

Ecosystem services: The many ways in which biodiversity sustains and fulfills human life

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ABSTRACT: Ecosystems are declining worldwide, largely due to ignorance of their value to humans and inadequate social and economic mechanisms to encourage individuals to invest in maintaining them. The concept of Ecosystem Services is becoming popular as a way to encourage discussion about the dependence of humans on nature and what that means socially and economically. Ecosystem services are transformations of natural assets (soil, water, air, and living organisms) into products that are important to humans. Examples include: provision of clean air and water; maintenance of soil fertility; maintenance of liveable climates; pollination of crops and other vegetation; control of potential pests; provision of genetic resources; production of food and fibre; and provision of cultural, spiritual and intellectual experiences. The value of ecosystem services to humans comes from their role in supporting our lives, their cheapness, and our limited ability to replace them with human-engineered alternatives. The problems we have in maintaining them come about because our economic systems don't cope well with goods and services that are publicly owned. This paper discusses the importance of ecosystem services for supporting food production and sustaining and fulfilling human populations. It briefly discusses an initiative being taken in Australia to apply the concept of ecosystem services to addressing the big drivers of ecosystem decline.

1. INTRODUCTION

The concept of ecological, social and economic sustainability is a poorly formed one in the minds of most people. For many years, ecologists have been arguing that the diversity of life on earth (biodiversity) provides the essential underpinnings for all three components of sustainability. These arguments have been focussed considerably over the past 5 years by promotion of the concept of Ecosystem Services as a way to get scientists, economists and the rest of our human communities thinking about and discussing the relationships between people and their natural environments and the values and opportunities that come from those relationships.

In a milestone publication "Nature Services: Societal Dependence on Natural Ecosystems", Gretchen Daily from Stanford University in the USA defined ecosystem services as "*the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life*". Some of what sustains human life is obvious. We need food, drinkable water, breathable air, and liveable climates. Each of these is underpinned by a set of ecosystem services, including: filtration and delivery of water; absorption of wastes; maintenance of atmosphere and climate within limits suitable for human life; maintenance of soil fertility and structure; natural pest control; pollination of crops and native vegetation; maintenance of habitat and biodiversity; maintenance of genetic resources; and protection from floods and other extreme weather.

These services are provided by plants, animals and other organisms above and below ground interacting with the non-living components of the environment (e.g. air, water, minerals etc.). Essentially, this complex of interacting living and non-living components is what defines ecosystems.

<p>Production of Goods</p> <p><i>Food:</i> Terrestrial animal and plant products, forage, seafood, spice</p> <p><i>Pharmaceuticals:</i> Medicines, precursors to synthetic drugs</p> <p><i>Durable materials:</i> Natural fibre, timber</p> <p><i>Energy:</i> Biomass fuels, low-sediment water for hydropower</p> <p><i>Industrial products:</i> Waxes, oils, fragrances, dyes, latex, rubber, precursors to many synthetic products</p> <p><i>Genetic resources:</i> The basis for the production of other goods</p> <p>Regeneration Processes</p> <p><i>Cycling and filtration processes:</i> Detoxification and decomposition of wastes, renewal of soil fertility, purification of air and water</p> <p><i>Translocation processes:</i> Dispersal of seeds necessary for revegetation, pollination of crops and native vegetation</p> <p>Stabilizing Processes</p> <p>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)</p> <p>Life-Fulfilling Functions</p> <p>Aesthetic beauty, cultural, intellectual, and spiritual inspiration, existence value, scientific discovery, serenity</p> <p>Preservation of Options</p> <p>Maintenance of ecological components and systems needed for the future, supply of goods and services awaiting discovery</p>

Figure 1: *A classification and examples of ecosystem*

Less obvious for many people is the importance of cultural, intellectual, and spiritual experiences in not only fulfilling human life but also sustaining it through effects on mental and physical health and well being and on people's ability to work productively. Further examples of ecosystem services are given in Figure 1. In the rest of this paper, I discuss the disturbing trends in ecosystem decline around the world, why this decline is happening and how the concept of ecosystem services is emerging as one tool for addressing the underlying causes of problems relating to food, population and resources.

2. WHY WORRY ABOUT ECOSYSTEM SERVICES – THE CONSEQUENCES OF WORLDWIDE DECLINE IN ECOSYSTEM FUNCTION

In 2000, the World Resources Institute in Washington DC published an assessment of the world's ecosystems made by experts around the globe. These experts concluded that most

of the world’s ecosystems are in fair, poor or bad condition with respect to delivering ecosystem services (Figure 2). They concluded that: *“If current trends continue, humanity will dramatically alter or destroy virtually all of the Earth’s natural ecosystems within a few decades”*.

These conclusions prompt many questions, but chief among them are:

- Why is this happening?
- What does it mean to ordinary people?

The literature offers answers to the first question, but scientists and economists have failed to answer the second question for the vast majority of people who have limited scientific or economic training. Later in this paper, I will suggest that the concept of ecosystem services offers a framework for answering this question. But first we need to consider why it might be important to provide an answer.

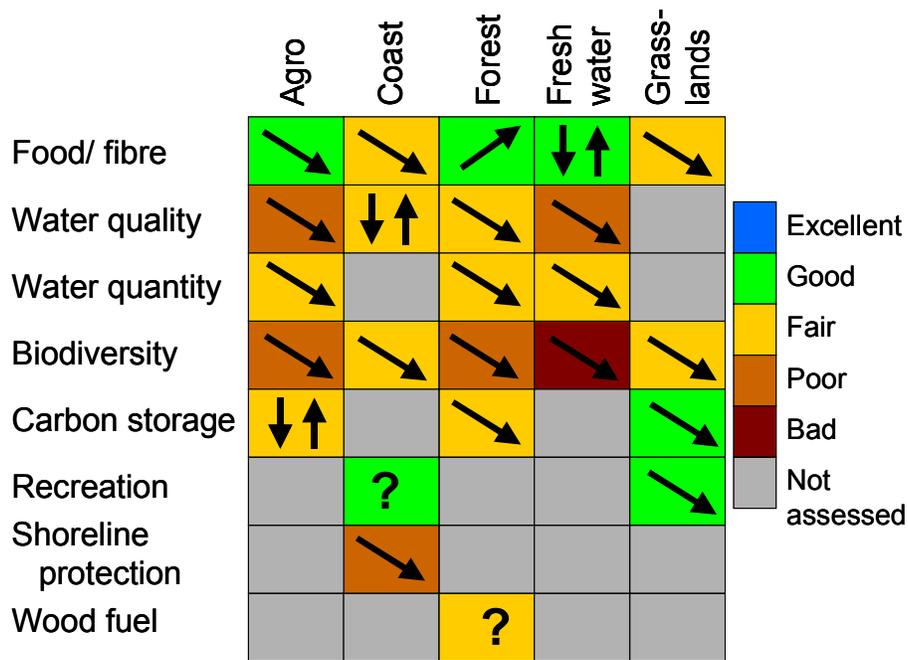


Figure 2: Summary of the findings of the World Resources Institute assessment of the world’s ecosystems. Arrows indicated the expected trajectory of the systems, with a combination of up and down arrows indication improvement in some aspects and decline in others.

3. WHY ARE THE WORLD’S ECOSYSTEM DECLINING?

In recent years, progressive economists have turned their attention to why humans have allowed ecosystem to decline to the state we see today. The reason, expressed simply, is that we have failed to give ecosystems and the services that come from them as much value as other activities and products that degrade ecosystems. Three broad reasons are advanced to explain this situation:

- Ignorance
- Market failure
- Institutional failure

Ignorance

People, who as voters and consumers ultimately determine the value of ecosystems, generally are not well informed about the benefits that come from the natural environment and the potential to lose those benefits under some management regimes. If they are aware, they tend to assume that ecosystems are endlessly regenerating. More than at any previous time in human history, we have the ability and confidence to at least partially replace ecosystem services with technological alternatives. Generally, however, there has been limited consideration of when and where this replacement is economically or socially effective.

Market failure

Many of the components of ecosystems are publicly rather than privately owned, meaning that private markets that might give price signals when resources decline do not emerge and that decline of ecosystems due to other economic activity is not factored into costs in those markets. Economists have developed tools to assess what people are willing to pay for non-market ecosystem services, but these methods have some major limitations.

Firstly, they focus on the preferences of individuals (a central assumption in neo-classical economics is that people make decisions as individuals and out of self interest). This is a useful approach if our objective is economic efficiency, but the preferences of individuals do not necessarily lead to social or ecological sustainability. Some economists argue that we need to move beyond neo-classical economic approaches towards forms of debate and dialogue that include the views of communities as well as social and physical scientists about what is ecologically and socially sustainable as well as what is economically efficient.

Secondly, people's willingness to pay for anything depends on their awareness and understanding of what is valuable, and we recognize that people's understanding of what is valuable about ecosystems is low. Therefore, although economic tools technically measure the value people currently give to ecosystem services, it would be a mistake to equate this to the *importance* of ecosystems to humans generally.

Thirdly, *value* and *price* are often confused in discussions about ecosystems and their services. The example most often used to illustrate this issue is the comparison between prices paid for diamonds versus water. Diamonds fetch a higher price because they are rarer but water is clearly more valuable and important to humans. However, policies with respect to trading off ecosystems against development often consider price rather than value and because the loss of a few extra trees will incur smaller costs for, say, flood protection, maintaining air quality and maintaining biodiversity than the financial benefits from the development, the ecosystem get a lower priority. This, of course, often ignores whether the costs of reduced ecosystem services are met by the developer.

Finally, impacts of human uses of land often occur at another place or time than where the activity occurs. This often means the impact occurs outside the market in which the activity occurs. Such effects are called “externalities”. Market processes often fail to include the costs of externalities in costs of production, and this favours greater degradation of ecosystems than would be warranted if all costs and benefits were considered.

Institutional failure

Institutional failure occurs when governments or other institutions impose policies and practices that make market failure worse (e.g. inappropriate subsidies that reduce the costs of technological alternatives to ecosystem services). Institutions also have generally done a poor job at creating demand for ecosystem services (e.g. through tax and other incentives) or manipulating scarcity (e.g. with usage caps and other regulations or standards). There is increasing interest in Australia about how to stimulate markets for, and investment in, ecosystem services.

4. HOW AN ECOSYSTEM SERVICES FOCUS CAN HELP AUSTRALIA AND THE WORLD ADDRESS THEIR BIG PROBLEMS WITH FOOD, POPULATION AND RESOURCES

The decline in the world’s ecosystems means a decline in the natural resources and ecosystem services that support production of food and other essentials for sustainable human populations. The consequences of this decline are gradually emerging. Cities around the world are facing crises with respect to water quality. They are finding that not only is it questionable whether technology can solve the problem but that it often is cheaper to invest in repair of the catchments to the point that they can do the filtration as well as providing a range of other services that filtration plants do not. The most famously documented example is New York City, but Australian cities including Brisbane, Sydney, Melbourne, Adelaide and Perth are moving towards similar conclusions.

Scandinavian cities have found that technology is not able to assimilate their wastes and that not enough ecosystems remain to receive waste assimilation as an ecosystem service. The result is steady pollution of the Baltic Sea. In agriculture, the role of plants and soil microorganisms is finally being recognised. Some estimates suggest that in parts of Australia we use as much as twice as much fertilizer, pesticides and water as would be needed for crop production if soil biodiversity were managed effectively. This would represent large direct savings on the billions of dollars spent annually in Australia on these inputs, but would also have large indirect savings related to cleaner water, better community health and a range of life-fulfilling services provided when ecosystems are managed for biodiversity as well as production.

One ecosystem service often overlooked is pollination – the transfer of pollen between flowers that results in production of seeds and fruits in both commercial crops and nature vegetation. Over 90% of plants worldwide are pollinated by animals and about 50% of those are limited in their production of seeds by how often they are visited by pollinators.

Pollinators are declining worldwide due to clearing of habitat and use of pesticides. Increasingly honeybees are being used to replace native pollinators at substantial costs to farmers. Now parasites and diseases threaten honeybees in Europe and North America and could soon reach Australia. Imagine if you can a technological substitute for the ecosystem service of pollination (thousands of people with paintbrushes perhaps?) and you will start to appreciate the potential value of this service. While on the subject of technological replacement, consider how we replace the value of knowing that other species are safe on this planet, the pleasure we get from seeing and experiencing natural places, or the medicines , chemicals and genetic materials that have improved human life and came originally from nature.

To put ourselves in a better position to consider ecosystem services in decision making, we need to address the underlying problems discussed in Section 3. To do this we need several ingredients:

- Assessments (e.g. inventories) that assemble information on what services come from which ecosystems around Australia and communicate that information to communities in ways that it can be used in decision making
- Imaginative use of coupled ecological and economic analyses that build people's understanding of what is valuable and move beyond the neoclassical paradigm of individual preferences
- A focus on real decisions facing communities, because the value that can be gained from better use of ecosystem services depends on what services are needed, what the demands are from people, where ecosystem elements like wetlands and forests occur with respect to where humans live, and the amount, type and cost of technological alternatives
- Above all, a framework and language that allows all sectors of communities to engage in the dialogue about natural resource management, rather than restricting it to those who understand technical jargon.

5. AN AUSTRALIAN INITIATIVE

With backing from The Myer Foundation (a philanthropic organization based in Melbourne) and Land and Water Australia, CSIRO and a range of other agencies, institutions and community organizations and individuals have formed a partnership to address the key causes of ecosystem decline and provide better support for natural resource policy and management using the concept of ecosystem services. The initiative is outlined at www.cse.csiro.au/ecoservices and several recent publications can be obtained by contacting me by email at steve.cork@cse.csiro.au. The initiative currently consists of seven cooperating projects around Australia (Figure 3) trying to:

- Perform assessments (inventories) of ecosystem services in different ecosystems in collaboration with communities
- Assess what is happening to those services and the processes underpinning them
- Work with communities to examine ecological, economic and social implications of relevant decisions and scenarios for land use change identified by communities

- Investigate better use of market mechanisms to encourage wise use of ecosystem services for increased public welfare.

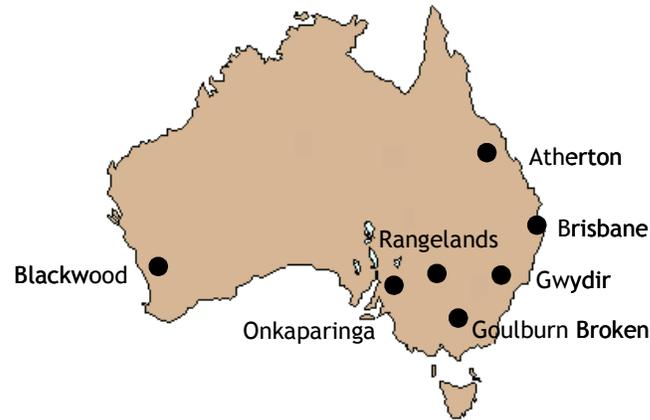


Figure 3: Existing case studies in the Ecosystem Services Project.

This initiative makes use of the concept of ecosystem services as a framework and language for engaging diverse groups from communities. Thus, instead of technical jargon like nutrient cycling, mineralisation, carbon sequestration, predator-prey interactions, phosphate sorption, and geomorphic recovery, we talk of services that most people can appreciate. For example: maintenance of fertile soil; maintenance of liveable atmosphere and climates; maintenance of healthy streams for clean water, fish, protection from erosion and floods. This puts our relationship with the environment into a similar context to our relationship with a baker, a chemical company, or an artist. All of these individuals and companies provide services by taking raw materials and transforming them into something of greater value, just as ecosystems provide services by taking soil, water, air and living organisms and creating tangible and intangible ecosystem products that people value.

The first stage in this initiative is an inventory of ecosystem services based on the Goulburn Broken Catchment of northern central Victoria. The inventory team worked with communities and technical experts to ask questions about:

- What tangible and intangible products (from wheat to cultural experiences) of importance to people come from the catchment?
- What ecosystem processes and services underpin those products?
- What is happening to those services?
- Which services are near a point where a small change in the service could have a large impact on products from a range of land uses or where a small change in natural resources could cause a big change in the delivery of the service?

The results (Figure 4) suggested that several ecosystem services are near critical points for a range of land uses and that every ecosystem service identified was near a critical point for at least one land use. The inventory is the first of its kind in the world. It

documented the thought processes of those consulted as a starting point for dialogue and focused research in later stages of the process.

SERVICES	LAND USES											
	Dairy	Fruit and grapes	Vegetables	Grazing	Crops	Intensive animals	Forestry	Food processing	Housing	Water production	Recreation	Culture/ biodivers
Pollination		■										
Life-fulfillment	■			■					■			■
Climate regulation	■	■				■		■				
Pest control		■	■	■	■							
Genetic resources				■								
Habitat regeneration		■	■	■			■		■		■	■
Shade and shelter	■	■		■	■				■			
Soil health	■	■	■	■	■							
Healthy waterways	■	■		■			■	■		■	■	
Water filtration			■	■	■					■		
River regulation	■	■		■	■					■	■	
Waste absorption	■	■	■	■	■	■		■	■	■	■	

Figure 4: Ecosystem services (rows) judged to be of high importance to various land uses (columns) in the Goulburn Broken Catchment.

6. CONCLUSIONS

The concept of ecosystem services echoes debates that have been under way for decades about the unrecognized impacts of human activities, the values and benefits that could come from better management of the natural environment, and the role of biodiversity in sustaining and fulfilling human life. What is new is that the emergence of this concept has led to unprecedented attention from scientists and economists around the world on documenting the full range of services from ecosystems and considering in detail the social, economic and ecological costs and benefits of trade-offs between ecosystem services and technological alternatives. More than any time in human history, we are able to address environmental problems with technology and this undoubtedly improves human welfare in many cases. However, more and more examples are emerging where the breadth of benefits from ecosystem solutions has been underestimated in decisions about land management and where it can be more efficient economically to go for an ecosystem service rather than a technological alternative. The concept will continue to be a focus for dialogue about these issues in the next decade and to provide a framework and language that includes diverse sectors of society in the dialogue by breaking out of technical jargon.

7. SUGGESTIONS FOR FURTHER READING

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