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The Nature and Value of Australia's Ecosystem Services: A Framework for Sustainable Environmental Solutions

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Abstract: A major reason for seeking sustainable environmental solutions is to maintain the benefits that come to humans from nature and its components. The term "Ecosystem Services" has been coined to describe these benefits. Ecosystem services include provision of clean air and water, natural fertilisation and nutrient cycling in soils, mitigation of climate, pollination of plants including crops, control of pests, provision of genetic resources, production of goods like food, fuel and fibre, maintenance of cultural and social values, and others. Most ecosystem services are not adequately considered in decision making and policy development because there is insufficient knowledge about the processes that deliver the services and because there are not adequate methods for assessing impacts on them in terms that can be compared with other policy or decision options. The Myer Foundation, as part of the Sidney Myer Centenary Celebration 1899-1999, has provided seed funding for a project involving CSIRO and a wide range of land managers, community groups, land management agencies, scientists and economists. The project aims to provide a detailed assessment of the goods and services coming from a range of Australian ecosystems, an assessment of the consumers and consumption of these services, and an evaluation of the economic costs and benefits of the services under future management scenarios. This paper outlines the concept of ecosystem services and its role as a conceptual framework for environmental decisions, discusses approaches to assessing the nature and value of ecosystem services, and describes the project itself.

1. INTRODUCTION

A major reason for seeking sustainable environmental solutions is to maintain the services, or benefits, that come to humans from nature and its components. In the past, these services were assumed to be endlessly renewable, but evidence is accumulating across terrestrial and aquatic ecosystems of a steady decline worldwide (Pimentel et al 1997; Daily 1997a; Vitousek et al 1997). The terms "Nature's Benefits", "Nature's Services", and "Ecosystem Services" have been coined to describe the processes and conditions by which natural ecosystems sustain and fulfil human life (Westman 1977; Daily 1997b; Mooney & Ehrlich 1997).

The concept of ecosystem services is a way to focus debate and research on the relationship between humans and the environment, and to provide a conceptual framework to support decision-making and monitoring change (Daily 1999). To enable this concept to be applied in practice it is vital to both document and study the *nature* of the services provided by ecosystems and assess the *value* or importance (in economic and other terms) of the services in various decision contexts (Daily 1997b; Bennett 1999).

In Australia, the concept of ecosystem services has received limited attention until recently (Hobbs 1992; Jones & Pittock 1997). In the last 12 months, however, several projects have begun, with the aim of assessing both the nature and value of ecosystem services in a range of Australian ecosystems. This paper describes the planned approach and progress to date of one of these projects, and considers its potential contributions to sustainable environmental solutions in Australia.

2. THE CONCEPT OF ECOSYSTEM SERVICES

Ecosystem services include life support, underpinning of agricultural production, and provision of the basis for fulfilment of human life (Figure 1).

Production of Goods
- *Food:* Terrestrial animal and plant products, forage, seafood, spice
- *Pharmaceuticals:* Medicines, precursors to synthetic drugs
- *Durable materials:* Natural fibre, timber
- *Energy:* Biomass fuels, low-sediment water for hydropower
- *Industrial products:* Waxes, oils, fragrances, dyes, latex, rubber, precursors to many synthetic products
- *Genetic resources:* The basis for the production of other goods

Regeneration Processes
- *Cycling and filtration processes:* Detoxification and decomposition of wastes, renewal of soil fertility, purification of air and water
- *Translocation processes:* Dispersal of seeds necessary for revegetation, pollination of crops and native vegetation

Stabilizing Processes
- Coastal and river channel stability, compensation and substitution of one species for another when environments vary, control of the majority of potential pest species, moderation of weather extremes (such as temperature and wind), partial stabilisation of climate, regulation of the hydrological cycle (mitigation of floods, droughts, salinity)

Life-Fulfilling Functions
- Aesthetic beauty, cultural, intellectual, and spiritual inspiration, existence value, scientific discovery, serenity

Preservation of Options
Maintenance of ecological components and systems needed for the future, supply of goods and services awaiting discovery

Figure 1 – A classification and examples of ecosystem services (adapted from Daily 1999)

The importance of these services is rarely recognised by ordinary people. Even most decision-makers are poorly informed about them. If asked what goes into making a meal, for example, most people would describe the ingredients, the cooking utensils and the oven. They would be aware that meat, grains, fruits and vegetables must be grown somewhere, but they would be unaware of the roles of soil organisms and plants in providing food for stock, making soil and fertilising it, maintaining its structure and pH, and moving nutrients and water around so that crops can grow.

They might hear stories of salinity problems and soil acidity on the news but not realise that these are symptoms of a decline in ecosystem services or that much larger impacts have been avoided by the ecosystem services still being provided. They would be unaware that crops and native vegetation are pollinated either for free by native insects or at very low costs by domesticated bees compared with what it would cost to pollinate using machines or human labour. They might be concerned about the use of pesticides in the environment but probably do not realise that encouraging natural control of pests by native animals in natural ecosystems reduces the need for chemical controls.

In all probability they would not even consider that the reason they are not waste-high in excreta is because of the detoxification and decomposition services provided by organisms in natural ecosystems, or that the carbon humans breath out is assimilated by plants as part of the service of maintaining the composition of air within suitable limits for human life. They almost certainly would not realise that, for every square kilometre of urban area they live in, over a thousand square kilometres of natural forests, woodlands, wetlands and waterways might be needed to provide the full range of ecosystem services (Folke et al 1997).

The concept of ecosystem services if more than an interesting use of jargon by academics. It is being promoted as a conceptual framework to resolve the inevitable and ever-increasing trade-offs that humans have to make among benefits from natural systems and between these benefits and technological substitutes (Daily 1999).

The use of water by humans and ecosystems provides one example. When the use of water by natural ecosystems, production systems, industry and urban centres is properly assessed, there is no excess capacity. The water that many people think is simply flowing away unused is supporting ecosystems that provide the range of services listed in Figure 1 (Rockström et al 1999). Therefore, as demands for more food or more water for other production and industrial uses increases, other services provided by ecosystems will have to be traded-off.

To make these trade-offs in an informed way, we need comprehensive information on what the services are and what options there are to substitute for them with technological solutions.

3. APPROACHES TO ASSESSING THE NATURE AND IMPORTANCE OF ECOSYSTEM SERVICES

In a report to the President of the United States of America (PCAST 1998), a group of eminent scientists, industry representatives and bankers identified a set of important questions that need to be addressed to allow an efficient, effective and equitable balance between economic development and ongoing delivery of ecosystem services. These questions are summarised in Figure 2.

What ecosystems provide which life support services?
Who benefits and over what scales of time and space?
What are the impacts of humans upon the supply of services?
How is the supply of services related to the condition of ecosystems?
How much damage has been done already? What is needed to repair damaged ecosystems?
Where are the problems geographically?
How interdependent are ecosystem services?
How reliant are ecosystem services on biological diversity?
How much can technology substitute for ecosystem services?
Given likely future technology, what area of natural ecosystems will be needed to support human life into the future?

Figure 2 – Important questions about ecosystem services (adapted from PCAST 1998 and Daily 1999)

Subsets of these questions have formed the basis for various attempts in the last decade to assess the nature of services coming from natural ecosystems around the world and to estimate their importance to humans (e.g., Costanza et al 1997; Daily 1997a; Pimental et al 1997; Alexander et al 1998). This work builds on research on the functional role of biological diversity, (e.g. Tilman 1997; Schwartz et al 2000) which also has emerged as a field of research over a similar time frame (Mooney & Ehrlich 1997).

Assessments of the contributions of ecosystem services to human welfare have been done with varying degrees of rigour and with varying numbers of assumptions and expert judgements included to fill the usually considerable gaps in data. Most assessments to date have focussed on the magnitude and value of services delivered under current or past land management regimes. This is important as it informs people of what benefits they are getting now.

Most major decisions relating to sustainable land management, however, require information on how the delivery of ecosystem services might change under a series of alternative scenarios (Salzman 1997). This demands a more complex modelling approach to the assessment of ecosystem services and pushes current knowledge to its limits (Bockstael et al 1995).

For example, a lower-bound estimate of the contribution of natural nitrogen-fertilisation to global crop production can be obtained using average estimates of net primary production and the nitrogen concentration in the crops produced (Daily et al 1997). The economic value of this contribution can be estimated as the cost of fertiliser to replace the naturally-fixed nitrogen (US$45 billion per year), taking into account that fertiliser nitrogen is used much less efficiently than naturally-fixed nitrogen (Daily et al 1997). A value for the contribution to production of all land plants can be estimated similarly (US$320 billion). If, however, we want to estimate changes in delivery of fertilisation services, we must take account of the effects of changed management on many influencing variables, including hydrological processes (surface and subsurface water flows), erosion, tillage and harvesting regimes, fire, climate and the many variables that in turn affect them.

A good example of a scenario-based approach is the work of Higgins et al (1997). They developed a dynamic ecological economic model of ecosystem services provided by the mountain fynbos ecosystems of South Africa. They considered these ecosystems to be threatened by invading alien plants and wanted to assess the relative costs and benefits of increasing funding for management of these invasions. The model comprised five interactive sub-models of hydrology, fire behaviour, plant ecology, management regimes and economic valuation. The model was applied to a set of alternative scenarios that differed with respect to management of fire, alien plants, wildflower harvesting, and controlling hikers and ecotourists. For each scenario, two levels of economic benefit (high and low) were considered for wildflower harvesting, hiking and ecotourist visitation, water production and future use of genetic resources stored in endemic plants. The model also addressed direct and indirect costs of implementing the management scenarios. The purpose of the high and low valuations was to encompass uncertainty associated with estimating values. It was concluded that water production and genetic storage were the most valuable ecosystem services and that the costs of clearing alien plants would be a tiny proportion of the overall value of the ecosystem services protected.

It must always be remembered when adopting modelling approaches such as this that all models represent trade-offs among realism, generality and precision and that the balance between these will be determined by the objectives of the modelling. In the case of modelling ecosystem services, a prime objective will be to reduce the complexity of multiple interactions among ecosystem processes sufficiently for decision makers and stakeholders to understand what has been done, while making the uncertainty associated with predictions both clear and within acceptable limits.

There is a long and strong history of studies valuing aspects of the environment in Australia. We will not attempt a review of these here, but readers might wish to consult the ENVALUE database of the NSW EPA for examples (http://www.epa.nsw.gov.au/envalue). Very few studies, however, have attempted to assess ecosystem services broadly in Australian ecosystems, or to apply such assessments to scenarios for the future. Walpole and Lockwood, for example, have assessed the benefits coming from retention of native vegetation on farms in south-eastern Australia (Walpole 1999; Walpole & Lockwood 1999). They considered benefits such as provision of fodder for stock by native grasses, shelter for stock and timber products. Costs included those associated with control of weeds and pests harbouring in native vegetation, maintenance of fences, and management of fire. Even this impressive and labour-intensive study addressed only a small proportion of the ecosystem services listed in Figure 1.

4. VALUATION OF ECOSYSTEM SERVICES

The debate about how to value natural capital and the goods and services that flow from it has been central to the development of the discipline of ecological economics, especially over the past decade. The debate has identified two major issues: the definition of “value” and its measurement.

Texts have been written on the concept of value and expert panels have been convened to seek a unifying definition. The consensus seems to be that it is not possible to develop a single unifying definition of value and that it is more constructive to recognise and understand the different perceptions within society and how they relate to one another (Bingham et al 1995; PCAST 1998). Economic value is seen by some as just one of many values that nature can have, while others argue that properly carried-out economic valuations encapsulate all societal values (Pearce & Moran 1994). Some commentators suggest that applying economic valuations to nature enhances rather than slows its degradation (e.g., Hildyard 1982), while others argue that both the causes and solutions to environmental degradation lie in economic assessments (Pearce & Moran 1994). With respect to ecosystem services, the choice of which services to value is in itself a value judgement usually made on the basis of economic and social values (Bingham et al 1995). A pragmatic approach is to focus on the full range of welfare-enhancing benefits of ecosystem services, accepting that economic value is often considered in decision making but is rarely the sole or primary determinant.

Most economic analyses are based on markets, which are a mechanism to “reveal” how much people will pay for tradeable goods and services. Some ecosystem services contribute directly to the productions of goods that have an established market value (e.g., food, fibre, fuel, pharmaceuticals). The goods themselves can be valued by conventional techniques, but valuing the ecological processes that contributed to the goods requires detailed information on the role of each process. Often, information is not available in this detail or there is no willingness to consider the value of processes that are regarded as common property and therefore available free to all (Pearce & Moran 1994).

Most ecosystem services, however, do not pass through markets directly. While huge improvements have been made in methods for inferring values of ecosystem services indirectly, there have been strong and persistent calls for urgent research in this area for at least the last decade (Bingham et al 1995; PCAST 1998).

Indirect valuation approaches include assessing the amount people are prepared to pay for real estate (hedonic pricing method) or to travel to natural places (travel cost method) to reveal the value they place on a view or the presence of natural systems. The choices people make about complex issues involving economic, social and environmental issues can be analysed (choice modelling) to reveal the value they place on the environmental components of the choice (Bennett 1999). Alternatively, people can be asked directly what they will give up to keep the service or would accept as compensation to lose it. This "contingent valuation" has been used most commonly to estimate the value of intangible services like the value of knowing natural systems and the species within them exist (e.g., Carson et al 1994).

In recent years there has been considerable attention paid to the cost of replacing ecosystem services, or the cost avoided by conserving the services, as a measure of their value. For example, the estimates of the contribution of natural soil fertilisation services given in the previous section were both costs of replacement and costs avoided by not having to make that replacement. In a similar way, the cost of replacing the support and nutrient translocating services of soil itself have been estimated at over US$900,000/ ha (Daily et al 1997). The services of water filtration and purification provided by ecosystems in the catchment for New York City were recently estimated to be worth at least US$8 billion, which was the difference between the cost of repairing the ecosystems and building artificial filtration facilities to replace the degraded capacity of the ecosystem services (Chichilnisky & Heal 1998). In a study of Melbourne's water catchment, recommendations for timber harvesting regimes were based partly on avoiding or minimising the costs of decreased water or timber yields under a range of scenarios (Read Sturgess & Associates 1992).

Estimating replacement costs raises the question of how much substitution of ecosystem services by technological alternatives is possible or advisable, especially within an objective of finding sustainable solutions. For example, it is unlikely to be possible or desirable to totally replace natural fertilisation of soils, but the question of the relative costs of partial replacement or supplementation with fertilisers is very relevant. The use of subsidies has long obscured this analysis in Australia. The recent decline in honeybees throughout the world has highlighted the very limited and costly possibilities for technological replacement of the service of crop pollination, and has focussed attention on conserving the remaining habitat for native pollinators (Watanabe 1994; Nabhan & Buchmann 1997).

Ultimately, the value of anything is determined by people based on their perceptions about what is valuable. The value placed on ecosystem services is limited not by the adequacy of valuation methods but by lack of awareness of the services provided and lack of recognition that these services are generally in decline. For example, until recently water was rarely traded or paid for. The ecosystem services that influence climate and weather, filter and purify water once it has fallen as rain, and distribute it to where it is needed to support ecological processes or channel it to convenient collection points for industrial uses were regarded as free and endlessly renewable. The emergence of salinity and other water quality issues in Australia has highlighted the roles played by native vegetation, soil biodiversity, and other ecosystem components in maintaining water quality and regulating water tables and the costs being incurred for present and future generations. The New York water example is another high-profile example of how awareness of the value of ecosystem services has been heightened by evidence of a decline in processes once thought to be inexhaustable.

Two of the most often discussed issues relating to valuing ecosystem services are the public versus private value dichotomy and the issue of discounting. Privately owned ecosystem goods and services (e.g. food produced on a farm or the soil used to grow crops in) should in theory be protected by the owner in his/ her own interest. On the other hand, it is often unclear who should take responsibility for publicly owned ecosystem goods and services, such as non-commercial wildlife, water filtration services, pollination services from native insects, birds and mammals, and flood mitigation services. When impacts of declining services are external to the decision making of the people causing the impact (e.g. the impacts of removing trees on water tables, salinity and carbon sequestration), there are no traditional economic forces to encourage better practices (Pearce & Moran 1994).

In both economic and non-economic decisions, humans tend to put more value on having goods and services now than later. Economists often apply discount rates to account for this in calculating net present value. Any positive discount rate works against sustainable management of ecosystem services. Many economists argue that applying discounting is ethically indefensible with respect to future generations, and that alternative valuation frameworks are possible (Heal 1998). Costanza and Folke (1997) argue that while economic analysis of people's willingness to pay is a relevant approach to achieving economically efficient decisions, achieving sustainable solutions requires integrated assessment of ecological, social and economic systems and consensus-building among stakeholders based on a wider range of objectives than economic efficiency. Whereas democratic principles and traditional economic analyses give equal weight to the preferences of all individuals, it is argued that achieving sustainable delivery of ecosystem services requires weighting for certain key life-support services. This challenges institutions to make tough decisions in the interests of the community as a whole (Goulder & Kennedy 1997; Daily 1999).

One solution to these dilemmas is seen in the emergence of progressive community organisations with the legislative support to develop strategies for equitable sharing of costs and benefits of better environmental management, that are not simply market-driven (Pretty & Frank 2000). Numerous examples of these organisations are emerging in Australia (e.g., Norman et al 2000).

Most of these problems would be solved if Australia and the world had an accounting system that could track changes in the biological status of ecosystems and the services they provide and measure the importance of changes in terms that could be considered along with changes in other economically and socially important assets and flows. There has been major discussion nationally and internationally about including natural capital in national accounts, but there remain large problems to overcome (Solow 1993). The furore surrounding the recent attempt by Costanza et al (1997) to estimate the total value of the world's ecosystems illustrates some of the problems. These authors were criticised because they violated some assumptions of economics by aggregating a series of estimates of marginal value, because they proposed a figure that no-one is likely to pay for a commodity that the world is unlikely to sell, and because they compared their figure with the world's Gross National Product, a measure that is influenced by ecosystem services but is incapable of recognising their importance. The magnitude of the estimate, which outstripped GNP, again underlined the need to take account of the ongoing contribution of ecosystem services to human welfare; economic and otherwise.

5. OPPORTUNITIES AND SOLUTIONS FOR AUSTRALIA

One of the key advantages of taking an ecosystem services approach to assessing natural resources, is the new insights gained about sustainable and cost-effective alternatives to engineering or technological interventions. In Australia, most of these options remain unrecognised, because they have not been looked for in a serious way. In this section, we present just a few examples of opportunities and potential opportunities for Australia that have emerged recently.

5.1 Cheaper and more sustainable delivery of clean water

The New York water study (Chichilnisky & Heal 1998) focussed world-wide attention on the cost-effectiveness of using ecosystems to filter and purify water. The Thompson River study (Read Sturgess & Associates 1992) brought attention to impacts of forest management on delivery of water to cities in Australia. We have not yet assembled data on the amount that Australian towns and cities spend on water filtration but a small example relates to the NSW town of Goulburn. This town receives water from two catchments, one heavily cleared and one retaining considerable native vegetation. Costs of filtering water in the vegetated catchment are considerable less than those for the heavily cleared catchment (John Williams, CSIRO, personal communication). This example awaits detailed study to determine what the contribution of ecosystem services is to the difference, but it illustrates that opportunities for better use of environmental filtration and purification services are at least as great in Australia as elsewhere in the world. Of course, any comprehensive assessment of the welfare benefits from retention or replacement of vegetation in catchments such as these would need to consider other benefits, like mitigation of water-table rise and soil acidity and improved conservation of biodiversity and aesthetic values, as well as possible dis-services like reduced water reaching dams and less area of land available for crops and stock.

Outbreaks of planktonic algae have become a major problem in terms of contamination of drinking water and reduction in fish numbers and recreational values of waterways in Australia. Recent evidence suggests that improved management of plankton-eating crustaceans and fish, together with management of nutrient flows into waterways, is likely to improve control of algal outbreaks substantially (Matveev 1998). This is an example of a pest regulation service from natural ecosystems that is likely to be more cost effective that engineering and chemical alternatives.

5.2 Trees do more than pump water

Clearing of native vegetation in Australia to establish pastures and European based agricultural production systems has had various negative impacts on soils, including salinisation, acidification, erosion, and structural degradation. Apart from the well-publicised effects of trees on water tables and salinity through the water-pumping action of their roots, trees maintain soil organic matter through the supply of litter and root residues, can enhance the nitrogen status of the soil, and take part in recycling and translocation of nutrients in association with mycorrhizal fungi (Noble & Randall 1998). All of these services are accomplished by nature at a fraction of the cost of any known engineering alternatives (Daily et al 1997). An additional opportunity for benefit from an ecosystem service has emerged with the recognition that trees may play a role in reversing soil acidity by bringing bases such as calcium and magnesium from deep in the profile and returning them to the soil surface as leaf litter containing organic anions (Noble & Randall 1998). There is little evidence on which to base estimates of the extent of this service, and other processes mediated by trees can work in the other direction. Nevertheless, there is optimism that acid amelioration could be economically important since acidification of soil is the most significant threat to agricultural productivity in many areas.

5.3 Services from soil organisms

Organisms living in agricultural soils in Australia feed on plant material and one another to form food webs. Between them, these bacteria, protozoans, fungi, nematodes, mites, earthworms and other animals maintain soil structure and fertility, move nutrients and carbon around the soil and to and from plant roots, breakdown wastes of wild and domestic animals and humans, detoxify pollutants and other chemicals, and control or prevent outbreaks of organisms that can be harmful to plants and animals, including humans (Daily et al. 1997).

Unpublished models and preliminary evidence suggests that measures to better manage the composition of soil and the food webs in it could decrease requirements for water, pesticides and fertilisers by at much as 50% in orchards in south-eastern Australia, while also helping to control above-ground pests like thrips (Matt Colloff, CSIRO, personal communication). This could lead to major reductions in costs and improvements in environmental quality given the very large amounts spent annually on pesticides and fertilisers in agricultural land and on treating water to remove phosphorus and other contaminants.

5.4 Pollination services

About 92% of plants worldwide are pollinated by animals, and in about half of these reproduction is determined more by the numbers of pollinators visiting them than by weather, soil fertility, diseases, parasites or animals that eat their flower (Nabhan & Buchmann 1997). There are more than 1200 vertebrate species and between 100,000 and 200,000 invertebrates involved in pollination of flowering plants (Nabhan & Buchmann 1997), yet most crops in the USA and Australia are pollinated mainly by introduced honey bees (Gill 1989; Nabhan & Buchmann 1997). The value of honey bees to agriculture in the USA is estimated to be US$2 – 8 billion annually, based on estimates of increased seed and fruit production due to bees alone and changes in commodity prices with supply (Nabhan & Buchmann 1997). An estimate for Australia is A$1 – 605 million (Gill 1989).

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

In Australia, a range of native moths, beetles, flies and bees are reported to be important pollinators of commercial crops (George et al 1989; Garrett 1999; Heard 1999). The role of vertebrates as pollinators of some native plants also has been emphasised (Carthew & Goldingay 1997). However, the overall potential for native pollinators to substitute for honey bees is unknown. Concerns have been raised about declining pollination rates of native vegetation in agricultural landscapes (Cunningham in press), suggesting that fragmentation and use of pesticides is having impacts on pollination services in Australia also.

Thus Australia, due to greater retention of native vegetation than the USA, has opportunities to:

- improve ecological insurance against declines in honey bees;
- investigate potential increases in production efficiency and decreased costs for some crops by encouragement of native pollinators;
- increase returns on investment in retention and restoration of native vegetation by arresting declines in pollination rates by native pollinators.

5.5 Assimilation of carbon and other wastes

The sequestration of carbon by plants can be seen as part of the ecosystem services of regulating air quality and assimilating wastes. Studies of cities around the Baltic Sea (Folke et al 1997) suggest that on average around 1,000 km^2 of forests, arable land, wetlands, and inland and marine waters are required to provide natural resources and assimilate carbon, nitrogen and phosphorus wastes per km^2 of city. This is around 0.09 km^2 per person (or about 120 average house blocks in Canberra). An assessment of a smaller set of ecosystem services used by Canberra estimated that around 60 house blocks are required per person in this Australian city (Close & Foran 1998). In the Baltic study, over 80% of the area was required for assimilation of carbon and the other wastes. Generalising the analyses to the 744 largest cities in the world, it was estimated that the world's needs for carbon sequestration already outstrips capacity substantially (Folke et al 1997).

Australia's international obligations with respect to minimising net carbon emissions have been a topic for hot debate recently, and plans to develop carbon credits as a mechanism to encourage planting of vegetation are well advanced. These developments present very large opportunities for Australia to link sustainable development with maintenance of a very important ecosystem service.

6. A NEW FOCUS ON ECOSYSTEM SERVICES IN AUSTRALIA

As part of the Sidney Myer Centenary Celebration 1899-1999, the Myer Foundation has provided seed funding for a project on ecosystem services involving CSIRO and a wide range of land managers, community groups, land management agencies, scientists and economists. The project will run from June 1999 to June 2003. It aims to provide a detailed assessment of the goods and services coming from a range of Australian ecosystems, an assessment of the consumers and consumption of these services, and an evaluation of the economic costs and benefits of the services under future management scenarios. The project seeks to provide information that is relevant and useful to policy writers and decision makers. It seeks two key outcomes:

- Changed thinking by Australians about the services and values from natural ecosystems;
- Greatly increased consideration of the benefits of ecosystem processes in natural resource policy and management

We hope to perform at least four case studies once additional funding is secured from a variety of sources. The case studies are expected to include: an agricultural catchment in temperate Australia; a mixed-use catchment in tropical Australia; a representative area of the semi-arid rangelands; a forested catchment supplying water to a major urban centre.

Work has commenced on the first case study, in the Goulburn-Broken Catchment of Victoria. CSIRO has entered a partnership with the Goulburn-Broken Catchment Management Authority, and additional support is being provided by the Land and Water Resources Research and Development Corporation. Community members, industry, technical experts, and agencies have been involved from the beginning to plan and execute the project. We have held initial workshops to identify ecosystem services and develop preliminary models and scenarios for change. These will be refined over the next two years with regular input from policy developers and decision makers at all levels to ensure products are appropriate.

A companion project is commencing as one program in the Rainforest Co-operative Research Centre based in Brisbane and Atherton. This project will examine ecosystem services in the Atherton region of north Queensland. Co-operative links are being developed with another project on interactions between rice growing and ecosystem services in northern NSW (Nick Reid, University of New England, personal communication).

To achieve the outcomes of changed thinking and greater consideration in policies and decisions, we have planned a major communication and marketing effort aimed at raising awareness of the issues and conclusions.

7. CONCLUSIONS

It has been argued that the benefits of conservative management of ecosystems often outweigh the costs when the true value of natural capital (including ecosystem services) is properly calculated (James et al 1999). The challenge for those seeking sustainable solutions for environmental management in Australia is to identify the full range of benefits (services) coming to companies and individuals from properly functioning ecosystems in ways and at scales that allow the benefits to be included in decisions based on social, environmental and economic considerations.

Evidence is emerging already that improved information of this sort can lead not only to more equitable sharing of the costs and benefits of environmental works but also to market advantage to those who take the lead. Communities in the Goulburn-Broken catchment have successfully negotiated cost-sharing agreements with the government of Victoria based on information about private and public benefits of environmental works. Historical lessons from our own region (e.g. the South Pacific islands such as Easter Is) show that failure to understand the long-term dynamics of ecosystem processes in relation to use of natural resources can have devastating economic, social and environmental effects (Daily 1999). Australia's own failure to recognise the emergence of salinity as a major problem should warn us that modern-day humans are still limited in their ability to appreciate complex ecological issues.

To learn from past mistakes and to achieve sustainable solutions, requires us to;

- accumulate a strong and relevant information base on the services from nature that maintain and fulfil human life;
- communicate widely among members of our communities;
- develop institutions that are able to adapt and learn within the uncertainties of the Australian environment and incomplete scientific knowledge;
- involve both the "ordinary" people and private enterprise more effectively in developing and implementing policies and plans (Berkes & Folke 1994; Daily 1999; Daily & Walker 2000; Pretty & Hardy 2000).

Hard decisions about major changes in land use might be required, but we can only make these with good information about how ecosystem services will be affected directly by management and indirectly by their own interrelationships, and by involving the people who can make policies work. Calls for institutionalising public involvement in decisions about land management were loud and clear at the recent International Landcare Conference in Melbourne. Both globally and in Australia, opportunities are being identified for synergies between private enterprise and science in developing solutions for achieving environmentally sustainability (Daily and Walker 2000; Baltzell 2000).

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