ECOSYSTEM SERVICES PROJECT

NATURAL VALUES

Exploring Options for Enhancing Ecosystem Services in the Goulburn Broken Catchment

PEOPLE ▸ ENVIRONMENTS ▸ VALUES ▸ OPPORTUNITIES

In the Goulburn Broken Catchment, the Ecosystem Services Project is a collaborative effort by the following organisations:

THE MYER FOUNDATION

The Sidney Myer Centenary Celebration 1899-1999

CSIRO

GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY

Land & Water AUSTRALIA

research • development • innovation

Natural Values: Exploring options for enhancing ecosystem services in the Goulburn Broken Catchment was edited and compiled by:

CSIRO Sustainable Ecosystems
Nick Abel
Steven Cork
Russell Gorddard
Jenny Langridge
Art Langston
Roel Plant
Wendy Proctor
Paul Ryan
Dave Shelton
Brian Walker
Mandy Yialeloglou

For further information please contact
Nick Abel, Project Leader
CSIRO Sustainable Ecosystems
Ph: (02) 6242 1534 Fax: (02) 6242 1705
Email: Nick.Abel@csiro.au
www.ecosystemservicesproject.org

ISBN: 0 9580845 7 2

Page design and typesetting: Adworks
Cover design: RTM Design, Canberra
Final artwork: Starkis Design

Photographs:
Goulburn Broken Catchment Management Authority
CSIRO Sustainable Ecosystems
CSIRO Land and Water

QUICK REFERENCE GUIDE

FOREWORD from the Governor of Victoria

Natural Values: Exploring Options for Enhancing Ecosystem Services in the Goulburn Broken Catchment is the culmination of four years work and the first of its kind in Australia. It began with a vision; to reconnect Australians with the environment that surrounds them and supports their life choices. In essence to change the way people view the environment, not as a resource to be taken for granted but one to be valued for the free services it provides and one worth investing in. Whilst it was always an ambitious goal the project has made tremendous progress in promoting the concept and contributing to the science.

The Myer Foundation, as part of the Sidney Myer Centenary Celebration, acted as a catalyst to initiate the project, strengthening the growing role of philanthropic organisations in promoting science not ordinarily funded through traditional sources. This association has proved very successful and facilitated the brokerage of further funding from Land and Water Australia for the case studies conducted in the Goulburn Broken Catchment and presented in this report, along with several sister projects.

The Goulburn Broken Catchment Management Authority (GBCMA) was quick to recognise the benefits that the ecosystem services approach could provide its members and the community as a whole. Already in the process of drafting their Catchment Management plan, they formed a strong and lasting relationship with the research team. This partnership between scientist and client, each learning from the other, brought out possibilities not before considered, guided the research effort and provided the GBCMA with a framework to achieve resource management targets. Their enthusiasm and dedication to the project has been invaluable, without their input this exceptional piece of science would not have been possible.

Natural Values builds on the outcomes of the inventory report *Natural Assets: An Inventory of Ecosystem Goods and Services in the Goulburn Broken Catchment*, which I was pleased to launch in Shepparton in 2001. This publication, the first product from the project, identified key industries that would benefit from the preservation and investment in nature's services, laying the foundations for much of the following work.

This second report presents the findings, recommendations and achievements of The Ecosystem Services Project in the Goulburn Broken Catchment. It documents theories and methods for assessing a variety of values attributable to ecosystem services under likely scenarios of catchment management in the Goulburn Broken. It discusses the implications of the results and methods in terms of catchment management, policy formulation and application of research.

Anyone involved in resource management or in the policies that guide the use of our natural capital should read and consider the recommendations of this report.

John Landy, AC, MBE
Governor of Victoria

FOREWORD
from our collaborators in the Goulburn Broken Catchment

The Ecosystem Services project has had an immense impact on the Goulburn Broken CMA and its partners, including the catchment community. It has opened our minds to new concepts and helped our thinking on the best ways to protect and enhance the Catchment's valuable natural assets and the services they provide.

The concept of Ecosystem Services has become an integral part of what we do at both the strategic level, (evident in the recent renewal of our Regional Catchment Strategy) and also at the operational level.

Indeed, our vision is very clear about the importance placed on Ecosystem Services in the Goulburn Broken catchment: "…The environmental footprint of irrigation and dryland farming will be significantly reduced, with farmers occupying less land and using less water whilst managing their water more sustainably. New opportunities will arise for increasing ecosystem services provided by the land retired from agriculture and by improved environmental flows".

The project has involved a wide range of stakeholders in the Catchment. The many workshops and events that informed the project provided an opportunity for people to exercise their minds, think about new concepts and look positively to the future.

The case studies have been useful in developing tools to aid decision-making. They have also helped demonstrate the range of values provided by floodplains and highlighted the range of benefits offered by landscape planning.

CSIRO has taken a brave step in the right direction with its willingness to start interpreting and presenting best available science in a form that will aid decision/policy making. It is part of a promising trend that is seeing researchers building closer links with the people involved in environmental management in a hands on way.

I hope you will take the time to read this report that is a wonderful addition to the thinking, planning and implementation of natural resource management policy in the catchment.

Bill O'Kane
CEO
Goulburn Broken Catchment Management Authority

FOREWORD from the Chair of the Management Advisory Board

This report marks the end of the first phase in a program to understand and promulgate the nature and importance of ecosystem services in Australia. It had a rocky start, being considered initially by the relevant research agencies as too vague or too risky. Only after substantial support from the Myer Foundation did it get going and from there it has never looked back.

At the very first meeting of the Management Board the importance of communication was emphasized and a significant proportion of the budget was chanelled into this. It has been a difficult task, balancing the allocation of limited funds between a very big demand for basic research and the need to educate resource managers, bureacrats, politicans, scientists and the public. I think the whole team has reason to feel satisfied that they have done an excellent job. The notion of ecosystem services has risen markedly on the agendas of many agencies. It has become known in the media, and has taken hold.

The research team wishes that it could have done more field work, but in my view they have provided a solid base given the resources they had, and this report lays the foundation for continued work. It is my hope that the next phase will not be just another 3 or 5 year funded project but, rather, an on-going national program with many such projects. A new initiative in markets for ecosystem services is underway. The challenge is to establish a way to maintain co-ordination between all the new projects that will emerge, so as to derive the benefits from the synergies that will flow from a collaborative program.

I commend this report to all those interested in achieving sustainable development in natural resource use. I thank my fellow Board members for their guidance and support for the project, and I congratulate the research team on a fine product.

Brian Walker
Chair
Management Board of the Ecosystem Services Project

CONTENTS

ACKNOWLEDGEMENTS

The project was funded by The Myer Foundation at a time when the ecosystem services concept was new to Australia and could not attract support from other major sources. The belief of Lindy Hayward, Charles Lane and others in The Myer Foundation in the importance of the concept has been borne out by the major emphasis now placed on ecosystem services in environmental and natural resource management policies. Land and Water Australia were also early supporters and funders and we thank Andrew Campbell, Chief Executive Officer, for the involvement of himself and his organisation throughout the project, including his valuable service on the Management Advisory Board. This project was conceived by Brian Walker, who subsequently became the chair of our Management Advisory Board. We thank him for his many contributions during the project, including authorship of one of the sections in this report. We thank the other board members: Michael Baevski, Samantha Bailleau, Andrew Cambell, Marc Carter, Rhonda Dickson, Lindy Hayward, Stephen Hunter, Phil Price, Peter Thomas and Bernie Wonder.

The work reported here is the result of a partnership between the Goulburn Broken Catchment Management Authority and CSIRO Sustainable Ecosystems. Bill O'Kane, Chief Executive Officer, John Dainton, Chair, his successor Steve Mills and Kate Bell, Biodiversity Manager have worked closely with us throughout the project and we thank them for their advice and insights. Our Steering Committee, chaired by Dianne McPherson with Terry Bailey, Neil Byron, Rob Floyd, Charles Lane, Pat O'Connor, Bill O'Kane, Kevin Ritchie and Mike Young, has provided valuable feedback during the project and on our final report. Kate Bell, Steve Hatfield Dodds, Allen Kearns, Denis Saunders and Mike Young are among those who reviewed our final report and suggested many changes that improved the document substantially.

We thank Carl Binning who was a key member of the research team until his secondment to Greening Australia in 2001, and lead author of our first publication (Natural Assets).

Some of the many individuals who have contributed to this work include:

Jason Alexandra, Dan Armstrong, John Avard, Terry Bailey, Roger Barlow, Sue Berwick, Rachel Cairns, Steve Clark, Anthony Cole, Mark Cotter, Hamish Cresswell, Barry Croke, Jim Crosthwaite, Mike Dalmau, Tom Davison, Ron DeRose, Liz Dobson, Josh Dorrough, Peter Doyle, Martin Dreschler, Pat Feehan, John Gallant, Brian Garrett, Alan Gale, Don Gaydon, Phil Gibbons, Barry Hinchcliffe, Peter Howarth, Angus Howell, Marion Howell, Maurice Incerti, Ian Johnson, Gail Kelly, Kevin Linton, Kim Lowe, Howie Marshall, Scott McDonald, Craig McKenzie, Dan McKenzie, Lisa McKenzie, Gerard McKew, Rod McLennan, Olive Montecillo, Geoff Mundy, Graeme Newell, Barry Oswell, Shane Papworth, David Parkes, Zahra Paydar, Ron Pearce, Russell Pell, Earl Phillips, Derek Poulton, Julia Reed, Nick Reid, Doug Robinson, Ken Sampson, Justin Sheed, Tish Silberbauer, John Steel, Phil Stevenson, Kate Stothers, Wayne Tennant, David Thompson; Guy Tierney; Jim Walcott, Keith Ward; Russell Wealands, Bruce Wehner, Jenny Wilson and Paul Wilson.

Our deepest thanks to all.

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

This report summarises results of the first ecosystem services project undertaken in Australia. The project has sought to introduce a new way of thinking about the relationship between people and the environment they depend on.

Ecosystem Services are "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life" (Daily 1997). They include: inputs to production; regeneration of ecosystems; stabilisation of soils, climates and weather; assimilation of wastes; amenity; and options for the future. Although sustainable human well-being depends on ecosystems, humans degrade them. The ecosystem services concept confronts this paradox.

Origin, aims and scope of this research

In 1998 a proposal for research on ecosystem services was judged by various agencies and the CSIRO to be too risky, too ill-defined or too unscientific to justify investment. The Myer Foundation decided that the concept could be important for Australia and deserved testing. Their support gave credibility to the research, and two projects were developed. "The Nature and Value of Australian Ecosystem Services", was a research and communication network funded jointly with CSIRO. The other, "Assessing Ecosystem Services in the Goulburn Broken Catchment" applied the ecosystem services concept in the Goulburn Broken catchment of Victoria. The Myer Foundation, CSIRO, the Goulburn Broken Catchment Management Authority and Land and Water Australia supported it. This report focuses on the Goulburn Broken work, but because the staff and communication activities of the projects over-lapped, we also report on the outcomes of the research and communication network project. This has arguably had a key

role in changing the way Australian policy makers, researchers and communities think about natural resource management.

The aims of the Goulburn Broken project were to:

- estimate the benefits of ecosystem services at a range of spatial and temporal scales as a way to help policy makers, planners and land and water managers take account of the inter-relationships among a range of ecological, economic and social values;
- work with policy makers, planners, land managers, industry and community groups to raise awareness of the values of maintaining ecosystem function;
- recommend policies and practices that maintain these values; and
- communicate project results widely.

Implicit aims were to evaluate the concept, and to develop and test methods.

The main elements of our approach to assessing ecosystem services were: the engagement of stakeholders in participative research; an inventory process to focus on sets of ecosystem services and select case studies across a range of scales; the development of scenarios; and analytical methods and models for assessing ecosystem services. The research was based on five case studies within the Goulburn Broken Catchment.

Economy and land use in the Goulburn Broken Catchment

The Goulburn Broken catchment covers 2.4 million hectares. It extends from the mountains of the Great Dividing Range, to the riverine plains of the Goulburn and Broken Rivers. The combined mean annual flow of its rivers is approximately 3,300 giga-litres, of which about half is extracted for irrigation and urban consumption. Extensive clearing of native vegetation has resulted in salinisation and deteriorating water quality and soil health. Land use is dominated by agriculture, with dryland agriculture covering more than 1,300,000 hectares and intensive irrigated agriculture, particularly for dairy and horticulture, accounting for approximately 300,000 hectares. Tourism and recreation are emerging as an important land uses. The human population of the catchment is currently 190,000 and increasing. Commodities from the catchment form a significant proportion of the agricultural exports from Victoria. Total gross dollar value of production from the catchment in 2001 was $ 8,709 M, and is predicted to grow. Like all regional communities, the Goulburn Broken faces numerous challenges in balancing the need to maintain economically and socially viable rural communities while simultaneously meeting the expectations of the wider community to manage natural resources sustainably and with minimal down stream impacts.

Development and the depletion of natural capital

Development is the improvement of economic, social, cultural and environmental well-being of people (Coombs 2001). To achieve it, economic and social capitals are applied to extract value from natural capital. Economic capital is the physical means of production and distribution. Social capital includes knowledge and skills, plus the social arrangements for production and distribution, and for monitoring, taxing, regulating, encouraging and punishing individuals. Natural capital is embodied in ecosystems, and it supplies numerous goods, such as timber, as well as ecosystem services. Natural capital can be self-sustaining, but can also be irreversibly damaged. Although many of the ecosystem services it provides are not substitutable with technological alternatives, as economic and social capitals have grown in the Goulburn Broken catchment, natural capital has been allowed to decline to levels where the benefits of development are less than they could be, and future well-being is threatened.

The production and valuation of ecosystem services

Valuation of ecosystem services is necessary if markets and institutions are to be established to promote the sustainable and efficient use of ecosystem services. One of the key assumptions of economic valuation is that consumers and producers have perfect knowledge about what they are paying for. However, this knowledge is not available for many important ecosystem services or the processes that underpin them. Given the complexity of the ecosystem processes and our general ignorance about them, our priority in this project was the biophysical basis of value, not the estimation of dollar values. In the

language of economics, we built "production functions" for ecosystem services. A production function is the quantitative relationship among a set of physical inputs, human knowledge, skills and labour, technology and the physical quantity of an output. This is fundamental to estimating value, and to understanding the degree to which other forms of capital can replace natural capital.

Communication and participative research

A network of policy makers and researchers was established by "The Nature and Value of Australian Ecosystem Services" project. It includes scientists working on ecosystem services in rangelands, rainforest and irrigated cotton. Our participative research approach in the Goulburn Broken Catchment was designed to link local and scientific knowledge, and channel research towards priorities in the catchment through an inventory process and subsequent workshops based on the five case studies.

Which services matter

Studying every ecosystem service is impossible so we used a participatory inventory process to select services important to the catchment community. Working with stakeholders we identified the main products from the catchment that people value. The ecosystem services supporting their production were also identified and ranked in terms of the revenue the products earn, the impact on production of a small change in the service, and the capacity of the industry producing the product to ensure the sustainability of the service. Five case studies focusing on selected services were chosen. The services considered in the case studies are: life-fulfilment; regulation of climate; maintenance and regeneration of habitat; provision of shade and shelter; maintenance of soil health; maintaining healthy waterways; water filtration and erosion control; and regulation of river flows and groundwater levels.

The case studies

The five case studies were selected to represent a range of spatial scales and ecological processes. Our study of a dairy enterprise is based on a non-spatial dynamic model. Our landscape study is an assessment of ecosystem services on a floodplain. It is based on a dynamic model that includes spatial variation. The next case study is an analysis of ecosystem services in a dryland sub-catchment. It is based on a spatial analysis of native vegetation patterns 'grown' in a geographical information system according to rules drawn from conservation policy. We evaluated the effects of these patterns on a range of important ecosystem services. Our study of tourism and recreation is at a sub-regional scale. It used a stakeholder process, expert knowledge and multi-criteria evaluation, and tracked changes in participants' understanding of ecosystem services. At the scale of the whole Goulburn Broken Catchment we used input-output modelling to relate water inputs to employment levels, and the outputs of dollar 'values' and nutrients. Details of each case study are in Sections 7 to 11. Achievements, findings, recommendations and future work arising from this project are summarised in the next two sections.

Achievments, findings and recommendations

The ecosystem services concept is now in the vocabulary of agencies, land managers and politicians

Our communication has been highly effective. The ecosystem service concept has entered the vocabulary of agencies, land managers and politicians and is being used in plans and policies at local, state and federal levels. The term appears in major state and Commonwealth environmental policy and discussion papers. The Bureau of Rural Sciences is establishing an ecosystem services unit to assess services at national scale. The New South Wales Environmental Services Scheme is operating at 27 sites across the State. A new $5 million 'Market-based Instruments' initiative has been launched by the Federal government to test a variety of mechanisms for sustainable use of ecosystem services. Ten pilot projects are located in Queensland, New South Wales, Victoria, South Australia and Western Australia. At least ten other ecosystem services projects have been proposed or have started. We cannot claim these would not have happened without our project, but we are confident our communication activities have helped create a policy, funding and intellectual environment in which ecosystem services projects are treated much more favourably than they would have been in 1998. Ecosystem services is a central theme in the Goulburn Broken Regional Catchment Strategy, agencies are introducing the concept to landholders, and it is used by other Catchment Management Authorities/ Boards.

We have built a national and international research network

We have built links with ecosystem services researchers in Australia, New Zealand, the US, Germany, Switzerland and South Africa, held scientific workshops, hosted two Ecosystem Services symposia, and developed links with other CSIRO divisions and a range of agencies and consulting firms. We have given conference papers or attended workshops on every continent except Antarctica. Almost 1500 copies of *Natural Assets: An Inventory of Ecosystem Goods and Services in the Goulburn Broken Catchment* (Binning and others 2001) have been distributed.

The ecosystem services website is spreading awareness of ecosystem services among the broader community

Our research network and communication strategy has promoted the sharing of knowledge about the value of Australian environments among researchers and other members of society through newsletters, leaflets, papers and presentations to state and Commonwealth natural resource management agencies, at public meetings in catchments, and at conferences. The new project website (http://www.ecosystemservicesproject.org/) is a major avenue for communication, and an electronic newsletter is distributed by email.

The ecosystem services concept provides a framework for integrating research across disciplines and among policy makers, stakeholders and researchers

The ecosystem services concept enables local and scientific knowledge to interact to their mutual enhancement. In addition to this exchange of ideas, local knowledge guides researchers towards work that has practical use. The concept also brings disciplines together under a common theme to facilitate better interaction among scientists.

Participatory research enhances the sharing of ideas and knowledge about ecosystem services

Participatory research enabled researchers to identify key issues that policy makers and land managers face, and to adapt the concept of ecosystem services to these issues. Through participation, the concept has become known in the major organisations in the Goulburn Broken catchment and regional environmental and primary industries agencies. These agencies have further adapted the concept for their purposes.

A participative process guides the direction and scope of the research and enhances learning

Scientific and local knowledge were exchanged, modified and combined through participatory research. The direction and scope of the project were guided through this exchange. The deliberative process used in the tourism and recreation case study is a model for further participative research.

Understanding about, and willingness to act on, the values of ecosystems appears to be increasing among land managers and policy makers

While the concept of ecosystem services is useful in increasing understanding of environmental issues and channelling dialogue towards solutions, it is only one progressive force among many. People and organisations in the Goulburn Broken catchment have a long history of re-conceptualising environmental challenges in ways that involve the public in solutions, and our project rode, to some extent, on the back of those earlier initiatives. Ecosystem Service projects currently running in other catchments will provide a comparison of the approach in catchments where the community is less proactive.

Generating stakeholder enthusiasm to value ecosystem services needs to be balanced against the capacity of researchers to estimate those values

Our communication effort, which raised enthusiasm among a range of partners and researchers, moved faster than our research effort, and some unrealistic expectations were raised. We have learned the importance of managing expectations among stakeholders and researchers, and how to do it. For example limiting the research to the five component case studies, has proven to be both feasible and useful.

It will take much more than changes in attitudes to achieve sustainability

There is an expectation of the ecosystem services concept that it will lead to national and regional sustainability through changes in attitudes. It is not so easy. Reversing ecosystem degradation will require changes in the distributions of benefits and costs within and across generations. We expect the concept of ecosystem services to play an informing role in this process, helping stakeholders to understand their relationships with nature, but to achieve sustainability people must also change their relationships with each other through institutional reforms, and deliver their obligations to future generations.

Research partnerships need trust

Project partners began to build mutual trust from the beginning of the project. We began with a workshop in which expectations of all parties were explored and documented. It was reinforced by a Relationship Agreement and by equal representation and shared authority on the project Steering Committee. During the project there were changes in key staff in the research team and CMA. There were also major changes in political

and financial pressures for all partners. It is a particularly important aspect of this project that these pressures did not undermine trust in the relationship and that all partners remained committed.

Ecosystem services need to be carefully defined

Ecosystem services were defined by stakeholders during our participative process to ensure the relevance of the services to their goals, and to ensure the services are communicated in a way that is understood by the community. However, multiple stakeholders reinterpret the intended meanings, so original definitions can come to mean different things. A description of the service and its context and purpose is needed to ensure the original meaning is retained and conveyed to researchers and others.

There is a range of ways to express ecological, economic and social values

This report focussed on the production and roles of ecosystem services, rather than users' perceptions of their values, so it was appropriate to represent ecological, economic and social values using different units, rather than lose information by expressing them as a single unit. The dryland catchment study used biophysical units. In the dairy and floodplain studies we brought ecosystem services and outputs such as soil and nutrient losses expressed in biophysical units together with gross margins in dollars. The evaluation of recreation and tourism in the upper Goulburn Broken Catchment showed how a deliberative process linked with multi-criteria evaluation can be used to quantitatively integrate values expressed in different terms and units. In the whole-of-catchment input-output analysis our units were numbers of people employed as a measure of social value, mega-litres of water as a measure of the ecosystem service input, sector outputs in dollars and tonnes of nitrogen and phosphorus as negative impacts on ecosystems.

The dairy case study illustrates the dependence of high intensity enterprises on ecosystem services provided from a broader scale

The dairy case study has identified the need for better understanding of the contributions of soil organisms and native predators to pasture production. It reinforced the need for more effective ways of capturing and recycling nutrients because of their negative impacts on other ecosystem services. It also showed the relatively low priority of on-farm ecosystem services. At a broader scale dairy farms could not continue to function if the external ecosystem services fail. The dairy industry is a source of much of the region's income so there is a strong economic argument for investing in natural capital at the broader scale.

The inclusion of ecosystem services may increase the net social benefit of changing management regimes

Ecosystem services not included in the floodplain benefit-cost analysis may represent a significant increase in the net social benefit of the proposed change in flood management. Our sub-catchment case study illustrates a related point — the ecosystem services provided by the sub-catchment under a different vegetation cover may be more valuable to the whole catchment than the value of the current agricultural outputs. This points to the potential of markets or other incentives through which land holders produce ecosystem services that support the functioning of the Goulburn Broken catchment as a whole.

Enhancement or maintenance of ecosystem services requires a priority setting process

The 'Inventory' approach to setting research priorities was appropriate for a participatory research project in which local knowledge and values guided priorities and played a central role in setting the research agenda. An extension to the Inventory approach is one based on functional roles of ecosystem services, and the biophysical processes that underpin them.

A hierarchical framework of interactions between services helps setting priorities

Ecosystem services can be grouped within an hierarchical framework according to their functional relationships and relative influences. The grouping enables services to be prioritised for research or management. Our implementation of this prioritisation framework applies to this catchment only, but the method can be generalised.

Scenarios enabled structured comparisons of options

To explore potential changes in ecosystem service outputs in a structured way we established scenarios in consultation with stakeholders. With the exception of the dairy enterprise, in each case study one scenario reflected current conditions as a baseline to compare with other scenarios. The other scenarios were chosen to represent desirable or undesirable alternatives, or alternatives reflecting different stakeholder groups or policies. The output of ecosystem services was then evaluated by comparing scenarios. We adapted this general approach to suit the context of each case study, but in each case stakeholder's participation ensured our scenarios were related to the priorities of managers, the Catchment Management Authority or state policy.

Interactions among variables in our case studies meant that responses of services to changes in land use or management were often unpredictable. The scenario approach enabled us to explore uncertainties as well as beneficial and unwanted thresholds. These have major implications for policy and implementation.

Better production functions are needed to evaluate the benefits and costs of changes in ecosystem services

A production function is the quantitative relationship among a set of physical inputs, human knowledge, skills and labour, technology and the physical quantity of an output. An ideal production function for ecosystem services should be able to model variation in time and space. These and other ideal criteria are discussed below. In practice simplification is necessary, and we adapted a variety of approaches to build production functions for the case studies. Evaluation of the dairy and floodplain case studies were based on dynamic simulation models with integrated evaluation of ecosystem service outputs. Dynamic models confer the ability to explore easily the effects of small changes in management and land use, and interactions among services can be captured well, but the capacity to explore spatial relationships is limited. Spatial capability was strong in the dryland sub-catchment case study, but the wide range of services evaluated led us to rely on a set of separate analytical techniques and models for evaluating the services separately. Given this lack of integration, interactions among services could not be evaluated comprehensively. Evaluation in the recreation and tourism case study was by expert knowledge. The ability to estimate changes in ecosystem services over time and space, and interactions among services, depended on the knowledge and human limitations of the experts. Evaluation in the input–output analysis of the Goulburn Broken Catchment was limited to water inputs and nutrient outputs by the simplicity of the model, but water and nutrients were well integrated with the structure and outputs of the economy.

Requirements of ecological-economic production functions

Production functions provide the fundamental link between ecology and economics. Ideal ecological economic production functions would:

- be calibrated against empirical data;
- be validated against independent empirical data or expert knowledge;
- deal with time;
- deal with space;
- incorporate industrial and ecosystem inputs;
- estimate the impact of current production on future production;
- estimate externalities; and
- be able to represent non-linearity.

It will not necessarily be worthwhile to build comprehensive production functions satisfying all these criteria within the one model. In most cases a set of partial analyses may be more cost-effective. The choice of models and analytical methods should be driven by the purpose and context of the analysis, more detail is not always better, and much useful work can be done with simple models and analyses.

Combining citizens' jury and multi-criteria evaluation is a powerful way to capture and develop community values

The Deliberative Multi-criteria Evaluation developed in this study provided a powerful means by which stakeholder values can be captured and complex decision problems broken down into more manageable pieces. The Citizens' Jury process enabled several decision-makers to express their priorities, debate their positions and learn more about the decision problem by calling on expert knowledge. The Jury process combined well with Multi-criteria Evaluation, which allowed for the unravelling of complex decision problems and the identification of trade-offs. The development of an impact matrix through expert input meant that decisions could be made regardless of the availability of formal information.

Complex research projects are likely to miss deadlines

The extensive gaps we found in theory, methods and data coupled with the complexity of the interactions in the systems we studied meant that some delays were experienced in producing the analyses expected by our stakeholders. The breadth of our analyses made us dependent on data generated by models that other researchers were developing, and as their timelines slipped, so did ours. Lacking input data, our floodplain model is still not operational, and is a demonstration of a concept, not proof of it.

Impediments to data sharing provide a significant barrier to understanding complex social-ecological systems

One impediment to data sharing is the absence of a standard data license agreement accepted by Federal and State Governments. Presently data licenses are created by individual organisations and vary in restrictions on data use and ownership of data generated by the user. Another impediment is the move of many Federal and State organisations to claim intellectual property in data sets created by their publicly funded organisation. The resulting data costs to the user in unnecessary and impedes research.

Investment to increase understanding of biophysical processes is a necessary foundation for better management of ecosystem services

Many policy makers and funders believe that most degradational processes are scientifically well understood, and that implementation should proceed without further investment in research. However, the development of incentive or regulatory

schemes, or markets for ecosystem services, even at a pilot level, needs reliable estimates of responses of ecosystem services to changes in vegetation cover or management. Participants, including governments, cannot be expected to commit resources when uncertainty is high. Schemes that proceed and fail through lack of biophysical understanding will discredit approaches that would have worked if knowledge had been sufficient. In our research we found large gaps in knowledge that often left us unable to calibrate and validate models and analyses. Where stakeholders identified a priority ecosystem service that is produced by ecosystem processes that are poorly understood, there is a strong case for investing in basic research. The many knowledge gaps we identified show there is a lot of that to be done. While the priorities will be different in other Australian catchments, the social and environmental returns to investment in research could be high if prioritisation followed the inventory and functional approaches we developed.

New incentives, regulations or markets are needed to protect ecosystem services that are over-exploited or under-managed

Policies should be focused upon ecosystem services that are vulnerable because they have not been captured by private or common property (group) rights, so that benefits and responsibilities are not attributed to an individual or group. These open access services are usually without clear biophysical boundaries, or with boundaries that do not match farm, forestry or conservation area boundaries. New institutional arrangements may promote their sustainable use. These could be regulatory, incentive or market-based. An example is clean water from agricultural sub-catchments provided by the service "water filtration and erosion control". This service is dispersed across the properties in the catchments, and agreements among farmers would be needed in order to realise the benefits of managing the whole catchment to improve water quality. Water users could make payments for the provision of the service. Used in combination with the prioritisation framework outlined earlier, a property rights approach can focus policy and research effort on services that are both functionally important and vulnerable.

The tourism and recreation case study identified particular policy needs for maintaining ecosystem services that support that sector

Through the workshop process the case study highlighted the need for greater research on public access issues, the effects of education on tourists and environmental damage, methods for the recovery of management costs and the role of market and other incentives in limiting environmental damage of recreation and tourism activities.

The sub-catchment case study shows where investment in native vegetation is worthwhile

We drew on State and catchment guidelines for conservation of biodiversity and applied them to the current landscape in a geographical information system (GIS) to drive the pattern of revegetation in the dryland sub-catchment case study. However, investment priorities could be determined for any future time period if the input data are updated to reflect on-ground plantings inside or outside the sub-catchment. Running the GIS to achieve an increase in the target identifies the next set of sites for priority planting. The rules and their weightings can be changed as new information is acquired from the sub-catchment or outside. The approach could also be applied at a broader scale, with different rules and weightings in different zones.

A native vegetation target of 15% produces only small increases in ecosystem services

Modelling of revegetation in Sheep Pen Creek suggests that an increase from the current level of 8% of native vegetation to a 15% target produces only small increases in ecosystem services as indicated by habitat configuration scores, carbon storage, shelter, shade, stream sediment load, sheet and rill erosion control, deep drainage control and control of soil acidity.

The response of ecosystem services to landscape changes may have thresholds that indicate where efficient revegetation targets should be set

Our analysis of Sheep Pen Creek shows thresholds in the relationship between area under native vegetation and the estimated value of native vegetation as habitat for native biota. The thresholds suggest that initial investment to increase the current cover to a 10% target give a good return per hectare revegetated, but the rate of return declines thereafter, increasing again after another threshold is crossed above the 30% target.

Policies aimed at restructuring the regional economy could increase the efficiency of water use without necessarily reducing jobs or gross regional product

The input-output analysis of the economy, water use and nutrient outputs illustrates which sectors could be targeted by regional development policies in order to restructure the economy to achieve more efficient use of water in the generation of dollar outputs or jobs. It can also examine, within the limitations of the data, economic structures that reduce pollution. The approach we developed is an effective way of engaging industry groups and state policy makers in exploring the possibilities of alternative economic structures and ways of achieving them.

Increased understanding of ecosystem function at different scales can improve the cost-effectiveness of investments in natural capital

In the past, vegetation patterns in catchments have been determined by property-scale decisions of farmers. The resulting vegetation patterns are inefficient for regulating salinity or conserving biodiversity, because many of the biophysical processes do not operate at property scale. To achieve efficient salinity control and biodiversity conservation, vegetation patterns and the policies that influence them need to be determined at sub-catchment scale or broader.

The Goulburn Broken Catchment is already pioneering ways of investing in natural capital, and the ecosystem services concept contributes to their strategic investment planning. From our case studies at enterprise, landscape, sub-catchment, regional and whole-of-catchment scales we can estimate the effectiveness of investment in natural capital at each scale, and consider the form of natural capital to invest in (e.g. commercial forestry or native vegetation). However, an investment in natural capital at one scale affects processes at other scales too. Our preliminary quantification of flows of ecosystem services at selected scales can contribute to a plan for strategic investment in natural capital that takes explicit account of scale effects. It enables better prioritisation of resource degradation issues, and replaces arbitrary targets for remediation, such as percentage tree cover, with process-based spatial layouts. The suite of models and analytical approaches we developed illustrates the strategic potential of a cross-scale approach.

Policies and practices for maintaining or enhancing ecosystem services

A set of policies and practices to maintain or enhance ecosystem services arises from our case study findings. Some can be generalised, others are specific to the Goulburn Broken Catchment. They are listed below.

Dairy enterprise

Strengthen policies (e.g. water markets, water property rights, water quality monitoring and regulation, tradable pollution permits) that promote water re-use and nutrient retention on farm.

Strengthen or establish policies (e.g. offset schemes) that promote establishment of native vegetation on outblocks (or elsewhere) to compensate for greenhouse gas emissions from, and lack of habitat for native species, on the milking areas.

Invest in research on soils and soil organisms under intensive irrigation and fertiliser regimes. Are there long term trends or critical thresholds? What are the limits of intensification? Can irreversible changes occur? Is the balance of soil ecosystem services to industrial inputs financially efficient and sustainable?

Invest in research on natural pest control in pastures.

Floodplain

Develop recommendations for floodplain policies and practices.

Invest in an adaptive management research program on regeneration of native vegetation under different flood regimes, the evolution of Habitat Hectares scores, and the interventions required to achieve benchmark structure and species composition

Invest in research on the filtration of water by floodplain vegetation

Dryland sub-catchment

Increase native re-vegetation targets to take advantage of thresholds in ecosystem service responses e.g. above 30% of the area re-vegetated for Habitat Configuration score, and around 40% for shelter.

Given these thresholds, investments should be focused, not spread across the Goulburn Broken Catchment.

Link incentives for re-vegetation to sub-catchment plans so that efficient trade-offs are made among the ecosystem services 'maintenance and regeneration of habitat', 'provision of shade and shelter', 'water filtration and erosion control', 'maintaining healthy waterways', and 'regulation of groundwater and river flows'. These services are more-or-less sensitive to the spatial arrangements of the vegetation.

Design incentives for native re-vegetation so they promote re-planting of species appropriate to the Ecological Vegetation Class (EVC) in which each site lies, on sites:

- that are geographically dispersed in order to reduce risks;
- in areas where where the soils are locally variable — this increases the range of habitat possibilities in a given area;
- in EVCs that are rare in the bioregion, so that representation of these EVCs is increased;
- where rare and threatened species occur in order to enhance their survival;
- near existing remnants that have a higher canopy density. This builds connections among remnants in which the higher canopy density indicates better habitat for native biota;
- in areas where patches of remnant vegetation are already numerous. The habitat value of the planted site is enhanced by the adjacency of the remnants;
- near larger existing remnants. The habitat value of the planted site is enhanced by the size of the remnant;
- near streams as these provide good habitat for native fauna and several other ecosystem services;
- that are enclosed by native vegetation. This enables small remnants to coalesce into a large patch with a higher overall habitat value;

- that make short links between remnants as fauna using short corridors may be less vulnerable to predation; and
- far from productive agricultural land to reduce the risks from intensive management practices.

Invest in an adaptive management research program on regeneration of native vegetation, the evolution of Habitat Hectares scores, and the interventions required to achieve benchmark structures and species compositions.

Tourism and recreation

Adopt deliberative processes combined with multi criteria evaluation in the development of other sub-strategies and plans for the Goulburn Broken Catchment

Invest in research on :

- public access;
- public education and the maintenance of ecosystem services;
- an efficient set of measures for reducing damage to or enhancing ecosystem services (e.g. user pays, markets and regulations);
- the utility of a code of practice for operators for reducing damage to ecosystem services; and
- the scope for reducing the number of or coordinating the many agencies involved in managing ecosystem services in the upper Goulburn Catchment.

Water inputs and nutrient outputs from the Goulburn Broken economy

Create regional development policies that take account of the sectoral output, employment, water and nutrient multipliers and promote economic restructuring.

Future Work

A high priority for future work is to analyse the institutions needed to maintain ecosystem services, and in particular explore ways of matching the scale and the design of institutions to the scale and nature of the ecosystem processes they are intended to influence. Another priority is to explore the feasibility of markets for ecosystem services, including the supporting institutions. We launched a new project in 2002, which is an attempt to redress market and property right failures and encourage investment in natural capital (http://www.ecosystemservicesproject.org/html/markets/aboutus/index.htm). It is funded by CSIRO, the Rural Industries Research and Development Corporation, Land and Water Australia, the Goulburn Broken CMA, NSW Department of Sustainable Natural Resources, Colleambally Irrigation, the Blackwood Basin Group, and the National Market Based Instruments Program. A supporting project on experimental economics funded by CSIRO will explore the decision-making behaviour of resource users under controlled conditions.

Another proposed ecosystem services project is called "Putting Ecosystems to Work for Town Water Supply", this project would draw upon the experiences of the Ecosystem Services Project and the Markets for Ecosystem Services Project in making use of natural capital to provide clean water to towns through ecosystem services markets in rural catchments. We predict a spread of similar projects as the costs of providing clean water increase in Australia and globally.

Concluding Remarks

The ecosystem services concept is rapidly influencing the way stakeholders perceive the relationships between natural capital and development, and is encouraging investment in natural capital, markets for ecosystem services, and in related research and communication.

If humans perceive themselves as separate from nature it then follows that development has no environmental cost. The contradiction of historical development is that it has caused the degradation of natural capital even though human well-being and survival depend on the services provided by that capital. The ecosystem services concept places humans and their economies within ecosystems so that 'natural' and economic processes are intimately interconnected. It is a step towards the integration of ecology and economics. It shows the need for investment in the maintenance of natural capital because it is the primary source of value and the provider of life support. This idea is obvious, but the reluctance of societies to bear the costs of maintaining natural capital shows the need for frequent restatement and reinforcement of the idea. The ecosystem services concept changes the need for investment in natural capital from an option to an imperative.

The Goulburn Broken Catchment Management Authority is already pioneering ways of investing in natural capital, and the ecosystem services concept contributes to this investment. We have shown how quantification of ecosystem services at selected scales (case studies) contributes directly to catchment planning. The awareness of transfer of services across scales can contribute to investment in natural capital that takes explicit account of otherwise unrecognised scale effects.

Within the framework of ecosystem services there is a range of ways to integrate ecological, economic and social values. The choice and definition of the services, an inherently social process, is critical to their understanding. They define the set of biophysical processes that underpin the ecosystem services, processes that lead to interactions between services and provide the indicators for the relative performance of each service. However, the processes are often poorly understood and greater investment to link process with service is required to ensure the ecosystem services concept reaches its full potential. Analysis can vary in scale from enterprise to catchment and can utilise tools from dynamic modelling to multi-criteria evaluation. All should be linked with participatory methods that connect researchers and community together. This increase in understanding of ecosystem processes is fundamental to the establishment of markets for ecosystem services, and for political acceptance of the need for other changes in institutions for natural resource management.

To take the concept of ecosystem services further we need to build on three themes introduced in this project. First, production functions that recognise spatial, temporal and feedback processes and provide the necessary link between ecology and economy. Second, it is unlikely there will be sufficient investment in environmental management to match the extent of degradation. There is therefore a strong need for priority setting tools that can guide society's investment in the management of ecosystem services. The nested hierarchy framework presented in this report is one process for setting priorities. Lastly because many ecosystem services are not readily captured and managed within private or group property rights institutions, there is a need for new institutions that will protect the value of these services.