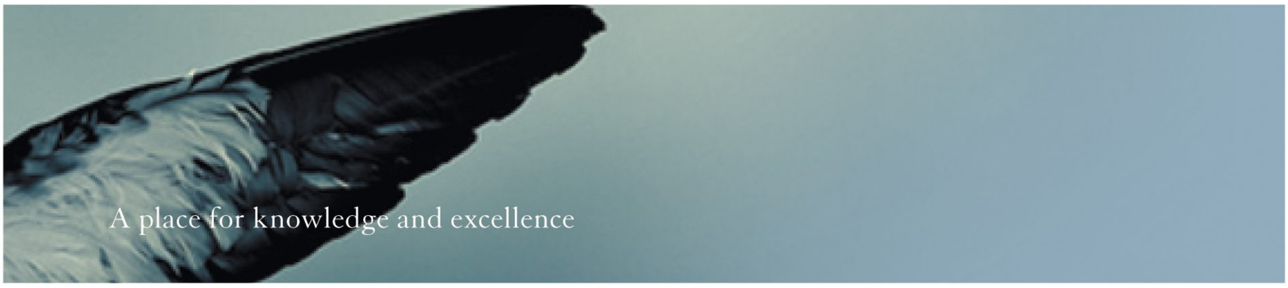

the ROYAL SOCIETY of NEW ZEALAND
TE APĀRANGI

ECOSYSTEM SERVICES

Emerging Issues

Humanity, like all species, lives within habitats, communities, and ecosystems. At each of these scales, the natural world provides numerous contributions to human well-being; however, few of these services are widely recognised, and fewer are valued. An awareness of ecosystem services involves the study of these contributions, with the aim of recognising, measuring, understanding, and enhancing their value. Recognising these contributions allows the inclusion of a wider range of ecological, social and economic factors into the trade-offs that are an integral part of natural resource management decisions. Ecosystem services approaches also provide a common language for conflicting users of natural resources to communicate and share their values, providing a way of breaking the impasses that characterise such conflicts.

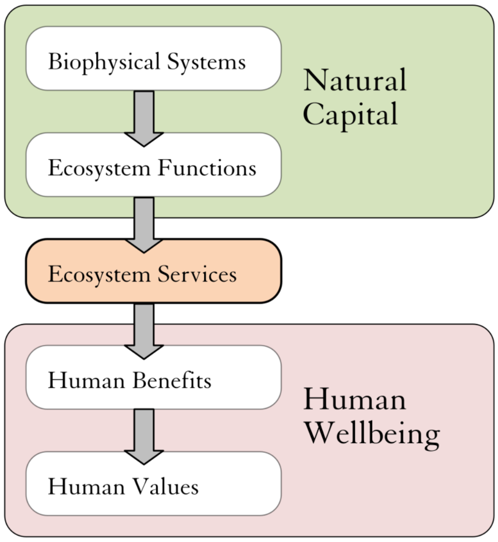

Figure 1: Linkages from natural capital through ecosystem services to human well-being.

Recognising the environment in economic decision-making

Internationally, the topic of ecosystem services has a high priority due to the growing awareness that the environment and the economy are fundamentally interlinked. An ecosystem services approach is a way of quantifying and incorporating what we implicitly value in the environment into production and governance practices. When the value of these services is not recognised in the marketplace, this leads to decision-making failures. In contrast, their inclusion enables practices that enhance overall economic, environmental, and social values. Inclusion advances decision-making that leads to more efficient and acceptable trade-offs between different economic, environmental, and social values.

From 2000 onwards, the UN-driven Millennium Ecosystem Assessment (MEA) highlighted the ongoing loss of those services and the major gaps in knowledge around the economic value of non-marketed services. There has been slow progress since then in incorporating the link between ecosystems and human welfare into policy. The Economics of Ecosystems and Biodiversity (TEEB) and the UNEP's Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) are significant initiatives attempting to address this through studying how "economic concepts and tools can help equip society with the means to incorporate the values of nature into decision-making at all levels".[1]

The UK's recent National Ecosystem Assessment shows the UK's decisive shift towards an ecosystems approach for their policy-making, seeing this approach as driven by the most up-to-date thinking about securing the environment. Explicit in this work is the recognition of the need for "a better grasp of the values of the full range of ecosystem services, including cultural values based on ethical, spiritual and aesthetic principles.[2]

Ecosystem services are ecosystem functions that bring benefits to people

The substantial MEA report defined ecosystem services as: "The direct and indirect contributions of ecosystems to human wellbeing". Figure 1 shows one commonly-used breakdown of the linkages explored by the study of ecosystem services. Stocks of natural capital (biophysical structure, processes, and ecosystem functions) provide flows of ecosystem services which bring benefits that are valued. The MEA categorised these contributions as: "provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, pests, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; with supporting services such as soil formation, photosynthesis, and nutrient cycling behind all others."[3]

Ecosystem services were brought to widespread attention by a landmark 1997 paper by Robert Costanza et al, a paper recognised as the second most highly-cited analytical paper in the history of environmental studies. That work estimated the economic value of global ecosystem services at US$33 trillion per year, nearly double the global GNP of US$18 trillion per year, making clear the magnitude of both the contribution that ecosystems make to human wellbeing and the extent to which the environment is latent in current economic measurement.[4]

At a regional level, these services remain substantial - a classic study is New York City's investment to preserve water supply from the Catskill Mountains watershed. A US$1 billion investment in supporting and regenerating ecosystems to secure natural water purification avoided an estimated US$7 billion cost in built infrastructure.[5]

There is specific and consistent evidence for New Zealand ecosystem services: forests prevent soil erosion; forests and riparian vegetation can improve water quality and affect water yield; microbial life and shellfish can reduce pollution and increase water clarity; marine reserves can benefit local fish stocks; and managed, unfarmed refuges improve natural pest control on nearby farmland.[6] In vineyards, an ecosystem services approach has guided the deliberate planting of plants that support natural predators of pests —where an investment of NZ$3 in seeds has the potential to reduce pesticide cost by $200 per hectare per year.[7] However, this impact of kind of 'ecological engineering' goes beyond cost efficiencies. Investing to build natural capital can enhance a wide range of services that provide numerous benefits, beyond just those valued by the market.

Ecosystem services has been used as a framework to consider the impacts of water storage dams. One example is shown in Table 1, where a list of the many ecosystem services provided by the Opihi River is presented, along with the expected and actual changes due to the construction of the Opuha dam.

Legal enablement of ecosystem services frameworks
In the Resource Management Act 1991, sustainable management includes "safeguarding the life-supporting capacity of air, water, soil, and ecosystems". Similarly, the Hauraki Gulf Marine Park Act 2000 includes recognition of the "interrelationship between the Hauraki Gulf, its islands, and catchments and the ability of that interrelationship to sustain the life-supporting capacity of the environment… including the capacity to provide for the historic, traditional, cultural, and spiritual relationship of the tangata whenua … and to maintain the soil, air, water, and ecosystems of the Gulf."

These statements illustrate how ecosystem services are already a part of policy frameworks. Tertiary level authorities are giving effect to them by developing tools to connect ecosystem services with habitats under management plans,[8] by considering ecosystem values in Environment Court proceedings,[9] researching how people value the benefits of a healthy environment,[10] and by starting to include ecosystem services in regional planning policies.[11]

Indicators of ecosystem services are currently of limited utility for policy
Biophysical and socioeconomic indicators are used to measure and quantify changes in ecosystem services. For example, the quantity of food produced from a given piece of land is a direct measure of the provisioning service. Indicators for provisioning services are generally more readily available than indicators for regulating and cultural services; indicators overall lack comprehensiveness, relevance across a wide range of scales, and environmental data is often inadequate to show long-term trends.[13] Indeed, in the Opuha Dam case study, the only conclusive evidence for changes in ecosystem services was for water supply and flood protection. For the other impacts, indicators were not extensive or meaningful enough to draw conclusions.[14]

Ideally, ecosystem service indicators should incorporate the complex connections between ecosystem functions and economic value. For example, soil porosity is an indicator of both pasture growth and nutrient loss. However, target ranges for porosity vary with soil type and are not clearly linked to outcomes at the pasture or catchment level. This complexity imposes difficulties, which suggests that practical indicators should be chosen to be relevant to natural resource management decisions.[15]

Similarly, the choice of ecosystem service indicators should incorporate the links between ecosystem functions and social values. Where there is little

Ecosystem service class	Ecosystem service	Sub-class	Impact of Opuha Dam	
			Hypothesized	Actual
Provisioning	Food	Salmon & trout	Mixed	Mixed
		Mahika kai (*e.g.* eel, whitebait)	Mixed	?
	Fibre	Flax, driftwood	↑	?
	Freshwater supply	Irrigation	↑	↑
		Hydroelectric production	↑	↑
		Municipal water supply	↑	↑
		Industrial water supply	↑	↑
		Stock water supply	↑	↑
	Abiotic products	Gravel extraction	Unchanged	Unchanged
Regulating	Disease regulation	Parasite & toxic algae regulation	↓	?
	Water regulation	Hydrological flow regulation (*e.g.* minimum river flows, flushing flows)	Mixed	↑?
	Water purification	Removal of pollutants	Mixed	↓?
	Erosion control	Stabilisation of river banks	↑	↓?
	Pest regulation	Invasive non-native species	↓	↓?
	Natural hazard regulation	Flood & drought protection	↑	↑
Cultural	Conservation	Native biodiversity & habitat	↓	↓?
		Endangered native species	↓	↓?
		Ecological landscapes of significance	Mixed	?
	Education	Historical/archaeological values	Unchanged	?
		Knowledge systems	Mixed	?
	Aesthetic values	Perceived beauty	Mixed	?
	Spiritual values	Natural character	↓	?
		Life supporting capacity (*mauri*)	↑	↓?
	Recreation	Boating	↑	↑?
		Fishing	Mixed	Mixed?
		Hunting (*e.g.* duck hunting)	↑	?
		Picnicking	↑	?
		Swimming	Mixed	?
		Walking	Unchanged	?

Table 1: The ecosystem services provided by the Opihi River and the hypothesised and actual impacts of the Opuha Dam ten years after construction. Note that '?' indicates uncertainty as to the impact on the particular ecosystem service." Supporting services were implicitly included via their effects on provisioning, regulatory, and cultural ecosystem services. Adapted from Table 18, reference 14.

consensus over socioeconomic values and high scientific uncertainty, problems will rarely be resolved only by more and better measurement. Instead, researchers have to recognise their role as creators and honest brokers of knowledge within a given social context and recognise that choices of biophysical and socioeconomic indicators reflect prevailing value systems.[16]

Values and valuation are always multifaceted and contingent

Valuation attempts to connect biophysical features with human values. Very often, that valuation is carried out with the aim of creating a level playing field for the comparison of market values against ecological losses or benefits. For some services, such as food provision, valuation is simple — the volume of production is known and an economic value is created by a market mechanism. Other services have an obvious economic value, such as natural pest control, crop pollination, or planting for shelter belts and erosion control, but that value may be difficult to measure directly. Further services may have future values - potential anti-cancer drugs from sea sponges currently have no commercial value, but may give access to a US$2 billion market.[17] Still less tangible values exist - the family farm is valued because it can be passed on to the next generation and this value is of a different kind to its market value.

Value type	Value sub-type	Examples
Use	Consumptive	Food & fibre provision, gravel supply
	Non-consumptive	*Mauri* & other spiritual values, recreation
	Indirect	Water purification & flood limitation
	Option value	Agricultural land sub-dividable in the future for residential use
	Quasi-option	Potential anti-cancer drugs from sea sponges
	Insurance	Resilience, the ability to sustain a flow of benefits
Non-use	Bequest	The family farm
	Altruist	Knowing that others have access to a pristine river
	Existence	The knowledge that the Kiwi is not extinct

Table 2: Common kinds of values. Based on Table 5.1, reference 18.

Valuation techniques are similarly multifaceted. Direct market values can be based on: market prices; the costs of replacement or substitute services; or production-based functions that link ecosystem service levels with marketed goods. Preference-based values include revealed preferences shown by buying behaviour or stated preferences such as people's willingness to pay for a service or willingness to accept compensation for the loss of a service. Both families of techniques have their limitations—markets often do not exist for ecological goods and services; public goods are difficult for private individuals to value; buying behaviour cannot reflect non-market values; and stated preferences provide answers about hypothetical trade-offs, not actual behaviour.

Thresholds and non-linear effects, such as the effects of low water flow in braided rivers, are difficult to include within economic valuations, as are other typical features of ecosystems such as: potentially irreversible changes, uncertain resilience both at ecological and social-economic levels, the changes in ecosystem responses at different scales, the limited substitutability between different ecosystem functions or between natural and man-made functions, and uncertainties about ecosystem responses. Changing social preferences with time and the plurality of existing social values add to the complexity of this challenge.

Any valuation necessarily reflects the socio-cultural and economic contexts under which it was generated. It should be acknowledged that any economic valuation is incomplete and often influenced by the ownership of ecosystem assets. More useful than any specific valuation may be the process of taking a holistic approach and developing an understanding within a community of the values of that community.

Ecosystem services research in New Zealand – an agroecosystem focus

In New Zealand, much of the research has focused on agricultural ecosystems, quantifying and understanding the ecosystem services such as food and fibre production, soil formation, filtering of nutrients, carbon accumulation in soils, plant disease management, biological control of pests, pollination, the effect of shelterbelts and hedges, water flow regulation and water provision, and the effect of biodiversity within agricultural systems. There is substantial work underway by AgResearch,[19] Plant & Food Research,[20] Lincoln University, Massey University, and others. Much of this research has the goal of changing agricultural practices to enhance ecosystem services, allowing for greater production of both market and non-market goods and services within environmental constraints.[21]

Landcare Research has a programme, based on the MEA categories, to assemble a national assessment of ecosystem services as a present-day baseline for New Zealand. This assessment will vary by ecosystem service – where little information exists, such as for genetic resources, it will be purely qualitative whereas other ecosystem services such as food, fibre and fuel provision can be described in more detail.[22]

An example from this work is a study of the multiple benefit of forests. Forests provide ecosystem services by reducing soil erosion and sequestering carbon, and influence water supply to other users downstream. These effects are summed using a national average cost estimate for erosion control, a global market price for carbon sequestration, and an estimated economic value for irrigation water. This integration allows a comparison of the total economic value of these forests with other potential uses of that land in a way that includes the impacts of these activities above and beyond just the commercial value. Trade-offs between management options can then be assessed to total economic, social and environmental value, rather than just narrow market value.

The complex relationship between biodiversity and ecosystem services

Biodiversity is often valued for providing resilience to environmental change. More biodiversity generally leads to more resilience, but the relationship is rarely simple. Ecosystem functions, such as nutrient regulation, are provided by the traits of organisms within that ecosystem. Greater genetic diversity provides a greater reservoir of traits that can replace traits lost if particularly important species are lost. More diversity also provides more opportunity for functions to operate across a broader range of conditions. In this way, biodiversity provides the insurance value that future environmental changes will not reduce services.

Biodiversity itself provides existence value and option value (in this case, the value of preserving the benefits of unknown future uses of currently-unused species and the opportunity for current use of those species).

The past fifty years have seen a "substantial and largely irreversible loss" of biodiversity.[3] New Zealand's unique endemic biodiversity has similarly seen serious decline—an unknown but large loss of common wealth and natural heritage.[12]

Work on the value of ecosystem services is underway at Scion, researching the value that people place upon recreation and indigenous species in planted forests and forest parks. Scion has other work underway estimating values of avoided erosion from forestry and a range of work on ecosystem function in forests, such as the functions involved in nutrient cycling.

The ecosystem services provided by our coasts and oceans are, apart from fish production, poorly recognised. Coastal environments are the most popular for New Zealanders to live and we are beginning to recognise the benefits from provisioning, regulating and cultural ecosystem services. NIWA and collaborators are engaged in research to both characterise the ecosystem functions that underpin services and developing tools for the translation of this knowledge into decision making processes.[23]

Domestically, the relevance or impact of ecosystem services in urban environments has not been addressed, despite 86% of New Zealanders residing in urban areas.[24] Ecosystem services in urban areas are rarely quantified and interactions between services in urban contexts are poorly understood. Social and psychological services such as access to green space are likely to be more relevant in urban areas than in rural areas. Expansion of urban areas, often onto high quality soils, reduces a number of services from those soils, such as flood mitigation.

Ecosystem services as a dialogue tool in environmental decision-making processes

The resolution of many natural resource problems has stalled because they involve groups of users in an adversarial setting, each with legitimate and conflicting demands on finite resources. Where disagreements about resource use constitute zero-sum games between commercial users (e.g., over water in a river, where abstraction for one use excludes its use for another), rights to use that resource can be simply traded to maximise economic outputs. However, different user groups often value resources in incompatible and non-tradable ways. Disagreements of world-view may even be clashes of incommensurable values, where the values of one user group cannot be expressed within the world-view of another user group. A classic example would be the non-substitutability between the economic value of water in a river for irrigation set against the value of recreational use for fishing or the *mauri* value of that river or the comparison of the potential economic value of minerals under a national park against the cultural value of the undeveloped area.[25]

An ecosystem services approach provide a common language to build bridges across such impasses, enabling communication between groups with incommensurable viewpoints. It helps different user groups to state their underlying values and how various ecosystem services are connected with those values. This approach allows for consideration of underlying features of ecosystems, such as the reversibility or irreversibility of changes. Laying out social values allows users to be engaged within a conversation about those values and provides a structured approach for dialogue that broadens the range of values acknowledged. This enables the discovery and creation of shared values, and can be used to explore ecosystem responses to different management approaches. Such transparent and participatory dialogue processes will achieve broader consensus and acceptance if emphasis is put on trust-building amongst diverse participants and if power asymmetries between stakeholders are taken into account.[16]

The recent Land and Water Forum was an example of this kind of collaborative, deliberative dialogue process. The process allowed for the discussion of values beyond the strictly economic and thus built more trusting relationships between the participants. Compared with more adversarial processes, participants reported that the Forum resulted in wider consensus.[26]

Contributors and Reviewers

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Further reading

The September issue of the *New Zealand Journal of Marine and Freshwater Research* will be a special edition on integrated catchment management in the Motueka River catchment. Much of this work has taken an ecosystem services approach to representing social processes and biophysical knowledge.

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