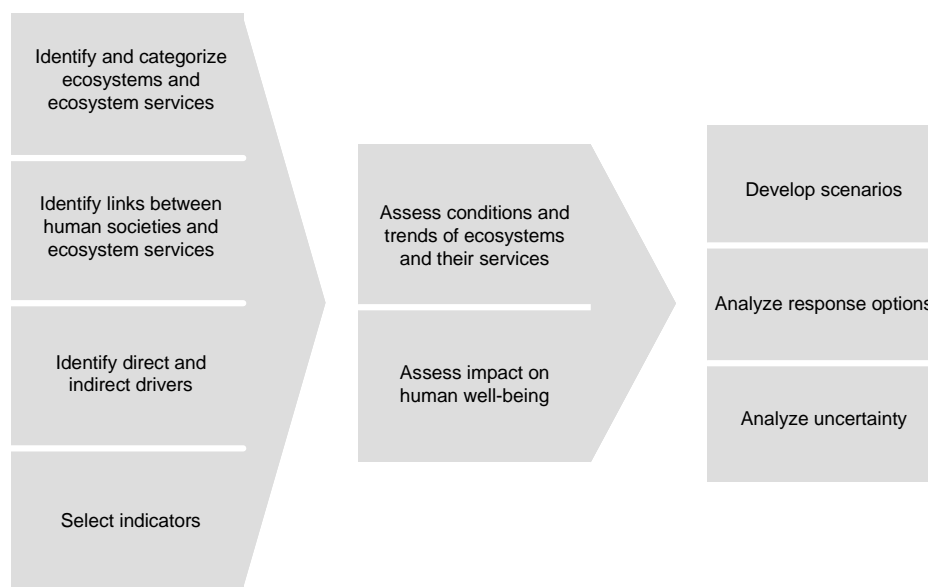
Indicators of biological diversity are taken from 20 state of the environment reports from Australia (1996 Commonwealth, ACT, NSW, SA and WA); environment reports from Canada, Denmark, Finland, Hong Kong, Italy, Japan, the Netherlands, Norway and the United Kingdom; and reports on environmental indicators from the OECD, United Nations Environment Programme (UNEP), World Bank and World Resources Institute, and the World Conservation Union. The table was collated by the State of the Environment Reporting Unit, Environment Australia. Only indicators used in five or more of the sources are listed.

For example, an examination of 20 state of the environment reports or other environmental reports from 10 countries plus several papers on suggested environmental indicators for Australia's State of the Environment reporting process found that only four indicators of pressure on biological diversity out of 68 used in the various studies were common to five or more studies (Table 10). Similarly, only seven out of 41 indicators of the condition or state of biological diversity were used in five or more studies, and none of the 36 indicators for responses was used in five or more studies. The most commonly used indicators were: the extent of vegetation clearance or conversion (an indicator of pressure); the conservation status of species; and the extent of protected areas (two indicators of condition or state).

#### **11.2.2 Developing ecosystem services-based approaches**

With the increasing interest in using the ecosystem services concept to integrate thinking about environmental, social and economic aspects of environmental management, the question of ecosystem services indicators has had to be addressed.

Figure 3 illustrates how an ecosystem services approach links environmental, social and economic change to human well-being via the benefits to people from ecosystems. Figure 16 shows how a set of indicators of ecosystem health and human well-being can be developed within an ecosystem services framework.



**Figure 16**  
**The analytical approach of the Millennium Ecosystem Assessment**

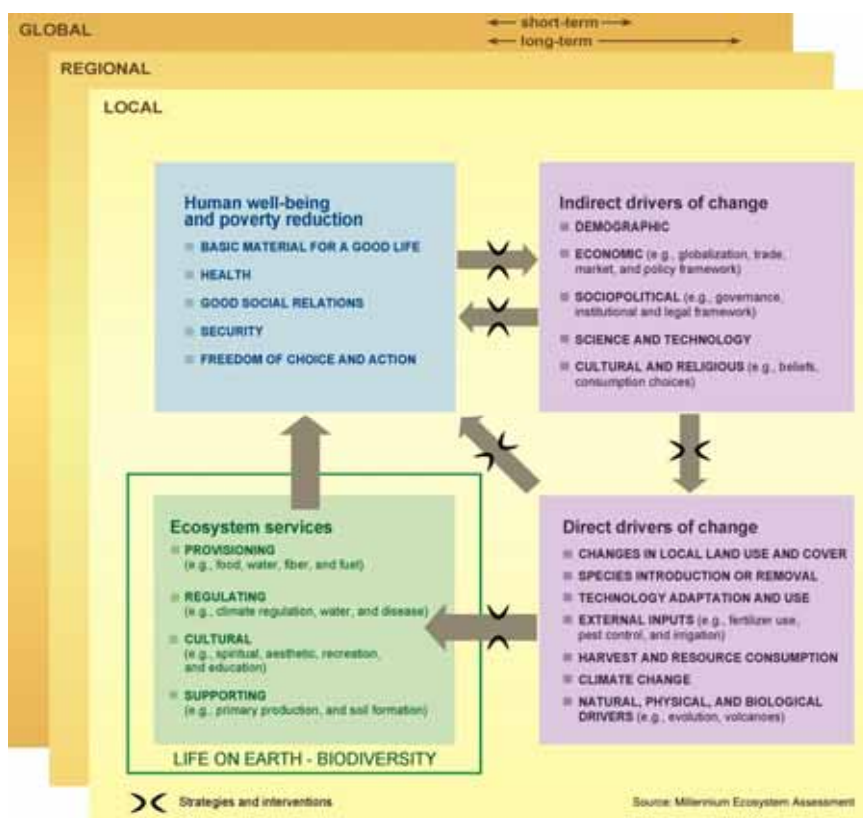
From MA (2005a)

As with other applications of an ecosystem services framework, this does not represent a totally new set of technologies or even indicators, although the framework might prompt program designers to look for indicators not used in other schemes. Rather, application of an ecosystem services framework encourages the program designer to go through a hierarchy of questions to ensure that there are internally consistent links between indicators and between environmental change and human well-being. As discussed previously in this paper, most approaches to ecologically sustainable development try to do this but the identification of services required from environmental management and the needs the services are meeting is rarely as explicit as in an ecosystem services framework.

In implementing the components of the approach outlined in Figure 16, the following steps were taken:

- *Identify and categorise ecosystems and their attendant services.* As well as using a scheme for classifying ecosystem services, it is useful to classify ecosystems themselves into a limited number of categories as a basis for assessing the services they provide.
- *Identify links between services and human societies.* This includes defining the components of human well-being that are affected by the services (such as health, livelihood, culture, and equity), as well as the human activities that in turn affect ecosystems and the supply of services (such as population growth, consumption, and governance).
- *Identify direct and indirect drivers.* This component is similar to the identification of pressures in a Pressure-State-Response model. The Millennium Ecosystem Assessment identified both indirect and direct drivers

of the state of ecosystems and their services (Figure 17). Indirect and direct drivers affect not only ecosystems and their services but also each other.



**Figure 17**  
Conceptual framework used by the Millennium Ecosystem Assessment

From MA (2005a). Direct and indirect drivers are illustrated as well as the links between ecosystem services and human well-being and points at which policy and other interventions are possible (indicated by the large arrows with black cross bars)

- *Select indicators of ecosystem condition, services, human well-being, and drivers.* Having established the framework and identified which aspects of the state of ecosystems, ecosystem services, human well-being, and drivers are of interest, it is necessary to identify indicators. This is not a straightforward process as indicators are difficult to establish for most ecosystem services. However, indicators of ecosystem pressures and state are possible. Qualitative inferences can be drawn about ecosystem services from these indicators. Examples of the sorts of indicators that have proven helpful are discussed in Section 12.
- *Evaluate impact on human well-being.* This aspect of assessing impacts of land management on the environment is often barely addressed. There are usually implicit assumptions that ecosystems in good condition are good for people but the link is rarely made explicit. This was among the most challenging tasks in the Millennium Ecosystem Assessment, since it involved translating information largely from the natural sciences (such as the state of

fresh water, soil, and forests) into variables of concern to society (health, livelihoods, wealth, and security, for instance). One challenge is that a given service can affect several components of human well-being. Other challenges lay in sorting out the many possible tradeoffs among services and the distribution of service benefits among societal groups.

- *Develop scenarios.* Although not normally a component of environmental impact assessments, some consideration of future implications of landscape trends is important if the objective of the assessment is to improve human well-being. This was done in the case of the Millennium Ecosystem Assessment using scenario planning (MA 2005b; Cork et al. 2006). Other examples of the use of scenario planning in an ecosystem services framework are given in Section 5.9, *Applications II: Studies of suites of ecosystem services*.
- *Evaluate possible responses.* Consistent with the Pressure-State-Response model, it is important to assess not just the impacts of land management actions but the implications of potential response strategies.

### **11.2.3 Examples of indicators**

While many countries have a set of indicators for assessing the state of the natural environment, few have systems explicitly based on ecosystem services. The development of such indicators is rudimentary. An example is the 2002 report on the State of the Nation's Ecosystems by the Heinz Center in the USA (Table 11), in which an indicator for 'natural ecosystem services' has yet to be developed.

**Table 11**  
**Summary of core national indicators from the USA State of the Nation's Ecosystems report**

From the H. John Heinz III Center for Science, Economics and the Environment (2002) and <http://www.heinzctr.org/ecosystems/report.html>

Indicator	Explanation	Status
<i>System dimensions</i>		
Ecosystem extent	What is the area of the six major ecosystem types?	Partial data available Some trends
Fragmentation and landscape patterns	How fragmented are natural lands into smaller, more isolated patches? How are developed lands intermingled within the natural landscape?	No data reported
<i>Chemical and physical conditions</i>		
Movement of nitrogen	How much nitrogen leaves watersheds across the country, and how much is delivered to coastal waters?	All necessary data available Trends
Chemical contaminants	How frequently are chemical contaminants found in ecosystems, and how often do they exceed standards and guidelines for the protection of human health and aquatic life?	Current data only, federal standards and guidelines
<i>Biological components</i>		
At-risk native species	How many native species are at different levels of risk of extinction?	Current data only
Condition of plant and animal communities	What fraction of US lands and waters are highly managed or highly altered, and what levels of disturbance are found on natural/semi-natural lands?	No data reported
Plant growth index	What are the trends in plant growth in different regions and different ecosystems?	All necessary data available Trends
<i>Human uses</i>		
Production of food and fibre and water withdrawals	How are the quantities of key ecosystem-related commodity goods changing over time?	All necessary data available Trends
Outdoor recreation	How often do people take part in outdoor recreation activities, and which kinds?	Current data only
Natural ecosystem services	What other services, such as soil building and flood protection, are provided by natural ecosystems?	No data reported

The Millennium Ecosystem Assessment (MA 2005c) developed a detailed methodology and indicators for assessing conditions and trends in a wide range of ecosystems and ecosystem services globally. A summary of the major conclusions can be found in Table 12 and examples of the indicators are given in Table 13.

**Table 12**  
**Global status of ecosystem services evaluated in the Millennium Ecosystem Assessment**

From MA (2005a, c)

Status indicates whether the condition of the service globally has been enhanced (if the productive capacity of the service has been increased, for example) or degraded in the recent past. Definitions of 'enhanced' and 'degraded' are provided in the note below. A fourth category, supporting services, is not included here as they are not used directly by people.

Service	Sub-category	Status	Notes
<b>Provisioning services</b>			
Food	Crops	↑	Substantial production increase
	Livestock	↑	Substantial production increase
	Capture fisheries	↓	Declining production due to overharvest
	Aquaculture	↑	Substantial production increase
	Wild foods	↓	Declining production
Fibre	Timber	+/-	Forest loss in some regions, growth in others
	Cotton, hemp, silk	+/-	Declining production of some fibers, growth in others
	Wood fuel	↓	Declining production
Genetic resources		↓	Lost through extinction and crop genetic resource loss
Biochemicals, natural pharmaceuticals	medicines,	↓	Lost through extinction, overharvest
Fresh water		↓	Unsustainable use for drinking, industry, and irrigation; amount of hydro energy unchanged, but dams increase ability to use that energy
<b>Regulating services</b>			
Air quality regulation		↓	Decline in ability of atmosphere to cleanse itself
Climate regulation	Global	↑	Net source of carbon sequestration since mid-century
	Regional and local	↓	Preponderance of negative impacts
Water regulation		+/-	Varies depending on ecosystem change and location
Erosion regulation		↓	Increased soil degradation
Water purification and waste treatment		↓	Declining water quality
Disease regulation		+/-	Varies depending on ecosystem change
Pest regulation		↓	Natural control degraded through pesticide use
Pollination		↓ <sup>A</sup>	Apparent global decline in abundance of pollinators
Natural hazard regulation		↓	Loss of natural buffers (wetlands, mangroves)
<b>Cultural services</b>			
Spiritual and religious values		↓	Rapid decline in sacred groves and species
Aesthetic values		↓	Decline in quantity and quality of natural lands
Recreation and ecotourism		+/-	More areas accessible but many degraded

Note: For provisioning services, we define enhancement to mean increased production of the service through changes in area over which the service is provided (e.g. spread of agriculture) or increased production per unit area. We judge the production to be degraded if the current use exceeds sustainable levels. For regulating and supporting services, enhancement refers to a change in the service that leads to greater benefits for people (e.g. the service of disease regulation could be improved by eradication of a vector known to transmit a disease to people). Degradation of regulating and supporting services means a reduction in the benefits obtained from the service, either through a change in the service (e.g. mangrove loss reducing the storm protection benefits of an ecosystem) or through human pressures on the service exceeding its limits (e.g. excessive pollution exceeding the capability of ecosystems to maintain water quality). For cultural services, enhancement refers to a change in the ecosystem features that increase the cultural (recreational, aesthetic, spiritual, etc.) benefits provided by the ecosystem.

<sup>a</sup> Indicates *low to medium certainty*. All other trends are *medium to high certainty*.

**Table 13**  
**Examples of indicators used to assess ecosystem condition and trends in the Millennium Ecosystem Assessment**

From DeFries et al. (2005)

Characteristic described by indicator	Example of indicator	Category of indicator	Availability of data for indicator	Units
<i>Direct drivers of change</i>				
Land cover conversion	Area undergoing urbanisation	Ecological state	High	Hectares
Invasive species	Native vs. non-native spp	Ecological capital	Medium	Percentage of plant species
Climate change	Annual rainfall	Ecological state	High	Millimetres per year
Irrigation	Water usage	Ecological functioning	High	Cubic metres per year
<i>Ecosystem condition</i>				
Condition of vegetation	Landscape fragmentation	Ecological state	Medium	Mean patch size
Condition of soil	Soil nutrients	Ecological capital	Medium	Nutrient concentration
.	Soil salinisation	Ecological state	Low	Salt concentration
Condition of biodiversity	Species richness	Ecological capital	Low	Number of species/area
.	Threatened species	Ecological functioning	Medium	Percent of species at risk
.	Visibility of indicator spp	Ecological functioning	Low-medium	Probability of extinction
Condition of fresh water	Presence of contaminants	Ecological state	High	Concentration of pollutants index of biotic integrity
<i>Ecosystem service</i>				
Production service	Food production	Ecological functioning	High	Yield (kilograms per hectare per year)
Capacity to mitigate floods	Change in stream flow per unit precipitation	Ecological capital	Low	Discharge (cubic metres per second)
Capacity for cultural services	Spiritual value	Ecological capital	Low	Not applicable
Capacity to provide biological products	Biological products of potential value	Ecological capital	Low	Number of products or economic value

## 12 Conclusions and recommendations

### Terms of reference Item 9

Make overall recommendations as to the practicality and benefits of adopting the ecosystem services concept in natural resource management policy and program development/implementation and outline next steps to be taken.

### 12.1 General observations

1. Ecosystem services are the flow of services valued by humans (e.g. clean air and water, commodity production) that are provided from stocks of the ecosystem (e.g. land, water, vegetation and atmosphere).
2. Changes in ecosystem function precipitate changes in the flow of ecosystem services which may have positive or negative impacts on human well-being. In many instances ecosystem function and the level of ecosystem services are influenced by land and water managers including private landholders and government.
3. The above points have implications for the design and delivery of NRM policy and programs that are further discussed in the following points.
4. The results of several flagship ecosystem services-based projects/programs (generally using a market-based approach) provide important insights into the contribution private landholders can make to a healthy landscape and a functioning ecosystem. The flagship programs provide some key lessons for the design of future NRM ecosystem services-based and stewardship programs.
5. Land use change influences the condition of environmental assets and the flow of goods and services from them. The landscape in much of Australia has been significantly altered in the 200 years of European settlement. Changes to the landscape such as clearing native vegetation, introducing exotic plant and animal species, increasing soil disturbance and using artificial fertilisers and pesticides have precipitated changes in the condition of environmental assets and the flow of services from these assets. For example, land clearing has resulted in an increased flow of commodities from primary production (a flow that generates income) and increased stream flow, but it has also impacted (positively and negatively) on the flow of other ecosystem services (e.g. soil health, water quality).
6. The impact of land use patterns on ecosystem function varies from site to site and with the type of intervention. The environmental outcomes generated from land use vary from site to site and over time, influenced by: the type of intervention in the landscape; the location of intervention; the timing of the intervention; the rate at which biophysical systems adjust; and influences such as weather, pests and other threatening processes.
7. Multiple environmental outcomes arise from individual land use changes. For example, revegetation could give rise to habitat improvement, carbon sequestration, reduced surface runoff and improved water quality. The mix of these environmental outcomes depends on the location, type and scale of the intervention and responsiveness of the ecosystem amongst other things. Landscape modelling in Victoria indicates that 72 per cent of interventions in one

sub-catchment generated more than one environmental outcome (Eigenraam et al. 2008). This observation is important: it means that the ecosystem services approach must take account of multiple outcomes. For instance, extensive revegetation in some locations could severely reduce stream flow, impacting on species persistence and/or on the reliability of water available for irrigation. This also has implications for determining the relative amount of different ecosystem services sought by the public and hence how priorities and preferences are determined.

8. Ecosystem services are systematically undervalued because they are not adequately accounted for in land/water use decisions. When only some ecosystem services are considered in the resource allocation processes of the economy there is the potential for over-production of ecosystem services where incentives for investment exist (e.g. commodities) and under-production of ecosystem services where incentives are missing (e.g. habitat). Over long periods of time, the accumulated impact of under-production can lead to species extinction, pollution of streams, rivers and air and declining soil health.
9. The systematic undervaluing of ecosystem services occurs because Australia's economic system does not:
  - reward investment in production of all types of ecosystem services. Landholders are rewarded for actions that produce goods reliant on ecosystem services (e.g. agricultural commodity production from land and water) while for other actions that improve ecosystem function, there are no financial rewards
  - reveal the 'value' that some ecosystem services provide to society. Again markets can reveal buyers' willingness to pay for agricultural commodity production but there is no robust mechanism for revealing the value of improved habitat even though it is highly valued. There is also no means by which changes in ecosystem function (positive or negative) arising from agricultural commodity production are appropriately measured or valued.
10. The ecosystem services concept has several important aspects that contribute to addressing these problems:
  - Ecosystem services as a means of improving NRM planning. An ecosystem service approach presents a means of progressing NRM planning, particularly at the regional and local level. It forces discussion on the full value of ecosystem services rather than a focus on individual threats. Framing NRM issues in an ecosystem services context forces NRM programs to focus on delivering outcomes costs effectively.
  - Ecosystem services as a way to engage communities and land managers in NRM. The experience of several Victorian projects is that landowners intuitively identify with the concept. Landowners are continuously balancing their choices and actions based on commodity production, local habitat, water quality and water quantity (all ecosystem services). The approach also provides a framework for dialogue with land managers about the public and private benefits and dis-benefits arising from various land and water use options.
11. Some new policy tools to address ecosystem services within the economy have been successfully trialled in Victoria and other jurisdictions. New ideas and techniques have emerged in science and economics that open up the policy tools available to address the above issues. The Market-Based Instruments Pilot Program has examined the application of some policy tools that efficiently include

environmental goods and services into the economic system. There is now considerable experience available to design institutions such as: tradeable emission permits (the Hunter River Salinity Scheme in NSW); the application of auctions to allocate conservation contracts (BushTender in Victoria); offset markets (NSW, Victorian schemes). These institutions have been specifically designed to correct for the ‘missing’ incentives for ecosystem services. Victoria is currently rolling out a set of approaches (under the Environmental Sustainability Action Statement) that will take account of the multiple outcomes arising from land use change (changes in carbon, stream flow, water quality, dryland salinity, habitat) and reward landholders for the provision of these services by employing combinations of the above institutions.

## **12.2 Lessons from experience with ecosystem services programs in Australia**

A number of lessons can be learned from the limited experience with the ecosystem services approach in Australia. The NRM investment principles adopted by Australian and state governments will need to reflect the following points.

1. The role of policy tools is crucial. Well-designed policy tools such as auctions, tradeable emission permits, offset markets, education and communication provide the incentives to encourage landholders to deliver environmental outcomes. These tools need to be carefully designed and tested to avoid perverse outcomes and ensure value for money.
2. A mix of policy tools is required to deliver value-for-money ecosystem services outcomes. Landholder ‘duty of care’ must be made clear. Investment should be designed to deliver improved ecosystem outcomes. Market-based instruments cannot be effective without well-designed underpinning regulation. Research is needed to identify opportunities to improve ecosystem outcomes and to inform land managers about these opportunities.
3. Complementary outcomes can be achieved. Designing a ‘complete’ set of markets for ecosystem services would enable complementary ecosystem outcomes to be achieved while reducing the risk of negative impacts. For example, the existence of a market for carbon permits would provide incentives for revegetation which can also generate other ecosystem functions (e.g. habitat, water quality and salinity services). Furthermore, if the price of carbon were to rise as a result of reductions to a carbon cap, the savings to government programs become substantial. Using field pilot data, it has been estimated that for one catchment area, there would be a 26 per cent saving to government programs (focused on public goods) if the price of carbon were \$12/tonne. These savings increase to 44 per cent if the price of carbon were to rise to \$20/tonne.
4. Science plays a critical role in the efficient provision of improved ecosystem services. Better understanding of ecosystem function, the spatial and temporal interaction between different attributes (e.g. soil, water, vegetation) and the links between actions and outcomes is required to quantify the environmental outcomes of various land and water use change options. Science underpins the use of metrics that express the change in ecosystem function resulting from investments in various interventions at different locations.

5. Policies and programs must minimise risk in the context of uncertainty and imperfect information. Appropriately designed ecosystem services policies and programs can help articulate community preferences for ecosystem services and influence land and water use decisions for the best outcome in the context of incomplete information.
6. Accountability and transparency are essential. The Victorian BushTender program has demonstrated the value of providing landholder payments through appropriately designed contracts between the government and landholder. On the demand side, such contracts ensure that landholder actions are ‘beyond duty of care’, that both parties meet their obligations under the contract and that payments proceed subject to satisfactory reporting and performance. On the supply side, the contracts have received a very positive response from participating landholders and have demonstrated landholders’ capacity to ‘learn through doing’. Feedback from landholders has shown the influence of well-designed contracts on complementary activities elsewhere on the property and their ability to influence landholder actions beyond the contract period. The form of the contract and its legislative backing are important.
7. Programs need to ensure sustained outcomes. Ecosystem services programs involving landholder payments need to ensure adequate landholder education and support to maximise the long-term outcomes.
8. Programs must take account of Australia’s international obligations. Programs that involve payments to landholders for producing environmental goods and services are subject to scrutiny by the World Trade Organization. Environmental programs that involve private landholders in the USA, Canada and the European Union are regarded by the OECD as providing implicit subsidies to landholders. Ecosystem services programs developed in Australia should have a stated objective of economic efficiency (i.e. no implicit subsidies).

### **12.3 Principles**

The following principles are proposed as operational standards to be taken into account in the design of future NRM programs.

1. The type and condition of assets, actions by landholders, the on- and off-site environmental outcomes arising from these actions and their cost are all highly variable. NRM investment needs to take account of this variability in order to make ‘value for money’ decisions.
2. NRM investment allocation processes need to be able to compare the change in landscape or ecosystem outcomes that will result from various site-scale investment options.
3. NRM investment allocation processes need reliable information including the ability to reveal ‘hidden information’ such as the value of public goods, society’s preferences for particular types of public goods and the cost of land use change.
4. Organisations involved in NRM processes should utilise the best available science to link actions to outcomes, to inform decision-making and to build capacity in the selection and delivery of policy tools including newer tools such as auctions and offsets.

5. These new policy tools may require regulation or legislation to support them in order to identify landholder actions beyond 'duty of care'.
6. It will be important to avoid schemes that involve implicit subsidies to landholders and it will be important to achieve tangible outcomes with respect to the condition of natural assets. There are World Trade Organization implications for schemes that provide subsidies.
7. Specific issues including multiple outcomes, the variable impact of different types of intervention, different timeframes and natural variability will need to be incorporated into the design of NRM investment mechanisms.
8. Where payments are made to landholders, the use of property rights (where feasible) and/or landholder contracts can improve transparency, accountability and reporting (when designed and managed appropriately).
9. NRM programs should collect appropriate environmental data that contribute to an understanding of progress to policy goals as well as regional, state and national environmental accounting processes.
10. Regional strategies should articulate the value of public goods and society's preferences for particular environmental outcomes while allowing for the heterogeneity of the market to further inform resource allocation decisions (see Item 1 above).
11. Science research should address gaps in the understanding of ecosystem function, the link between on-ground actions and environmental outcomes, and alignment with social preferences and behavioural changes.

#### **12.4 Recommendations and next steps**

In considering future approaches to NRM in Australia, the Australian and state governments would benefit from having a considered position on how to approach the concept of ecosystem services, because it is now routinely incorporated in leading thinking and action with respect to sustainable land management worldwide.

The concept progresses the broader sustainability agenda through a structured approach to valuing the many services society expects from the environment. It has recently been used as the basis for a global assessment of ecosystems and their links to human well-being.

This paper demonstrates that the concept and language of ecosystem services offer substantial benefits for framing and communicating environmental policy and programs. There are, however, pitfalls, especially as interpretations and applications can and do differ among interest groups. Agreement among jurisdictions on at least the broad definition of ecosystem services and what an ecosystem services approach entails would eliminate much of the unhelpful confusion.

An ecosystem services approach can provide governments with a credible framework to support the design, implementation, evaluation and communication of environment

and NRM policies and programs. It should complement – not replace – existing approaches.

## Appendix A: Examples of ecosystem services classifications

**Table 14**  
Classification of functions, goods and services of natural and modified ecosystems

Extensively adapted from Costanza et al. (1997), De Groot (1994), De Groot et al. (2002), and Reid et al. (2006)

	<b>Ecosystem functions</b>	<b>How vegetation influences ecosystem processes</b>	<b>Example goods and services</b>
	Regulating and supporting functions	Maintenance of essential ecological processes and life support systems	
1	Regulating climate	Mediation of climate by vegetative cover	Moderation of climate change; maintenance of a favourable climate for food and fiber production and for human habitation and health; modulating fire regimes
2	Regulating microclimates	Creating and ameliorating conditions for germination, recruitment, growth, etc	Shade and shelter for plants (including windbreaks) and animals (including corridors)
3	Controlling (attenuating) environmental disturbances	Influence of vegetation structure on the magnitude of environmental disturbances	Storm protection (e.g. by mangroves); reducing negative impacts of floods (e.g. wetlands and forests)
4	Regulating water flows (quantity over time)	Water cycle processes (interception, evaporation, runoff and percolation)	Water supplies for production, consumption, irrigation, wetlands and environmental flows; reduced salt concentrations
5	Regulating water quality over time	Interception and filtering of sediments, chemical and biological constituents	Quality water for consumptive uses; conditions that support aquatic biodiversity
6	Regulating soil health	Protection / improvement of soil surface, root matrix and soil biota; accumulation of organic matter	Arable and productive soils; productive ecosystems; reduced damage from erosion / siltation; waste absorption and breakdown; reduced salt loads
7	Regulating nutrients	Cycles of bio-geochemical exchange	Life-support
8	Regulating gases and composition of the atmosphere	Role of vegetation in atmospheric exchange cycles	Maintenance of (good) air quality; underpinning CO <sub>2</sub> /O <sub>2</sub> balance and moisture content of atmosphere
9	Controlling reproduction and dispersal of species	Regeneration and assembly of plant communities; providing critical life cycle requirements (e.g. breeding sites)	Pollination of native plant species, crops, fruits etc; natural restoration of degraded areas (succession); biological diversity; 'natural' weed control
10	Creating and regulating range of habitats for plant and animal species	Providing diverse structural and nutritional niches; moderating plant, soil, animal interactions and environment (competition)	Structural and spatial distribution of niches, food sources, fire loads etc that maintain biological and genetic diversity and modulate fire regimes (the basis for most other functions)
11	Recycling of organic matter	Rate of biomass accumulation and	Instigation of germination; favourable seedbeds, soil moisture

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	Production Functions	combustible materials Provision of natural resources etc.	retention; benefits from litter biota
12	Conversion of energy, minerals and water	Uptake and conversion into edible plants (direct and indirect sources for all life)	Food and feedstocks
13	Generation and supply of raw materials	Conversion into vegetative biomass for human uses	Materials for building and manufacturing; fuel; fodder and fertilizer (e.g. compost); natural fibres (plant and animal derived); resources for art and decoration
14	Regeneration / life cycling and adaptation	Continuity and evolution of plant genetic material and biochemicals	Resources for improving resistance to pathogens / pests; pharmaceuticals and related uses (e.g. health care)
	Cultural Functions	Providing opportunities for human (cognitive) development	
15	Providing structure and content for landscapes and places (conditions for recreation, aesthetic, spiritual, cultural, historic and artistic information and experiences)	Contributes to landmarks and other culturally significant sites and features; varied and attractive landscape patterns; and scenery	Sacred or spiritually important sites (e.g. groves of trees); scenery and aesthetically and historically attractive places wilderness qualities, special features, resources for recreation and eco-tourism, adventure sports, artistic inspiration, painting, streetscapes etc.
16	Providing opportunities for research, teaching and learning	Variety in nature with scientific and educational value	Use of natural systems for scientific research, school excursions, individual learning etc

**Table 15**

**Relationships between key functional groups of organisms, the ecosystem level functions they perform and the ecosystem goods and services they provide**

From Swift et al. (2004)

<b>Ecosystem goods and services</b>	<b>Ecosystem functions</b>	<b>Key functional groups</b>
Ecosystem goods including:		
Food	Primary and secondary (herbivore) production	Plants, vertebrate herbivores
Fibre and latex	Primary production and secondary metabolism	Plants
Pharmaceuticals and agro-chemicals	Secondary metabolism	Plants, bacteria and fungi (decomposers, etc.)
Ecosystem services including		
Nutrient cycling	Decomposition Mineralisation and other elemental transformations	Decomposers Elemental transformers
Regulation of water flow and storage	Soil organic matter synthesis	Decomposers
Regulation of soil and sediment movement	Soil structure regulation—aggregate and pore formation Soil protection	Ecosystem engineers Plants
Regulation of biological populations including diseases and pests	Soil organic matter synthesis Soil structure maintenance Plant secondary metabolism	Decomposers Ecosystem engineers Plants
Detoxification of chemical or biological hazards including water purification	Pollination Herbivory Parasitism Micro-symbiosis Predation Decomposition	Pollinators <sup>a</sup> Herbivores <sup>a</sup> Parasites <sup>a</sup> Micro-symbionts <sup>a</sup> Hyper-parasites <sup>b</sup> , predators <sup>b</sup> Decomposers
Regulation of atmospheric composition and climate	Elemental transformation Greenhouse gas emission	Elemental transformers Decomposers, elemental transformers, plants, herbivores

## **Appendix B: Attributes of policy problems in sustainability**

**Dovers (2001) lists the following policy problems for achieving sustainability:**

- broadened and variable spatial scales;
- deepened and variable temporal scales;
- the possibility of ecological limits to human activity;
- irreversible impacts;
- complexity within and connectivity between problems;
- pervasive risk, uncertainty and ignorance;
- important environmental assets not traded or valued in markets;
- often cumulative rather than discrete impacts;
- new moral considerations (eg. other species or future generations);
- ‘systemic’ problem causes, embedded in patterns of production, consumption,
- settlement and governance;
- lack of accepted research methods, policy instruments and management approaches;
- lack of defined policy, management and property rights and responsibilities;
- demands for increased community participation; and
- sheer novelty as a set of policy problems.

## Appendix C: Ecosystem services: A Victorian example

The Avon-Richardson pilot project under the National Action Plan for Salinity and Water Quality, National Market Based Instruments Pilot Program conducted in Victoria illustrates the way that ecosystem services could be built into the economic fabric of the economy. The objectives of this pilot were to:

- (a) develop methods to measure the contribution that landholders could make to the provision of ecosystem services by changing land use or land management
- (b) design and test the way landholders would interact with the new institutions needed to reward landholders for producing ecosystem services.

The pilot was conducted in the Avon-Richardson sub-catchment of the North Central Catchment Management Authority in Victoria (see Figure 18). Biophysical models (Beverly et al. 2003 and Eigenraam et al. 2006) have been developed to illustrate the impact of land use change, since European settlement<sup>6</sup>, on the production of ecosystem services (stream flow, water quantity, ground water level (dryland salinity), terrestrial habitat and carbon).

**Figure 18**  
**Avon-Richardson sub-catchment**

Figure reproduced from Eigenraam et al. (2006) with permission of the authors.



### A.1 Measuring ecosystem services from land use change

As shown in Table 16, landscape change has a significant impact on quality and quantity of water in rivers and streams. Changes in vegetation alter surface flows and

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<sup>6</sup> Ecological Vegetation Classes were used to represent the pre-European landscape compared with current land use according to Australian Bureau of Statistics information.

ground water accessions, which in turn change environmental stocks in rivers and streams. Modelled results, reported in Table 16, indicate that current land use is estimated to result in a 362 per cent increase in surface water, a 437 per cent increase in ground water contribution to stream and a 409 per cent increase in mean annual flow compared with a pre-European landscape.

**Table 16**  
**Change in aquatic function due to land use change**

From Eigenraam et al. (2005)

<b>Land use</b>	<b>Surface water (contribution to stream flow GL/year)</b>	<b>Ground water (contribution to stream GL/year)</b>	<b>Mean annual total flow (GL/year)</b>
Pre-European settlement	7.3	12.5	19.8
Current land use	26.4	54.6	81
Current as a percent of pre-European (%)	362%	437%	409%

Removal of deep-rooted perennial vegetation has been estimated to have caused large changes to ground water accessions and subsequent expression of dryland salinity. Table 17 compares ground water levels resulting from current land use patterns with the landscape that existed pre-European settlement. These results illustrate that there has been a 152 per cent increase in the area of land where ground water is less than 2 metres and a 204 per cent increase in the area of land with ground water at 0.8 metres or above. Importantly, the model results show that changes in ground water accessions do not simply lead to reductions in the area of land that becomes saline. Eigenraam et al. 2005 showed that there was only a 27 per cent correlation between change in recharge and changes in saline land area.

**Table 17**  
**Estimated impact of land use change on depth to ground water**

From Eigenraam et al. (2005)

<b>Land use</b>	<b>Depth to ground water</b>			
	<b>2 m</b>	<b>1.5 m</b>	<b>1 m</b>	<b>0.8 m</b>
Pre-European settlement	73,247	47,949	24,125	17,375
Current land use	111,270	80,872	46,949	35,374
Current as a percent of pre-European (%)	152%	168%	194%	204%

Table 18 illustrates the estimated change in the stock of terrestrial biodiversity associated with pre-European settlement compared with current land use. The metric used in this analysis is habitat hectares (Parkes et al. 2003) which is a measure of the area and quality of habitat. Using this metric it can be seen that the original stock of biodiversity equated to approximately 370,000 habitat hectares (theoretical maximum depending on natural disturbance regime) but this has declined to 14,000 habitat hectares representing only 4 per cent of the initial stock of terrestrial habitat.

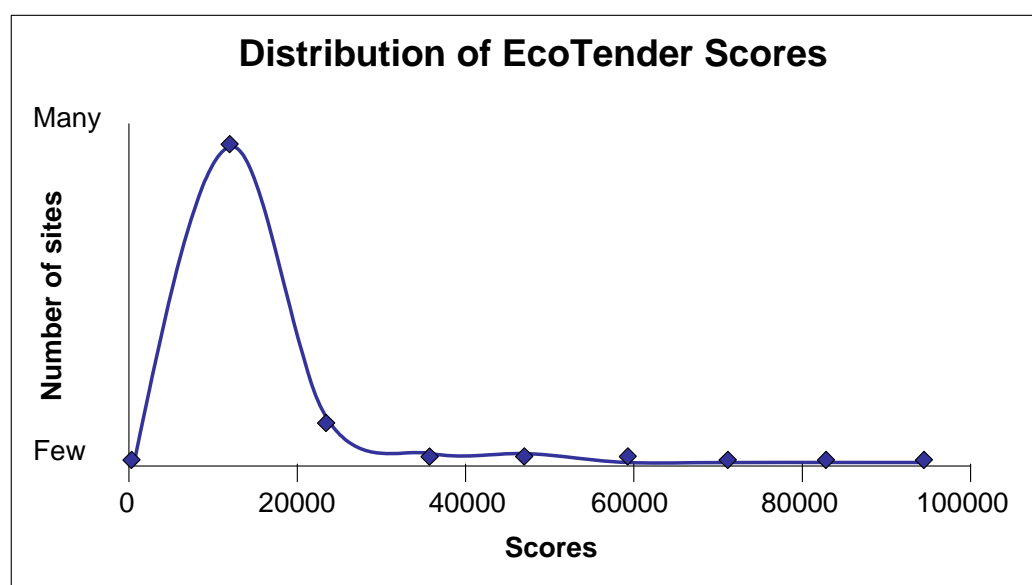
**Table 18**  
**Estimated impact of land use change on the stock of habitat**

From Eigenraam et al. (2005)

Land use	Stock of habitat (habitat hectares)
Pre-European settlement	370,000
Current land use	14,000
Current as a percent of pre-European (%)	4%

## A.2 Production of ecosystem services

By introducing new institutions such as a tradeable emission permit for carbon and an auction of conservation contracts as markets for ecosystem services in addition to existing commodity markets, the pilot demonstrated that landholders changed the mix of goods and services produced. Where the rewards for selling carbon into a tradeable permit market plus the returns from changing land use to supply additional units of habitat, water quality and salinity control were sufficient to outweigh the lost profit associated with reduced commodity production, landholders produced a new set of goods and services from land including ecosystem services.

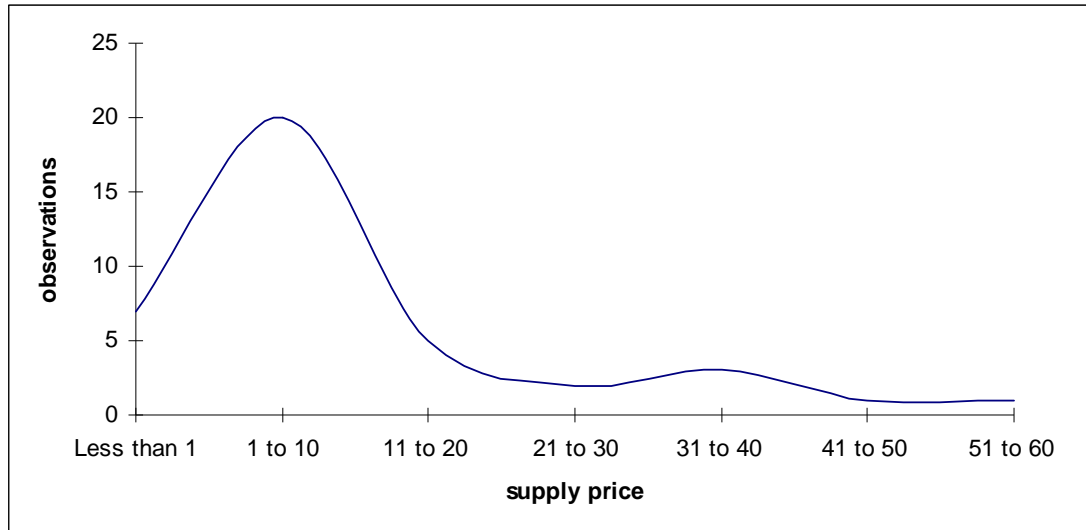


**Figure 19**  
**Heterogeneous supply of ecosystem services**

From Eigenraam et al. (2006)

The pilot caused landholders to allocate 259 hectares of land to the production of ecosystem services. Of this land 76 hectares were contracted for revegetation and 183 hectares were contracted to manage native vegetation. These sites generate habitat benefits and 97 per cent of sites generated two or more ecosystem services from the one land use change (e.g. habitat benefit, carbon sequestration and water quality improvement). The pilot will sequester an expected 10,078 tonnes of carbon which is sold to carbon emitters (e.g. electricity generators) at a market clearing price of \$12/tonne. Each site in the pilot project generated a unique set of environmental

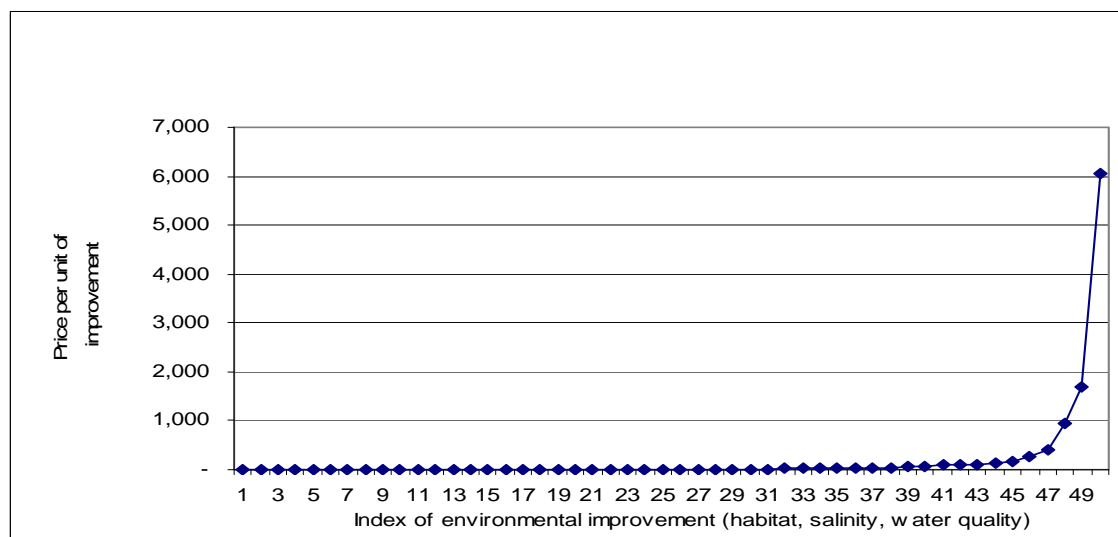
outcomes as illustrated in Figure 19. This is referred to as heterogeneous environmental impacts. Each landholder offered different prices to supply ecosystem services as shown in Figure 20; landholders are heterogeneous with respect to supply price for ecosystem services.



**Figure 20**  
**Heterogeneous cost of supplying ecosystem services**

From data obtained in the project reported by Eigenraam et al. (2006)

Figure 21 illustrates the bid prices offered per unit of additional ecosystem service supplied. In this figure, ecosystem services (habitat, water quality improvement and salinity mitigation) are indexed and added together. This figure shows that some landholders can produce ecosystem services at very low cost while others have high costs of production. Competitive processes allow purchasers of these ecosystem services to distinguish which are the low cost producers and which are high cost.

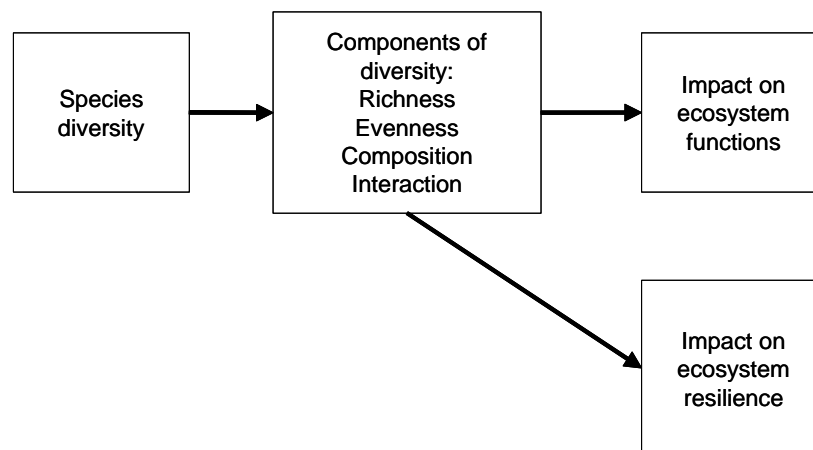


**Figure 21**  
**Cost of additional units of ecosystem services (Eigenraam et al. 2006)**

## Appendix D: Biodiversity, ecosystem services and resilience

### D.1 The issues

The ecological underpinnings of most ecosystem services remain poorly understood (Balmford et al. 2005; Luck et al. 2003; Palmer et al. 2004; Robertson & Swinton 2005). Central to this understanding is an understanding of how the mix of species present in an ecosystem affects the nature of ecosystem functions and services at one point in time and through time in the face of environmental change. There has been a long debate about these relationships (e.g. Woodwell & Smith 1969; Ewel et al. 1991; Naeem et al. 1994; Schulze & Mooney 1993; Tilman & Downing, 1994; Mooney et al. 1995, 1996; Naeem & Li 1997; Tilman et al. 1996, 1997; Hooper & Vitousek, 1997; Kinzig & Pacala 2001; Tilman & Lehman 2001). Experimental work on the relationship between species mixes and ecosystem function has been almost entirely on artificial, simplified communities of organisms because of the difficulty manipulating naturally occurring ecosystems (Kremen 2005).



**Figure 22**

**Broad conceptual relationship between species diversity and the functions and resilience of ecosystems**

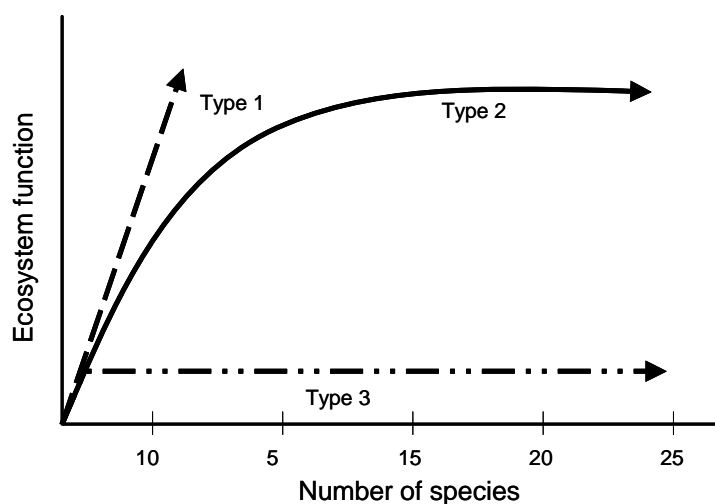
From OECD (2002)

As the use of the terms biodiversity and biological diversity has become more widespread in research and policy over the past 30 or so years, the debate about species and ecosystem function has incorporated consideration of the significance of *diversity* itself (Figure 22). This sometimes esoteric question has become an issue because of the worldwide focus of environmental conservation on biological diversity.

An important reference point for this debate was the work of Vitousek & Hooper (1993), who suggest three different possible relationships between plant diversity and ecosystem functions (Figure 23). On the basis of what was known at the time, they concluded that the asymptotic relationship shown as Type 2 in Figure 23 was the most

likely one. This relationship is expected to come about because the essential functions of an ecosystem, including nutrient cycling and decomposition processes, are provided at any point in time by a relatively small number of species and addition of more species primarily replicates these essential functions. In general the research cited above has supported this conclusion. Following sections of this appendix address some of the key questions that follow from this hypothesis, including:

- Do all ecosystems follow the relationship depicted in Type 2 of Figure 23?
- What significance do ‘replicate’ species have through time and space?
- What happens if ecosystems assemble or disassemble non-randomly?
- How does diversity of species and functions relate to production of ecosystem services?
- Can we identify ecosystem service providers and measure their efficiency?



**Figure 23**  
Possible relationships between biological diversity and ecosystem functions for the plant subsystem

From Vitousek and Hooper (1993)

## D.2 Relationship between diversity and ecosystem function

The research cited above generally has supported the existence of the Type 2 relationship of Figure 23 (Hooper et al. 2005).

Research on agricultural ecosystems has suggested that genetic, species and functional diversity are all important for providing the ecosystem service of natural pest control but that the right combinations of functions are also important (Hooper et al. 2005). In some cases, natural pest control increases with increasing diversity of plant and insect

species (Naylor & Ehrlich 1997) but, in other cases where the combinations of functions are not conducive, higher biodiversity appears to encourage greater pest populations through such mechanisms as providing key hosts of high palatability or that allow pests to complete a complex life cycle (Brown & Ewel 1987; Prieur-Richard et al. 2002).

### **D.3 The significance of 'replicate' functions**

There are at least three ways in which diversity of species and functions might be important in agricultural landscapes (Vandermeer et al. 1998):

1. Biodiversity might enhance ecosystem function because different species or genotypes perform slightly different functions (have different niches).
2. Biodiversity might be neutral or negative in that there are many more species than there are functions and thus redundancy is built into the system.
3. Biodiversity might enhance ecosystem function because those components that appear redundant at one point in time become important when some environmental change occurs.

More and more evidence is emerging that the third possibility is most often the reality. Maintaining a diversity of functional types is thought to confer resilience on ecosystems. Resilience is a complicated issue but put simply is the ability of a system to cope with change (Resilience Alliance 2007). Resilience often comes from the presence of rare species that can take on critical functions when conditions previously favouring dominant species change. In other words, maintaining a mix of species that respond differently to different environmental perturbations maintains management options (Hooper et al. 2005). For the below-ground community, for instance, there is evidence that the same enzymatic function is carried out by different species of bacteria or fungi from the same soil under different, and even fluctuating, conditions of moisture stress or pH (Griffin 1972).

In the case of plants, different species may play a similar functional role in different seasons, under varying conditions of climatic or edaphic stress and in different stages of patch-level succession (Swift et al. 2004). In savanna rangeland communities in Australia minor species that were functionally similar in trait space (redundant) to the dominant herbaceous species responsible for the majority of ecosystem functions (carbon storage, nitrogen cycling, etc.) were also more resistant to grazing, becoming superior competitors under conditions of high grazing (Walker et al. 1999).

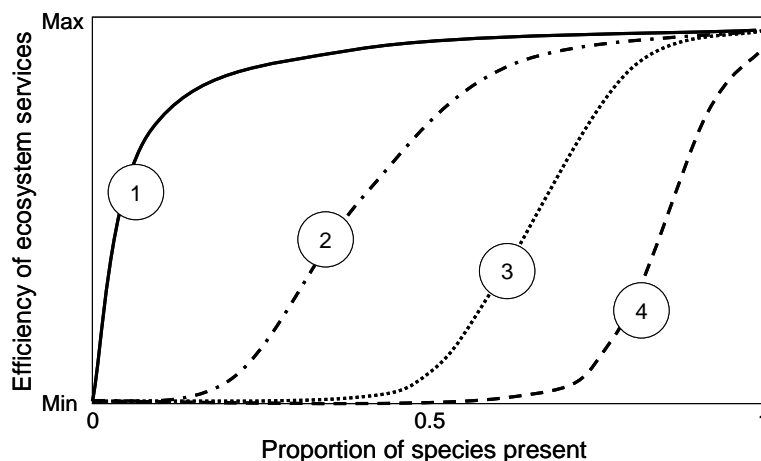
These and other arguments and research findings argue that protecting as much biodiversity as possible is a wise strategy for managing risks associated with medium- and long-term climate and other environmental change and for keeping future management options open. Because lost diversity is difficult or impossible to reconstruct, it would be unwise to sacrifice it simply because of uncertainty about the extent and mechanisms by which it affects ecosystem properties and services (Hooper et al. 2005).

### **D.4 How do ecosystems assemble and disassemble?**

The number and types of species in an ecosystem are the result of dynamic interactions among many factors, including competition for resources among species,

synergies among species, the history of which species arrived first and when other species arrived, local extinctions or adaptation of roles (e.g. competitors, predators, pests or diseases) by new or existing species to changed species composition and/or abiotic environmental conditions and influence of random events (Hubbell 2001; Swift et al. 2004). Attempts to assemble combinations of the same number of species under slightly different conditions, and in particular without the history of interaction, often fail (Ewel 1986, 1999; Swift et al. 2004).

In agroecosystems farmers become part of this dynamic interplay by the selection of which organisms are present, by modifying the abiotic environment and by interventions aimed at regulating the populations of specific organisms. In addition to the biodiversity that farmers manipulate in a planned way, there is *associated biodiversity* (Swift et al. 2004). Some species leave and some move into the agricultural system as a result of the planned changes. Some species support the agricultural endeavours (e.g. soil organisms that take over essential nutrient cycling functions) while some do not (e.g. pests, weeds and diseases). Conversion to agriculture almost always results in fewer species and fewer functional groups (Swift et al. 2004), making it important to consider managing diversity at larger scales than the farm to ensure that sources of functional groups exist to colonise the farms and to continue providing broader ecosystem services as conditions change in the future.



**Figure 24**  
Some possible relationships between loss of species and loss of ecosystem services

Research from Dobson et al. (2006) suggests that the progression through Curves 1 to 4 reflects what happens when species successively higher in the food chain decline (that is, Curves 1, 2, 3, and 4 reflect decline in decomposer species, plants, herbivores, and predators respectively).

Decline in biodiversity with intensification of land management could follow various paths. Until recently, speculation about the implications of these paths for ecosystem services was limited. A few recent publications have summarised the evidence about decline (disassembly) of ecosystems and concluded that this is rarely, if ever, a random process (e.g. Swift et al. 2004; Dobson et al. 2006) – in other words, some species groups and functions are more likely than others to decline first. Using this

knowledge, it is possible to speculate about different rates of loss of different ecosystem services (Figure 24).

The scientific community has come to a broad consensus on many aspects of the relationship between biodiversity and ecosystem functioning, including many points relevant to management of ecosystems (Hooper et al. 2005). Detailed management prescriptions and monitoring are not possible for all ecosystem services, and there are complications because ecosystem processes and services overlap and interact with one another. Understanding is, however, adequate for broad management objectives to be set within a framework relating ecosystem function to human needs and for progress against those objectives to be assessed.

### **D.5 How much biodiversity is enough?**

For over 50 years ecologists have pondered the question ‘Why are there so many species?’ Allied to this question is the one occupying the minds of policy makers and land managers worldwide, i.e. ‘How much biodiversity is enough?’ An implication from current understanding of the relationship between biodiversity and ecosystem function is that it is not possible to define a level of biodiversity that is ideal for all ecosystems or all purposes. Optimal levels will depend on the ecosystem functions required for specific purposes and needs, what functions are present at a site and in a landscape, the degree of overlap in functions between species, the degree of change possible, the resilience of the ecosystems and the preferences of people who derive value from the ecosystem (Swift et al. 2004).

Some generalisations have, however, been offered in the literature. There is substantial experimental evidence that many key functions can be maintained by only small numbers of species within a particular functional group in an artificial and space-restricted ecosystem. For example, single-species plantings of perennial plants can be as effective as a diverse plant community in controlling erosion. In a laboratory, decomposition of organic matter can be achieved by a single species of fungus yet across a landscape there might be thousands of species of fungi, bacteria or invertebrates, with different species playing a role in nutrient distribution and decomposition functions at different places and in different environments (Swift 1976; Giller et al. 1997; Swift et al. 2004).

The role of replicate species in providing resilience over time has been discussed previously. The same argument leads to the hypothesis that the diversity of functional groups and diversity of species within functional groups need to be higher in nature than in laboratories and higher at landscape scales than at plot and farm scales because of greater variation in abiotic environments and biotic and abiotic perturbations (Swift et al. 2004). Resilience also depends on the degree of connectivity between and among the elements of ecosystems and landscapes (Holling 1973, 1986; Allen & Starr 1982; Resilience Alliance 2007). It follows that diversity of land uses within a landscape is likely to be an important strategy for maintaining resilience of both ecosystem services and human welfare in the medium and long terms (Swift et al. 2004).

## D.6 Identifying ecosystem service providers and their efficiencies

As a way to advance thinking about the relationships between biodiversity and ecosystem services, some researchers have attempted to characterise ecosystem services by the component populations, species, functional groups (guilds), food webs or habitat types that collectively produce them. These have been termed ‘ecosystem service providers’ (Kremen 2005) or ‘service providing units’ (Luck et al. 2003). Ecosystem service providers are defined at different levels within ecological hierarchies depending on the type of service being provided, and the geographic scale over which it operates (Table 19). For example, maintenance of resistance to pests, weeds and diseases in crops is a service provided at the scale of genes and operates at local scales (Luck et al. 2003). On the other hand, biological control of crop pests operates at the population and/or food web level at landscape scales (Wilby & Thomas 2002) and regulation of water flow by vegetation occurs over landscape and larger (e.g. regional) scales (Guo et al. 2000).

A few studies have applied this reasoning to perform functional inventories of ecosystems. These studies have identified the component ecosystem service providers and measured or estimated the contribution of each in terms of its abundance and the efficiency with which it performs the service (Balvanera et al. 2005; Table 20).

Functional inventories have been performed for ecosystem services such as pollination, bioturbation, dung burial, water flow regulation, carbon sequestration, leaf decomposition and disease dilution (see Table 20 for citations). Examples of the units in which functional efficiencies are measured include pollen grains deposited per bee and dung burial rates by dung beetles (Larsen et al. 2005). Both efficiencies and abundances are functions of the biotic and abiotic environments (e.g. resources, predators, competitors, mutualists, climate and other physical or biophysical characteristics).

According to Kremen (2005), functional inventories provide a range of insights into ecosystem function that can form the basis for prioritisation of research, policy and management. For example:

- Particularly influential ecosystem service providers can be identified by ranking ecosystem service providers in terms of their contribution in relation to abundance.
- The functional structure of an ecosystem can be explored by ranking species by their functional importance and investigating how equal or unequal the contributions of different ecosystem service providers are
- Species traits such as body size, dispersal distance, and response to disturbance can be correlated with functional efficiency to characterise the suite of response and effect traits that a community exhibits and predict its resilience to disturbance (Walker et al. 1999; Elmquist et al. 2003; Larsen et al. 2005).
- Using functional importance values, predictions can be made about how delivery of ecosystem services might change as the composition of ecosystem service providers changes over space or time, along disturbance gradients, or with different management regimes.

It is important to understand how ecosystem function changes as species are lost (Schwartz et al. 2000; Loreau et al. 2001). This understanding would provide warning of which functional groups and which ecosystem services might decline first under disturbances or stresses (Kremen 2005). For example, if functionally important species or guilds are lost early then there will be more rapid loss of ecosystem function than if less important groups are lost first. At present we can only say that the relationship between ecosystem function and species richness could follow a range of relationships (Larsen et al. 2005).

**Table 19**

**Ecosystem services, classified according to the Millennium Ecosystem Assessment (MA 2003), and their ecosystem service providers**

'Functional units' refers to the unit of study for assessing functional contributions of ecosystem service providers; spatial scale indicates the scale(s) of operation of the service. The author's (Kremen 2005) assessment of the potential to apply this conceptual framework to the service is purposefully conservative and is based on the degree to which the contributions of individual species or communities can currently be quantified

<b>Service</b>	<b>Ecosystem service providers/trophic level</b>	<b>Functional units</b>	<b>Spatial scale</b>	<b>Potential to apply this conceptual framework for ecological study</b>
Aesthetic, cultural	All biodiversity	Populations, species, communities, ecosystems	Local–global	Low
Ecosystem goods	Diverse species	Populations, species, communities, ecosystems	Local–global	Medium
UV protection	Biogeochemical cycles, micro-organisms, plants	Biogeochemical cycles, functional groups	Global	Low
Purification of air	Micro-organisms, plants	Biogeochemical cycles, populations, species, functional groups	Regional–global	Medium (plants)
Flood mitigation	Vegetation	Communities, habitats	Local–regional	Medium
Drought mitigation	Vegetation	Communities, habitats	Local–regional	Medium
Climate stability	Vegetation	Communities, habitats	Local–global	Medium
Pollination	Insects, birds, mammals	Populations, species, functional groups	Local	High
Pest control	Invertebrate parasitoids and predators and vertebrate predators	Populations, species, functional groups	Local	High
Purification of water	Vegetation, soil micro-organisms, aquatic micro-organisms, aquatic invertebrates	Populations, species, functional groups, communities, habitats	Local–regional	Medium to high
Detoxification and decomposition of wastes	Leaf litter and soil invertebrates; soil micro-organisms; aquatic micro-	Populations, species, functional groups, communities, habitats	Local–regional	Medium

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Soil generation and soil fertility	organisms Leaf litter and soil invertebrates; soil micro-organisms; nitrogen-fixing plants; plant and animal production of waste products	Populations, species, functional groups	Local	Medium
Seed dispersal	Ants, birds, mammals	Populations, species, functional groups	Local	High

**Table 20**  
**Examples of efficiency measures for different ecosystem services from the literature**

From Kremen (2005), where citations for each example are provided. Services are classified as regulating or supporting according to the Millennium Ecosystem Assessment (MA 2003)

Service classification	Service	Ecosystem service provider	Efficiency measure(s)
Regulating	Carbon storage	Tree species	Biomass accumulation rate
Regulating	Crop pollination	Bee species or community	Pollen deposition per visit; seed or fruit set with and without bees
Regulating	Crop pollination	Bee species	Ratio of pollen deposition to removal
Regulating	Disease control	Vertebrate host species	Disease dilution rate
Regulating	Leaf litter decomposition in streams	Stream invertebrate species	Leaf-shredding process rate
Regulating	Pest control	Insect parasitoid species	Parasitism rate
Regulating	Dung burial	Dung beetle species	Burial rate
Regulating	Water flow regulation	Forest habitats	Water flow rate
Regulating	Invasion resistance	Herbaceous community (native plus naturalised species)	Invader biomass m <sup>-2</sup> ; change in resident biomass/unit invader
Supporting	Bioturbation	Benthic marine invertebrate species	Bioturbation potential index
Supporting	Nutrient mineralization cycling,	Soil microbial community/ functional groups	Process rates
Supporting	Above-ground primary productivity net	Herbaceous community	Biomass accumulation rate
Supporting	Mineralization and decomposition	Herbaceous community	N leaching or retention; decomposition rate; microbial biomass, etc.

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## Appendix F: Acronyms

CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFF	Australian Government Department of Agriculture, Fisheries and Forestry
DEWHA	Australian Government Department of the Environment, Water, Heritage and the Arts (formerly Department of the Environment and Water Resources)
DSE	Victorian Government Department of Sustainability and Environment
EEA	European Environment Agency
ESD	Ecologically sustainable development
GUMBO	Global unified metamodel of the biosphere, anthroposphere and ecosystem services
MA	Millennium Ecosystem Assessment
NRM	Natural resource management
NRMMC	Natural Resource Management Ministerial Council
NRPPC	Natural Resource Policies and Programs Committee
NSESD	National Strategy for Ecologically Sustainable Development
OECD	Organisation for Economic Co-operation and Development
SEEA	United Nations System of Integrated Environmental and Economic Accounting
WTO	World Trade Organization