ASSESSING ECOSYSTEM SERVICES IN AUSTRALIA

Wendy Proctor, Steven Cork, Jenny Langridge, Art Langston, Nick Abel, Mark Howden, Marty Anderies, Rachel Parry, David Shelton

Sustainable Ecosystems
Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

7th Biennial Conference of the International Society for Ecological Economics
Sousse, Tunisia, 6 – 9 March 2002

Abstract

The Ecosystem Services Project focuses on the values and opportunities that come from the relationships between people and their natural environments. The quality of these relationships is thought to be decreasing as ecosystems change worldwide. This national project seeks to convey an understanding of the services and benefits that we receive from ecosystems. The project will also seek to address the problem of traditional techniques and approaches used to estimate 'value' as such techniques do not deal well with goods and services that do not pass through markets, that are publicly rather than privately owned, or that are of importance to communities rather than individuals. In this first case study of the project carried out in the Goulburn Broken Catchment of South Eastern Australia, ecological, social and economic techniques are used to give a detailed assessment of the goods and services from ecosystems in an agricultural water catchment. These techniques are designed to give estimates of the interactions and consumption of those services, the economic and other benefits, and the beneficiaries at a range of temporal and spatial scales. These estimates are expected to help policy makers, planners and land managers take account of the interrelationships among a wider range of ecological, economic and social values. The scales of analysis range from local through regional to national and international. Central to this work will be techniques designed to acknowledge priorities and values of a wide range of policy makers, planners, land managers and industry and community groups. We seek in this first case study to develop and promote the project outputs for application elsewhere - in particular as one possible national approach to assist sound resource management in Australia. This paper outlines the specific techniques used including the use of a deliberative multi-criteria evaluation as the basis of the overall integration and decision-making framework.

Résumé

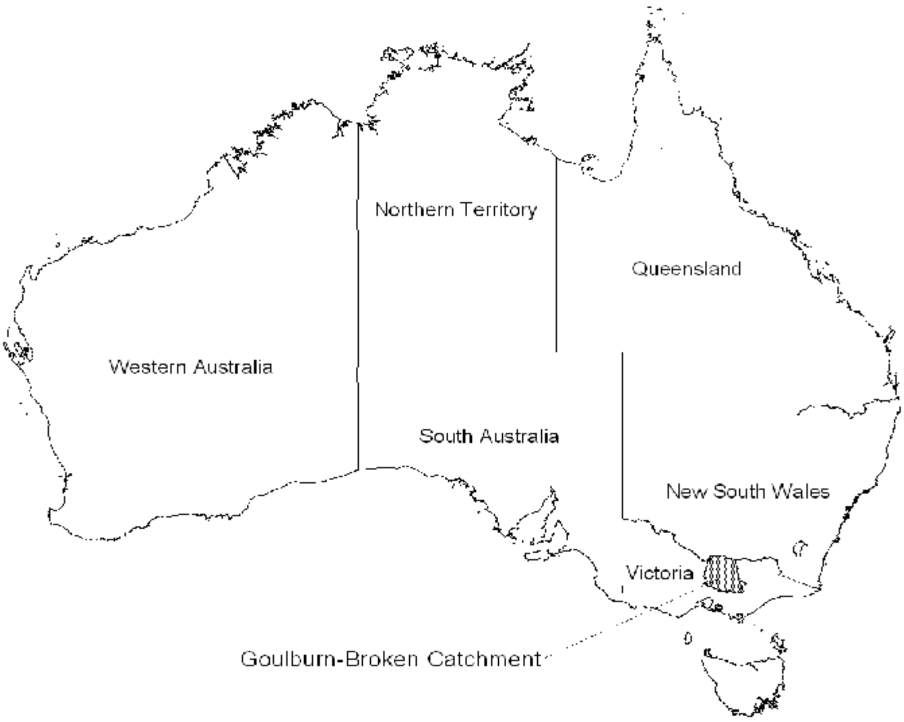
Le Ecosystem Services Project se concentre sur les valeurs et opportunités qui découlent des relations entre l' Homme et son environnement naturel. La qualité de ces relations se dégrade en même temps que les écosystèmes declinent partout dans le monde. Ce Projet cherche à apporter une meilleure compréhension des services et des bénéfices que nous recevons des écosystèmes. Le Projet cherchera aussi à aborder le problème des techniques et approches traditionnellement utilisées pour estimer une « valeur » alors que de telles techniques ne traitent pas convenablement des biens et services qui ne passent pas par les marchés, qui sont publics plutôt que privés , ou d'importance pour les communautés plus que pour les individus. Cet article met en avant les techniques spécifiques utilisées comportant l'utilisation de l'évaluation multicritères délibérative comme base du cadre d'analyse de l'intégration et de la prise de décision. Dans la première étude de cas du Projet réalisée dans le Goulburn Broken Catchment, dans le Sud Est de l'Australie, des outils à la fois écologiques et économiques sont utilisées afin de donner une évaluation détaillée des biens et services des écosystèmes dans un bassin agricole (le Goulburn Broken). Ces techniques ont été conçues afin d'estimer les interactions et la consommation de ces services, des bénéfices économiques et autres, et des bénéficiaires à différentes échelles temporelles et spatiales, cela afin d'aider décideurs, planificateurs et gestionnaires à prendre en compte les interrelations entre une plus grande gamme de valeurs écologiques, économiques et sociales. Les échelles d'analyse vont du local au paysage et au bassin entier. Au coeur de ce travail se trouvera une technique conçue pour reconnaître les priorités et valeurs d'une large gamme d'acteurs : décideurs, planificateurs, gestionnaires, industriels et communautés. Cette approche cherche à combiner les avantages d'une Analyse Multi Critères, qui fournit structure et intégration pour les problèmes de prise de décision complexe, avec les avantages du principe de délibération et d'interactions avec les acteurs, fournis par une approche du type Jury de Citoyens. Nous cherchons dans une première étude de cas à développer et promouvoir les réalisations du projet pour une application à d'autres cas. En particulier, en tant qu'approche nationale pour permettre une gestion censée des ressources naturelles en Australie.

Introduction

The Ecosystem Services Project brings together a large number of researchers and a range of expertise in assessing the nature and value of ecosystem services in Australia. Ecosystem services are those services provided to humans by nature, largely free of charge and often unrecognised. They include the necessary requirements to the production of foodstuffs such as pollination and provision of nutrients. When these necessary services fail, often due to many years of human intervention, then we try to make up for these failings by the costly provision of technological remedies. For example, farmers pay beekeepers to come and provide the means for pollinating crops or spend money on expensive fertilisers when the health of our soils fails to the extent that nutrients are not sufficiently available for plants. A major objective of the Ecosystem Services Project is to encourage Australians to recognise the incredible worth of nature's services to us and in doing so, protect and encourage the provision of these services for future generations. This is by no means an easy task, however. First we have to be able to identify and measure these services and their interactions with production processes and other services. Second, we have to find some way of attaching a value to these services which reflects their overall worth to individuals and to society as a whole. Third, we have to communicate this knowledge to the Australian community so that decisions concerning natural and agricultural resources can be made with sufficient knowledge of the likely consequences for these services. This paper attempts to provide some detail on how we might achieve the first two objectives of this project by identifying the key natural resource and agricultural issues involved in our first case study region, the Goulburn Broken Catchment of Victoria. As well, a broad evaluation framework will be identified to assess various scenarios for the region in terms of the ecosystem services involved using the integrative and decision aiding qualities of a multi-criteria evaluation.

Catchment Issues

The Goulburn Broken Catchment is a diverse region of Australia that is characterised by agriculture, tourism, manufacturing and service industries (Map 1).



Map 1: The Goulburn Broken Catchment

The catchment's total area is almost 2.5 million ha of which approximately two-thirds has been cleared for agriculture. About 200,000 people reside in the catchment of which 17,000 are employed in agriculture and associated industries. Irrigated agriculture predominates in the lower elevation (northern) end of the catchment whilst the upper (southern) reaches are devoted largely to recreational ('hobby') farming, forestry, tourism and some grazing. On the plains of the mid catchment, dryland cropping and grazing are the main land uses. The manufacturing sector is the largest in terms of gross value of production (45 per cent of total) and this is mainly comprised of dairy, fruit and grapes processing.

There are many environmental problems in the catchment that require urgent attention. The most serious of these are rising water tables and saline soils that have been brought about by widespread clearing of native vegetation and replacing this with shallow rooted annual crops.

An approach to documenting the goods and other products of importance to people from the catchment, the natural assets and ecosystem services responsible for delivering those products, the land uses on which the services depend, and the issues and priorities relating to ongoing delivery of those services, was documented in *Natural Assets: An Inventory of Ecosystem Goods and Services in the Goulburn Broken Catchment* (the 'Inventory Report', Binning et al. 2001). The Inventory Report lays the foundations for the development of various scenarios to be used as the basis of our ecosystem services assessment. The report identifies what ecosystem services are provided by the catchment, what land uses are important to ecosystem services and which ones impact on them, and what trends are apparent in land uses, delivery of ecosystem services, and persistence of the underpinning natural assets. The identified scenarios will form the basis for economic, ecological and social assessments of alternative futures for the catchment.

The basis of our approach to developing the scenarios has been to focus on the key issues of the catchment identified by the Inventory Report (Table 1) and refined through discussion with community representatives and other stakeholders. The purpose of doing this is to learn about the behaviour of the various ecosystem services in the catchment through the study of specific issues at several different scales of analysis.

Table 1: Key issues identified in the Inventory Report

1	Integrating management across ecosystem services by: • re-establishment of the Lower-Goulburn River floodplain; • alternative revegetation strategies; and • nutrient management including the merits of alternative approaches.
2	Managing land-use intensification.
3	Managing transitions in land-use.
4	Managing vegetation for the full suite of ecosystem services.
5	Managing cultural, heritage and option values.
6	Maintaining soil health.
7	Accounting for the value of non-agricultural land and water-uses.
8	Water and salinity management.
9	Anticipating and adaptively managing emerging issues.

Stakeholder Participation

Continued community and stakeholder participation is a key aspect of the Ecosystem Services Project and the theoretical framework adopted here in assessing and valuing ecosystem services has been developed with recognition of the pluralistic nature of Australian society. Various interest groups holding differing values compete and cooperate to bring about changes in institutions that favour those interests (Godden 1997). Values of resources depend on institutional arrangements (e.g. property rights in particular), the distribution of political power and wealth, the scarcity and substitutability of resources, cultural preferences and technology. Economic valuations only have meaning within a context defined in these terms. The scenario approach taken here (explained later) provides contexts, and the values of ecosystem services will be estimated by comparing options within each scenario set using a multi-criteria evaluation.

The diversity of values held means that there may be no optimum solution to many resource use conflicts. Nevertheless, trade-offs can be made and win-win solutions are often possible, even though institutional arrangements and lack of knowledge often prevent them. Stakeholders with conflicting values are able to express those values through the participatory multi-criteria framework. Our estimates of value are not only, therefore, based on market prices or pseudo-market techniques, but we actively seek to capture the heterogeneity of economic and other values that characterises a pluralist society.

In 2001, we convened the first of a series of workshops of stakeholders in the Goulburn Broken Catchment. The purpose of the meeting was to develop the scenarios. The stakeholder group was selected in close consultation with the Goulburn Broken Catchment Management Authority (GBCMA). A broad cross-section of representatives covering a wide range of occupations and interests was chosen informally. The representatives have, in most cases, a strong association with the management of the catchment and were also chosen with the purpose of bringing knowledge, experience and skills to the project's development. A more formal or structured process of selecting members from a sample of the population of the catchment was not undertaken because of the technical nature of the work and the short time frame available for familiarising members with the complex biophysical and other analyses.

A key point from the workshop was that we need to focus on ecosystem service issues at a catchment wide scale. Smaller and more focused scale analysis should be used to support catchment wide analysis.

Scenario Development

Developing a set of plausible scenarios for the future management of the Goulburn Broken Catchment, and assessing how ecosystem services change under these different future scenarios, are also central components of this project. The scenarios approach has been adopted for several reasons:

- to focus discussions of value (economic and otherwise) on specific circumstances that are relevant to decision makers
- to allow for a rigorous and systematic assessment of interactions between different ecosystem services under different land-use assumptions
- to use as an input to prioritising and valuing ecosystem services within a specific context
- through the use of an 'impact matrix', provide a useful and transparent aid in the decision-making process for any future land-use change.

As a result of the concerns of the stakeholders, land use change has been acknowledged as an overriding scenario. Land use change can be identified as the catchment wide scenario and can be used to guide the development of more focused issues/scenarios associated with dairying (at the enterprise scale) and floodplains, vegetation, culture and tourism (at the sub-catchment scale).

The process needed to be, and will continue to be, iterative and involve the catchment community for at least two reasons:

- our definitions of the scenarios will change as we and the community understand them and their consequences better
- the views on what questions need to be addressed and the way the answers should be presented most usefully will change as we learn together with the members of the catchment.

The preliminary scenarios were refined with input from the stakeholders and technical experts in the catchment. Further refinement will be undertaken as the quantitative analyses and data collection proceed. In defining scenarios, we have adapted a hierarchical framework (Figure 1).

We define scenarios as alternative approaches to addressing objectives set by decision-makers in the catchment. While the catchment objective may be broad (e.g. sustainable development), the sub-objectives are more specific and can relate to a range of different scales of time and space. The sub-objectives and scenarios identified, range in scale from local to catchment wide. The ecological, economic and social assessments initially focus on the local or regional scales and will then move up to catchment wide assessments. The catchment wide scenarios will be initially based on a suite of options comprising the possible extremes in design as follows:

- a business as usual option
- an economic and social/cultural bias option
- an environmental bias option.

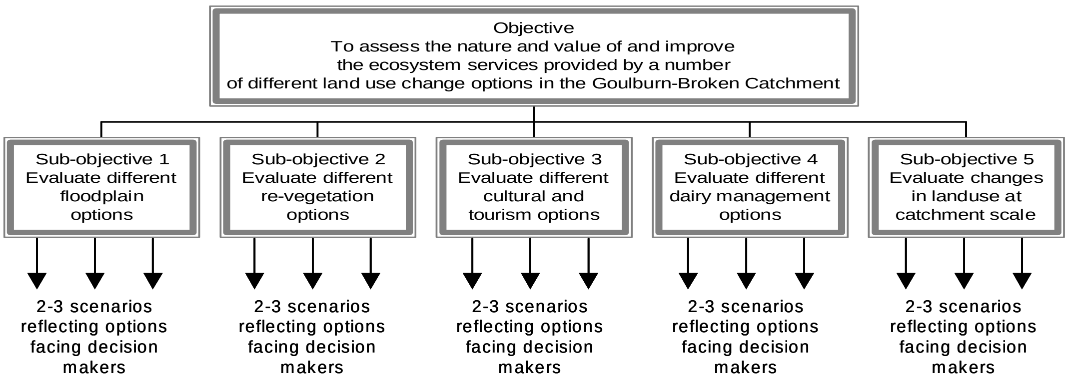


Figure 1: Relationships among objectives, sub-objectives and scenarios for the Goulburn Broken Catchment

Central to our analysis has been the development of an Impact Matrix (Table 2). The Impact Matrix will guide our thinking about which ecosystem services should be considered in each scenario. In this approach, each scenario is scored with respect to a set of indicators for each group of criteria. The indicators are chosen to represent criteria important for deciding which scenario ultimately best meets the overall objective. In this study, ecosystem services are considered important criteria and contribute to a large proportion of the total number of decision criteria. The matrix represents a powerful tool for organising complex information, aiding the decision-making process and defining the scope of our analysis.

Table 2: Example of an Impact Matrix for a land use decision problem*

Criteria	Possible Indicators	Impacts		
		Scenario 1	Scenario 2	Scenario 3
Ecological (chiefly Ecosystem services) criteria				
Pollination	Pollination sensitivity to landuse (index[1])	4	7	2
Life Fulfilment	Impact of landscape change on landuse (index[2])	++	+	+++
Climate Regulation	Capacity to adapt to climate change - Level of carbon sequestration (index[2])	++	+++	+
Pest Control	Estimated plague pest species (No.)	10	3	5
Genetic Resources (ecosystem, species and genetic diversity)	Habitat Hectares Score (Index[3])	23	14	10
Habitat	Area of native vegetation (ha.) No. of species (No.)	450 000 3 150	380 000 2 000	230 000 1 500
Shade and Shelter	Area of suitable species Average crop yield Average animal growth Average mortality rate	. . . .	. . . .	. . . .
Water Health	Quality of runoff from sites -Index Fish, insect, plant, algae numbers Salt concentration of streams	. . .	. . .	. . .
Soil Health	Area of salinised land Soil biodiversity area Catchment water yield (volume) Salt concentration of streams	. . . .	. . . .	. . . .
Economic Criteria				
Economic benefits and costs	Costs of managing sites, revegetation, capital works Variations in land prices Costs of pest control Costs of alternatives Income from production Cost of replacing ecosystem services with technology Other estimated benefits and costs	. . . .	. . . .	. . . .
Social and Cultural Criteria				
Aesthetic values Cultural value Heritage value	Variations in land prices Qualitative index Qualitative index Qualitative index	. . . .	. . . .	. . . .
Cultural and spiritual value	Index to reflect identity with the natural environment in relation to the cultural backgrounds of residents, including indigenous people Employment change Social cohesion index	. . . . . .	. . . . . .	. . . . . .

*Some hypothetical values are given as examples of the sorts of quantitative and qualitative measures that could be used.

1 On a scale of 1 to 10 with 1 being nil sensitivity and 10 being maximum sensitivity
2 + = low, ++ = med, +++ = high
3 On a scale of 1 to 100 with 1 being the lowest level and 100 being the maximum level.

Assessment criteria can be grouped into ecological (essentially ecosystem services) and economic and social criteria (many of which depend in some way on ecosystem services). The criteria may be based on the scenario or land use assessed. For example, specific ecosystem services will be identified as important for some scenarios and not others. Indicators represent the measures of a criterion and these measures may be quantitative or qualitative. Indicators will be based on the criteria and available data. These will be identified through the modelling or assessment process. During the course of the assessment they will be more specifically defined by the analytical process and the available data.

In developing our approach to ecological analyses, we have avoided attempting detailed models of whole ecosystems. Instead, we have put considerable effort into defining the questions asked by stakeholders and analysts and looking for appropriate ways to address these questions with the simplest models possible. At some scales, conclusions can be drawn with confidence about the behaviours of ecosystems in relation to ecosystem services, but our understanding often does not allow detailed predictions. This means that our ecological analyses are best seen as exploring possibilities for future benefits from better environmental management rather than making precise predictions. Our stakeholders in the Goulburn Broken Catchment seem comfortable with this.

The following sections outline our approaches to providing values for the indicators using ecological analyses at three different scales: the enterprise scale, the landscape/sub-catchment scale and the catchment wide scale (Table 3). An outline of the economic analyses and some preliminary results from the research is then provided. More information can also be found in Cork et al. (2001) and Shelton et al. (2001).

Table 3: Scales of ecological analysis in the Goulburn Broken Catchment and the associated economic and resource management issues

Scale of analysis	Economic and resource management issues
Enterprise (e.g. a dairy farm)	Costs of replacement of ecosystem services with technological alternatives; farm budgets
Landscape/sub-catchment (e.g. a floodplain)	Costs of replacement of ecosystem services; impacts between enterprises; broader impacts on public welfare; returns on public investment
Catchment	How and when should catchment managers intervene in land-use and ecological processes to achieve increased welfare at the scale of catchment communities? How do we measure welfare at this scale?

Ecological analyses – Enterprise Scale

A major issue for the future development of the Catchment is the objective of further intensification of dairying to produce more milk on less land. In order to explore knowledge gaps, management scenarios and to refine the model framework, two small workshops were run in the Goulburn Broken Catchment. Key ecosystem service issues for dairy farms, identified in the workshops are listed in Table 4. A simulation model for a dairy farm was developed with consideration of these ecosystem service issues in order to assist in clarifying these issues.

The conceptual model (Figure 2) illustrates the flows of goods and services on a dairy farm and the links between natural assets (capital) and goods via input services and those that maintain natural assets. The aim of the biophysical assessment was to evaluate the condition of the various components in Figure 2. Based on stakeholder input, the simulation model we subsequently developed was applicable to an irrigated dairy pasture system consisting of annual and perennial grasses. It combined empirical relationships, biophysical processes and hypothetical relationships (explored with dairy researchers) and included such elements as a simple empirical pasture growth routine, a milk production routine, nutrient dynamics and in particular nitrogen and phosphorus cycling, a pH routine, fertilizer and irrigation routines. It also included consideration of the role of soil organisms, a heat stress routine and greenhouse gas calculations.

The farm scenarios defined in the workshops involved management practices including fertiliser addition, irrigation regimes, feed supplementation and water use efficiency practices. For initial model runs four farm types were defined: high input, low input, high input plus water reuse and high input plus shade and reuse. The farm types were broadly defined with the stakeholders but some of the model runs were based on survey information collated by Armstrong et al. (1998) and Cairns et al. (2000).

Table 4: Key Ecosystem Service Issues on Dairy Farms

Ecosystem Service	Issues
Regulation of climate	Specific issues concern greenhouse gas emissions. Animals produce methane emissions equivalent to about 1480kt CO_2 per year, an additional 340kt CO_2 per year is generated from the pasture and is exacerbated by nitrogen fertilisation, water logging and legume pastures. Animal waste contributes to nitrous oxide emissions equivalent to approximately 160kt CO_2 per year.
Provision of shade and shelter from trees	Heat stress in animals has many adverse effects on livestock, including reduced reproductive efficiency, decreased live-weight gain and reduced milk production.
Maintenance of soil health	Soil fertility has been enhanced by fertiliser use and in particular by nitrogen application over the last 10 years. However, the role of soil organisms in promoting the efficient cycling of nutrients is poorly understood. Compaction and water logging of soils through irrigation, trampling, farm machinery and cultivation all contribute to the decline of soil health. Management of stock and irrigation can minimise these effects.
Waste absorption and breakdown and maintenance of healthy waterways	A major issue to the wider community is nitrogen and phosphorus loads in waterways. Dairy farms contribute to this load through fertiliser application and irrigation. Soil erosion associated with compacted laneways and stock tracks exacerbate the problem by mobilising nutrients. Improved nutrient management practices could minimise the problem.
Regulation of river flows and ground water levels	The availability of irrigation water to dairy farms is now a major issue in some regions, and will undoubtedly be a growing concern in the future. Salinity, associated with rising water tables, is reducing the area of productive farming land and given the lag period associated with ground water movement will continue to do so even if action is taken to reverse the trend. Dairy farms can contribute to the salinity problem as accession of water from rain and irrigation beyond the root zone is added to water tables.

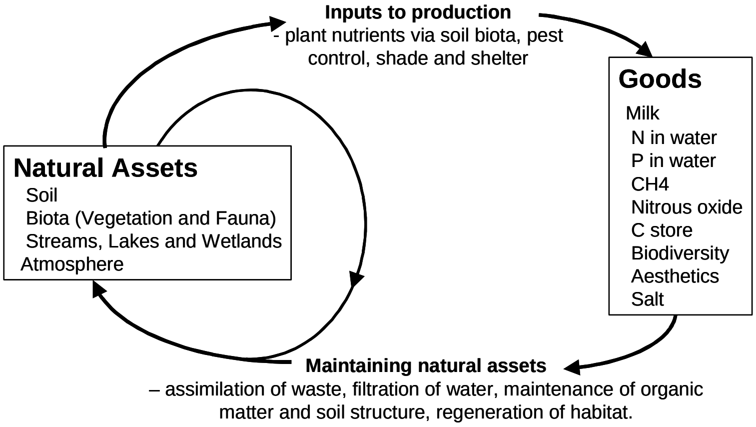


Figure 2: The flows of goods and ecosystem services on a dairy farm

Ecological Analysis – Landscape scale

The GBCMA has proposed to re-establish the northern floodplain of the Goulburn River. In doing so they have undertaken processes to broadly consult the community and to evaluate several costs and benefits associated with the proposed options. The cost-benefit analysis tended to focus on the engineering and damage components but acknowledged that a broader evaluation was needed. It was agreed with stakeholders that there is a need to further explore the implications of different approaches to the valuation of ecosystem services as input into a process of more detailed design of the proposed floodplain rehabilitation scheme. We developed a conceptual model of all key ecosystems services in the floodplain and the biophysical processes that contribute to them. The model is being implemented with a focus on the three major scenarios recommended by stakeholders:

- a baseline reflecting the current levee system and land management
- the floodplain rehabilitation scheme as proposed but with minimal livestock grazing
- the floodplain rehabilitation scheme as proposed and with maximum livestock grazing.

The basic model structure is displayed in Figure 3. It addresses issues raised in both the scenario workshops and the inventory of the main ecosystem services. The model has a yearly timestep, and is driven by flood records and rainfall. Key user-defined inputs are grazing pressure, landuse and rehabilitation action. There is a range of critical relationships which forms the main part of the model. These are arrayed on the left and right-hand sides of Figure 3. Examples are the amount of herbage consumed as a function of livestock stocking rate, the deposition of sediment as a function of vegetation structure and biomass, and biodiversity value as a function of vegetation structure, biomass and species. Key ecosystem services are indicated in bold type.

The model is partially spatially explicit and the floodplain is divided into a small number of units that are considered to be unique in terms of characteristics such as habitat and herbage type, position in the landscape and soil type. Within each of these units we have defined attributes associated with each scenario and flooding regime. The capacity of habitat to regenerate within each unit is then modelled, under different scenarios, and assessments made of the contribution to the ecosystem services of water filtration, erosion control, maintenance of habitat, livestock productivity, carbon sequestration and biodiversity.

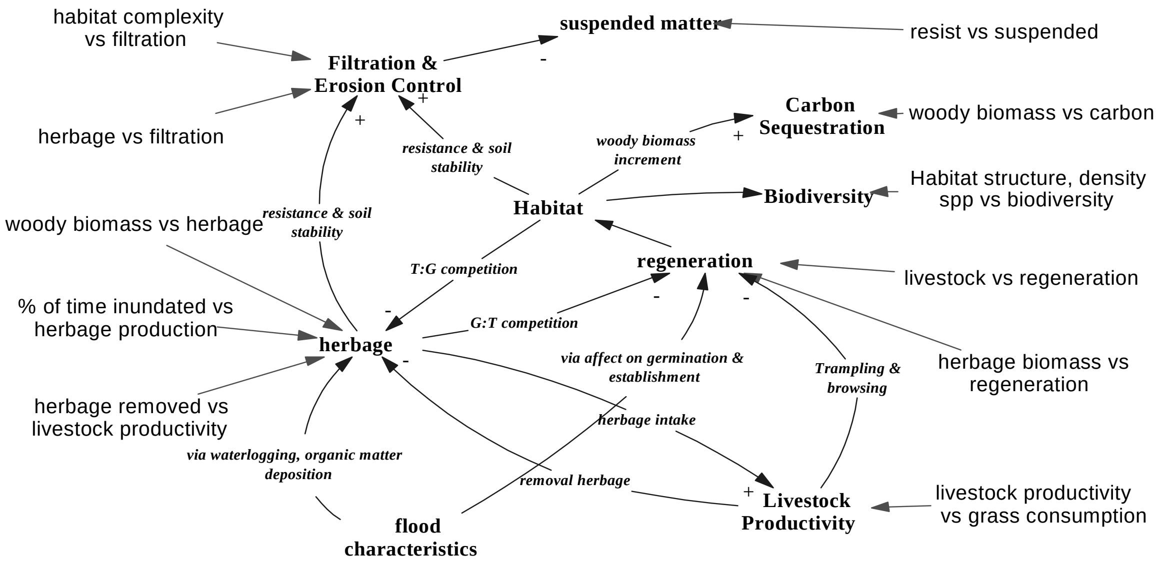


Figure 3: A simplified model of the linkages between ecosystem services and the factors that effect them on the lower Goulburn River and Floodplain

Ecological Analysis – Catchment wide scale

To address the key issues at the catchment scale, we are considering the catchment as different geographic and land-use components: mountains dominated by forestry enterprises, foothills dominated by grazing and, increasingly, recreational farming, plains dominated by grazing and dryland cropping, and the irrigation area dominated by irrigated dairy and horticulture. Key ecosystem services included in the different land use areas are listed in Table 5.

The catchment analysis has three purposes:

- to explore the implications of land-use change on ecosystem services that link the major biophysical zones of the catchment
- to provide coarse information about changes in productivity and viability of land uses over time, either under the influence of changes in ecosystem services or any instruments that might be implemented to manage those services
- to enable exploration of the trade-off between ecosystem services and potential technological substitutes.

Figure 4 shows the key environmental variables that influence the maintenance of healthy waterways within the forestry component. Note that not all services that were listed in the Inventory Report have been accounted for in this model.

For example, maintenance and regeneration of habitat was listed as a highly ranked service. However, only services that have processes with significant links to other zones or land uses or that significantly impact on the productivity of the land use are included, as initially these are the only ones needed to fulfil the purpose of the model (as developed by the stakeholders). Other land use modules are yet to be developed.

Table 5: Ecosystem services included in each land use of the catchment-wide model

Land use	Services
Forestry	Maintaining healthy waterways
Grazing – hills zone	Water filtration and erosion control, maintenance of soil health
Grazing – slopes zone	Regulation of river flows and groundwater levels, maintenance of soil health
Cropping	Regulation of river flows and groundwater levels, maintenance of soil health, pest control
Dairy	Regulation of river flows and groundwater levels, maintenance of soil health, maintaining healthy waterways
Horticulture	Regulation of river flows and groundwater levels, pest control, maintaining healthy waterways

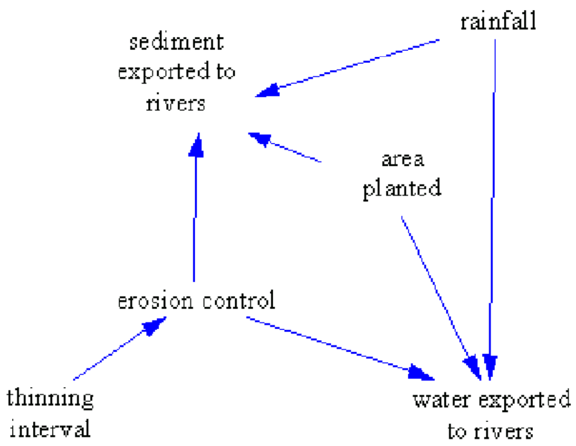


Figure 4: Biophysical processes supporting ecosystem services in forestry

Economic Analyses

A key difference between the ecosystems services approach and conventional economic analyses is in the design of the production functions of the relevant goods produced in the region. Conventional production functions are simple equations that do not show interactions among inputs. Ecosystem services production functions are dynamic bio-physical models. They reflect bio-physical interactions (e.g. between industrial fertiliser and soil nitrogen), and show the feedbacks from production to the ecosystem services that support production (e.g. soil acidification), and to ecosystem services important to other human needs (e.g. water quality). The models also include regenerative services (e.g. the regrowth of vegetation) and waste absorption services that ecosystems provide (Figure 5). The bio-physical models are the basis for the economic valuations.

Our measurement of the value of marketed goods will be estimated as the sum of producers' and consumers' surpluses because these surpluses take account of demand for and scarcity of resources. Value of production to land holders is producers' surplus based on the supply curve estimated at market cost. The value of consumer benefit is consumer surplus based on demand at market prices. For this study, marginal changes in the areas of the surpluses under the various scenarios will be estimated.

The supply curve of an enterprise is the marginal cost curve. We are using the bio-physical models and published input cost data to estimate likely shifts in this curve, thus changes in producers' surplus under different scenarios.

We can obtain demand curves for the main commodities from the literature, or estimate them econometrically by linear modelling (Boardman et al. 2001). A demand curve is affected by both national and international influences. To estimate changes in Australian consumers' surplus, national demand needs to be separated out. We assume the shape and location of this curve will not be affected by the marginal changes in our scenarios.

Economic valuation includes the value to society of both marketed and non-marketed goods and services. So far in the project we have focused mainly on the valuation of ecosystem services that contribute to marketed goods. We will be looking at a number of different economic techniques that will attempt to put values on non-marketed goods. The results of these techniques will be included in the Impact Matrix under the various economic criteria for consideration in the scenarios analysis.

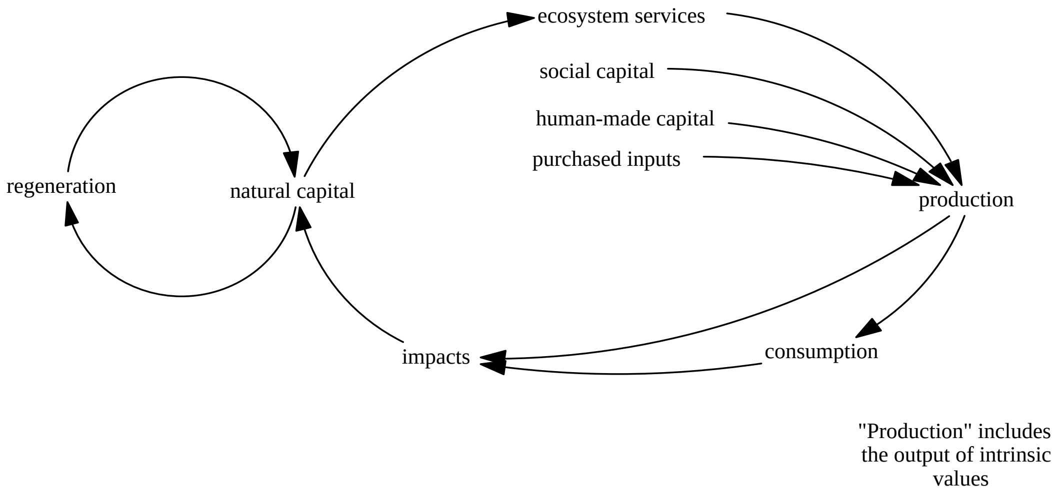


Figure 5: Production and its consequences

Changes in producers' surpluses based on market prices will give us many of the benefits and costs of changes in resource use for the individual user or firm in our scenarios. The bio-physical models will reveal the negative effects of production on ecosystem services as declines in production, or increases in management costs over time under various assumptions about commodity price changes. At the scale of the farm or firm, optimisation is useful as objectives and timescales can be clearly specified. We are adding financial components to the bio-physical models, giving us the ability to optimize dynamically.

At larger scales, such as those for many of the different scenarios, part of the value to a community of a change in resource use is the net change in the sum of producers' and consumers' surpluses at market prices under various commodity price assumptions. In the scenarios, we are analysing externalities by estimating the distribution of benefits and costs among stakeholders. This will contribute to policy recommendations by showing the level and type of incentives and regulations needed to change the current pattern of use of ecosystem services towards one that is more equitable and efficient.

At the catchment wide scale, we will also estimate the impacts of changes in resource use patterns on employment, household income, welfare payments and gross regional product. We are exploring the use of physical and economic input-output modelling as a practical planning tool for these purposes (Figure 6) (United Nations, in prep.). Input-output models, despite the limitations of being static and linear, are a useful way of accounting for interactions. The ecosystem supplies services (b) as inputs to production (y). Sectoral production (y) flows to other sectors and to final consumption (x). Wastes impact on the ecosystem through their effects on bio-physical interactions (a to b). At the very least this approach enables planners to explore the physical resource use implications of changes in economic structure. We are exploring ways of including in such models feedbacks from economic activity to consequences for ecosystem services (e.g. water quality and quantity, carbon storage and native vegetation cover).

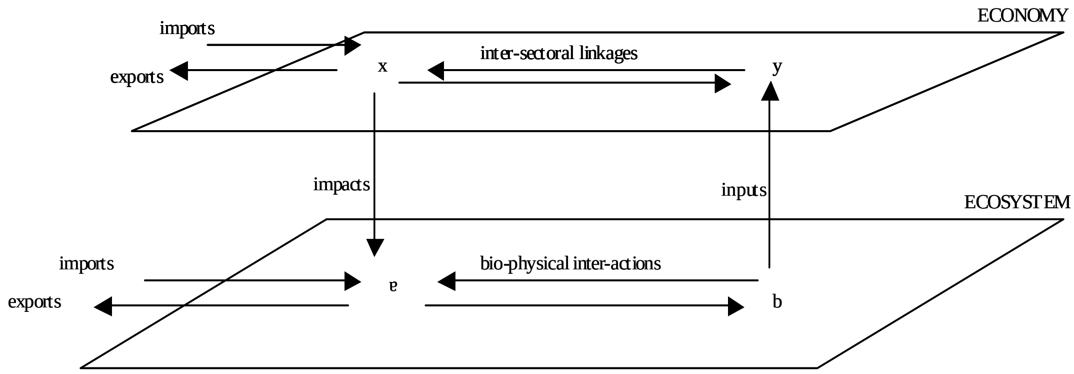


Figure 6: Catchment scale input-output modelling

Preliminary Results

Preliminary results of the dairy enterprise model, suggest that increased use of trees for shade and of water re-use systems would increase milk production by recycling nutrients and decrease off-farm impacts with less nitrogen and phosphorous leaving as runoff. In addition, these scenarios could have biodiversity benefits that might provide income if a market for biodiversity develops in the future. Further development of the model, will focus on including additional ecosystem services.

Management actions, which included the maintenance of an unfertilised buffer strip at the end of irrigation bays, number of days after fertiliser is applied that pasture is irrigated and number of irrigation events in a year in association with inputs to production (e.g. superphosphate application, quantity of irrigation water applied and stocking rate) tempered the effectiveness of ecosystem services such as filtration. The role of soil micro and macro-organisms in the maintenance of soil fertility via mineralisation and decomposition are not well understood and so model runs were undertaken to test the sensitivity of model output to changing values in the effectiveness of soil organisms.

Some simple economics was incorporated in the model based on income from milk production and these, and other physical quantities, were compared for various management scenarios. From Table 6 it can be seen that the addition of a water re-use system to the high input farm not only increased productivity in terms of income via increased milk production through the recycling of nutrients but it also reduced the off-farm impacts with less nitrogen and phosphorus leaving the farm as runoff affecting water quality in nearby streams and rivers.

The increased income for high input farms with water re-use and the provision of shade, when compared to the scenario without shading, is attributable to an additional 15 000 litres of milk produced as a consequence of reducing temperature stress in cows by the provision of shade. This increased income would be offset by the cost of either planting trees and/or constructing shelters and perhaps loss of productive pasture but if a climate change scenario for the Goulburn Broken Catchment were considered it may be that the benefits would outweigh the costs. If shelter were provided by carefully designed revegetation there may be some additional benefit in terms of carbon sequestration and perhaps some biodiversity benefits.

Table 6: Value of output goods from the dairy model*

Value of Output Goods	High input	Low input	High input + reuse	High input + shade + reuse
Standard Product $$				
Milk	**316 119**	**158 970**	**319 711**	**323 160**
P fertiliser*	**14 930**	**7 204**	**14 930**	**14 930**
N fertiliser*	**3 254**	**0**	**3 254**	**3 254**
Irrigation*	**16 254**	**6 972**	**16 254**	**16 254**
Total cost supplement	**25 232**	**17 316**	**21 782**	**21 782**
other costs (Topping,Harrowing, weed/pest control, channel maintenance, pasture rennovation)	**18 000**	**9 500**	**18 000**	**18 000**
Net income	***238 449***	***117 978***	***245 491***	***250 830***
Other "Goods" Ecosystem outputs				
Biodiversity/conservation Value ?	**?**	**?**	**?**	**?**
Carbon store under pasture (tonnes/ farm)	**37 600**	**18 500**	**40 400**	**40 400+?**
CO2 discharge (tonnes/ farm/year)	**100**	**52**	**100**	**100**
methane discharge (tonnes/farm/year)	**28**	**14**	**28**	**28**
Total P loss (kg/farm/year)	**530**	**300**	**130**	**130**
Total N loss (kg/farm/year)	**6 100**	**2 800**	**4 400**	**4 400**

*Under four management scenarios; high input and low input with no water reuse system and high input with a 60% efficient water reuse system and with the provision of shade.

At the landscape scale analysis, productivity of the grazing system is an important ecosystem service based on the views of stakeholders. Preliminary results of the floodplain model show that large fluctuations in total liveweight reflect the impact of rainfall on pasture yield and hence number of animals able to be supported, and the flooding regime. Flooding reduces the amount of time in a year an animal can be supported and depending upon the length of inundation can have a positive or negative impact on potential pasture yield. There is a trend for total liveweight over time to decline which is attributable to lower pasture productivity due to the increasing woody component of the vegetation and its competition with palatable grass. This is exacerbated under some livestock utilisation scenarios as the regenerative potential of woody vegetation is increased as the effects of trampling and browsing are reduced. However, under extremely low livestock numbers, this trend is not observed due to the increased production of herbaceous biomass which inhibits the germination of woody vegetation.

Carbon sequestration is another potentially important ecosystem service which is affected by livestock production (Figure 7). The model allows the trade-offs between these different services to be evaluated. Under a high livestock utilisation scenario germination of woody vegetation is inhibited by trampling and browsing so although livestock production may be maximised, the service of carbon sequestration and value of biodiversity may be reduced when compared to a livestock exclusion scenario. The results presented are for one land unit only. To obtain a more complete picture we need to consider the value of ecosystem services across the entire floodplain.

Although a particular scenario may result in the maximising of livestock production in some units at the expense of other services such as carbon sequestration and biodiversity, consideration of the overall mosaic of land units may lead to an overall increase in these 'other' services and may have surprising effects on the service of filtration as indicated by downstream sediment and nutrient loads.

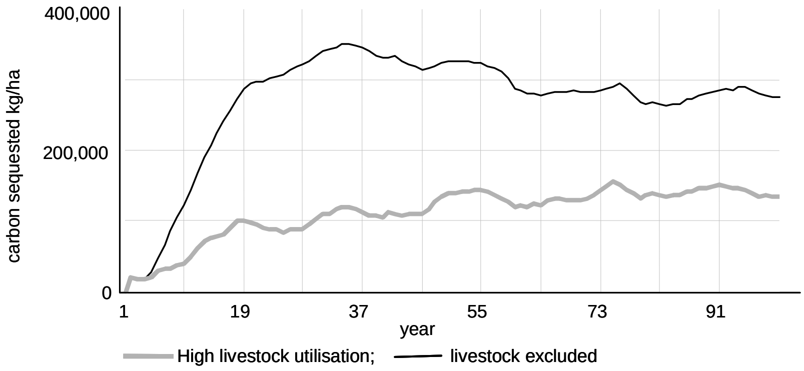


Figure 7: Carbon sequestration over time with different grazing scenarios

Preliminary results for the catchment wide analysis are still being assessed.

The Decision-making Aid

The process of deciding between the scenarios will be based on all of the decision criteria involved (both monetary and intangible). This process will utilise a decision-making aid that combines Multi-criteria Decision Analysis with deliberative stakeholder input in a similar form to that of a Citizen's Jury. The sub-catchment level scenarios will be addressed first and the information gained from these assessments will be used in developing the catchment wide scenarios. The scenarios, preliminary objective of the project and a preliminary series of criteria (social, economic and ecological) deemed necessary to meet the objectives have been developed using both expert opinion and stakeholder input. These will be further refined during the consultative process. A Citizen's Jury type process involving stakeholders will be run to obtain consensus on a weighting scale for the criteria. 'Expert witnesses' will be called on to provide information where required. Each scenario will be assessed in terms of the identified indicators and criteria weights using Multi-criteria Analysis. This part of the analysis will provide a framework for the decision problem and identify any trade-offs that may exist between different criteria. Consensus is to be reached, using both the jury approach and the multi-criteria evaluation on a preferred scenario for the region. This approach seeks to combine the advantages of Multi-criteria Analysis in providing structure and integration in complex decision problems with the advantages of deliberation and stakeholder interaction provided by a Citizen's Jury. More information on this part of the analysis can be found in Proctor (2001).

Summary

This paper has provided an overview of a multi-disciplinary analysis of ecosystem services in the Goulburn Broken Catchment of Victoria, Australia. Details of the conceptual basis of the study and the preliminary results of some of the analyses have been provided. This analysis is largely based on assessing different scenarios for land use change in the catchment. It depends greatly on input from stakeholders in the region and biophysical, economic and social analyses that will complete the Impact Matrix used to decide between scenarios. The analysis will be completed using a deliberative multi-criteria evaluation to aid in the choice of a preferred land use scenario for the region. Ultimately this will help to provide enhanced knowledge of the nature and value of these ecosystem services to the catchment community.

References

Armstrong, D., J. Knee, P. Doyle, K. Pritchard and O. Gyles. 1998. *A survey of water-use efficiency on irrigated dairy farms in Northern Victoria and Southern New South Wales*. Department of Natural Resources and Environment, Tatura.

Binning, C., S. Cork, R. Parry and D. Shelton. 2001. *Natural Assets: An Inventory of Ecosystems Goods and Services in the Goulburn Broken Catchment*. CSIRO Sustainable Ecosystems, Canberra.

Cairns, R., C. Welch and N. Chapman. 2000. *A survey of fertiliser and Irrigation practices on dairy farms in the Goulburn Broken Catchment*. Natural Resources and Environment, Kyabram, Vic.

Cork, S., Shelton, D., Binning, C., and Parry, R. 2001. A framework for applying the concept of ecosystem services to natural resource management in Australia. In "Third Australian Stream Management Conference August 27-29, 2001". Rutherford, I., Sheldon, F., Brierley, G., and Kenyon, C. (Editors). Cooperative Research Centre for Catchment Hydrology: Brisbane. Pp 157-162

Godden, D.P. 1997. *Agricultural and resource policy: principles and practice*. Melbourne, Oxford University Press.

Proctor, W. 2001. 'Valuing Australia's Ecosystem Services Using a Deliberative Multi-criteria Approach', Paper presented to the European Society for Ecological Economics Frontiers 1 Conference, July 3-7, Cambridge, England.

Shelton, D., Cork, S., Binning, C., Parry, R., Hairsine, P., Vertessy, R, and Stauffacher, M. 2001. Application of an ecosystem services inventory approach to the Goulburn Broken Catchment . In "Third Australian Stream Management Conference August 27-29, 2001". Rutherford, I., Sheldon, F., Brierley, G., and Kenyon, C. (Editors). Cooperative Research Centre for Catchment Hydrology: Brisbane. Pp 157-162

United Nations. In prep. *Integrated Environmental and Economic Accounting – an Operational Manual*.

*** More information and related publications can be found at: ***
www.ecosystemservicesproject.org