Sustainable Ecosystem Management

Alison Smith[1] and Pam Berry (Oxford University, UK);

Paula Harrison (Oxford University and CEH, UK)

Introduction and 'State-of-the-art'

Sustainable Ecosystem Management (SEM) is one of the 'four challenges' for ecosystem services (ES) to be addressed by OpenNESS; the others relate to human well-being, competitiveness and governance. The challenge is to manage ecosystems in such a way that they can sustainably deliver an optimal combination of ecosystem services both today and into the future, with resilience to environmental and social change.

Definition and history

The term 'ecosystem' was introduced in 1935, to describe the entire system of living organisms and interacting abiotic factors such as air, water and minerals occupying a given space (Tansley, 1935). Prior to this, land management had typically been geared towards either the conservation of single iconic species, or the production of single resources such as timber or food. However, increasing recognition of the way in which species interacted with each other and with the surrounding environment led to the concept of ecosystem management, which originated with four principles established by the Ecological Society of America: protect entire habitats as well as particular species; maintain a wide range of native ecosystem types within each region; manage for resilience to disturbances; and establish buffer zones around core reserves (Grumbine, 1994). These ideas rose to prominence during the 1970s and 80s, triggered by debate over the future of species such as the grizzly bear. This led to wider recognition of the need to provide a large enough area of primary habitat to sustain the largest carnivore in a region, even if that area crosses administrative boundaries (such as national park or even national boundaries), thus requiring increased co-operation and co-ordination between agencies. There was also growing awareness that resource extraction was leading to accelerating biodiversity loss and ecosystem degradation, but this was coupled with increasing acceptance that conservation had to take account of human social and economic needs (Grumbine, 1994; Szaro et al., 1998).

By the late 1980s, the term 'Ecosystem Management' was widely used to describe an approach that tried to tackle all these issues. There are many competing definitions, but one of the most widely accepted is:

> *Ecosystem management is the application of ecological science to resource management to promote long-term sustainability of ecosystems and the delivery of essential ecosystem goods and services to society (Chapin et al 2002).*

There is no separate definition of 'sustainable ecosystem management', but the concept of sustainability is at the heart of the definition above, with its emphasis on balancing human needs with the long term sustainability of ecosystems. This is consistent with the well-known definition of sustainability as 'meeting the needs of the present and local population without compromising the ability of future generations or populations in other locations to meet their needs'. Over the last two decades, this has been reinforced by the concept of 'socio-ecological systems', which recognises that humans and their social and political systems are an integral part of ecosystems, and that successful ecosystem management therefore requires sustainable and equitable governance. The key characteristics of Ecosystem Management (derived from Brussard et al., 1998; Slocombe, 1998; Szaro et al., 1998; McLeod and Leslie, 2009; Chapin et al., 2011) include:

[1] Email Contact: alison.smith@eci.ox.ac.uk

- It considers entire ecosystems, with their complex connections, rather than individual sites or species;
- It aims to balance human social, economic and cultural needs (the delivery of essential ecosystem services) with ecosystem sustainability (maintaining healthy, productive and resilient ecosystems in the long term);
- It involves all stakeholders in collaborative decision-making, including scientists, national and local government, NGOs, business, local residents and the public;
- Conflicts will arise due to different stakeholder needs: these must be resolved through negotiation;
- It is an interdisciplinary approach bringing together science, resource management, planning, economics, sociology, law and politics;
- It involves co-operation between different agencies, crossing political and organisational boundaries;
- It is place-based, but also considers wider objectives such as cumulative environmental, social or economic effects at regional, national or global scale;
- It uses a flexible adaptive management approach, with continual monitoring, learning, feedback and adjustment of goals and strategies to meet changing needs and incorporate new information.

Procedural sustainability (Binder et al, 2010) is a key feature of sustainable ecosystem management. Co-operation between stakeholder groups allows socio-ecological systems to innovate and adapt to change (Chapin et al., 2011). Goals should be set as a result of negotiation between all stakeholders, and indicators should be chosen carefully to match the goals. Adaptive management is the key to dealing with the highly complex, uncertain and unpredictable nature of socio-ecological systems (Williams et al 2011). Typical steps in setting up a sustainable ecosystem management system are listed below (partly derived from Brussard et al., 1998; Slocombe, 1998; Tallis et al., 2010).

1. Define the boundaries of the ecosystem to be managed.
2. Assess the ecosystem, using all available sources including local and traditional knowledge. Determine key components and their interactions (species, habitats, abiotic factors); assess the condition and integrity of the ecosystem; evaluate supply and demand of ecosystem services; and identify carrying capacity, potential thresholds and tipping points.
3. Identify stakeholders, understand their use of different ES and the values they attach to those ES, and define management goals through a collaborative/negotiation process involving all stakeholders.
4. Select suitable indicators to measure achievement of the goals.
5. Design and implement actions to achieve the goals, e.g. defining protected areas and buffer zones, setting appropriate levels of resource extraction in certain areas (typically excluding high-integrity areas), restoring degraded ecosystems, and improving connectivity.
6. Monitor results, perhaps using GIS and/or remote sensing to help assess impacts on land cover.
7. Regularly review and adjust the strategy, in consultation with stakeholders, in the light of environmental, social and political developments and new scientific information.

Indicators for sustainable ecosystem management

Selection of suitable indicators for monitoring and managing ecosystems is crucial, in order to ensure that different needs are balanced and ecosystems are not being over-exploited. The choice of indicators will vary depending on the goals prioritised by the stakeholders, but they can reflect the different stages of the ES cascade model: ecosystem structure (e.g. species diversity), function (e.g. water and nutrient cycling) and ES delivery (e.g. visitor numbers, water quality regulation), as well as socio-economic indicators such as jobs or incomes.

To assess long term sustainability of ecosystems, and detect signs of over-exploitation, indicators of ecosystem health and resilience are needed. Rapport et al. (1998) define ecosystem health as being based on vigour (e.g. productivity), organisation (e.g. functional diversity) and resilience (the ability to maintain structure and function under stress). As more 'natural' systems tend to be more diverse and more able to cope with change, resilience is related to ecosystem integrity, defined as the degree to which ecosystems have changed from their natural state due to human intervention. However, the stability of ecosystem functions is now viewed as being more important than 'naturalness' per se. For example, Palmer and Febria (2012) recommend monitoring ecosystem structure and function to determine ecosystem health and resilience, while Kandziora et al. (2013) adopt a definition of integrity that is based on structure and function, not on naturalness.

Related terms

'Ecosystem Management' is synonymous with a number of other terms, including 'ecosystem-based management' (EBM), 'ecological stewardship' and the 'ecosystem approach'. It is distinct from 'natural resource management', which tends to refer to management of a particular resource (e.g. timber, water) for human use, but it is similar to the more holistic 'integrated natural resource management'. Sustainable Forest Management (SFM) is an evolution of this approach that is similar to Ecosystem Management, though Sayer and Maginnis (2005) point out subtle differences linked to the fact that SFM is typically led by foresters whose main aim is to maximise sustainable yield, whereas Ecosystem Management is typically led by people seeking to protect ecosystems. There is some overlap of 'Ecosystem Management' with other approaches that consider ecosystems at a wider spatial scale, e.g. 'integrated river basin management', or 'landscape level conservation' (e.g. using wildlife corridors to improve connectivity). There are also similarities with terms that link human use of ecosystems with environmental protection, e.g. 'sustainable development' or 'integrated conservation and development'.

Controversy over the definition and main goal

Although the definition of Ecosystem Management presented above clearly emphasises the need to balance human needs and long term ecosystem sustainability, the concept has attracted controversy. A review by Lackey (1999) concluded that the definition and aims adopted by different groups tends to reflect their personal views. Conservationists tend to see ecosystem management as a powerful tool to protect ecosystems from damage by humans, whereas many natural resource managers see it as justifying the further exploitation of ecosystems to provide goods and services for humans. Lackey (1999) cites one as saying:

> '*I promise you that I can justify anything you want to do by saying it is ecosystem management. Not that I don't think it is a good idea. I applaud it. But right now it's incredibly nebulous*.'

The debate between 'biocentric' conservationists, who emphasise the intrinsic value of nature, and 'anthropocentric' conservationists who argue that the primary function of nature is to provide services for humans, is still ongoing today (Doak et al., 2014; Hunter et al, 2014). Similarly, while many conservationists emphasise the importance of integrity in providing resilience to change, resource managers tend to argue that 'preservation from all change is not usually the main goal' (Slocombe, 1998). However, the process of ecosystem management described above is explicitly designed to arrive at a sensible balance between these competing viewpoints, through a process of negotiation and mutual learning.

One approach to reconciling the use of ecosystems by nature and by people is that adopted by Brussard et al. (1998), who propose different management goals for 'high-integrity ecosystems', 'impacted ecosystems' and 'cultural ecosystems', as follows.

High integrity ecosystems are those which are relatively unchanged by humans. They are rich in native species and tend to be well-adapted to the prevailing patterns of disturbance. They are also an important source of rare species which may become more important for maintaining biological functions and delivering ecosystem services when environmental conditions change, and they provide baselines for assessing the relative condition or state of other ecosystems. These ecosystems – including national parks, nature reserves, wilderness areas, critical watersheds and multiple-use lands of particularly high conservation value - should be maintained in, or restored to, high-integrity states.

Impacted ecosystems are natural or semi-natural areas that have lost much of their original integrity due to human activity, but they still provide many services. These lands should be managed for ecosystem viability or 'health'. Impacted ecosystems may be considered viable if they meet the following criteria:

1. Current utility: the ecosystem is providing the goods or services expected from it with reasonable efficiency (e.g., preventing erosion, detoxifying wastes);

2. Future potential: present uses are not disrupting processes that generate and maintain the desired composition, structure, and functional organization of the ecosystem;

3. Containment: present uses or current conditions do not degrade areas beyond the system's borders;

4. Resilience: the system has the capacity for self-maintenance and self-regeneration i.e., it can maintain the desired structure, composition, and functional organization after moderate external stresses or perturbations.

For example, an impacted stream ecosystem might include non-native fish species, but it would still be considered viable if: it is providing the services expected of it (e.g. fresh water, fishing); the remaining native species in the system are stable; it is not contributing to the degradation of other streams (e.g. by exporting excess nutrients or non-native species); and it has resilience (i.e. it can self-organise and adapt in the face of change, e.g. continuing to provide the expected services after a serious flood or drought).

Cultural ecosystems, such as agricultural fields and urban areas, have been transformed completely by human activity. They are important to human wellbeing and livelihoods, and for delivery of certain provisioning ecosystem services such as food, but require constant input of energy and materials. These ecosystems are not self-sustaining and probably not viable: they have current utility for humans, but no resilience and little future ecological potential; most also fail the containment criterion. Brussard et al. do not specify what approach should be applied to these areas, but it seems likely that they would present considerable opportunities for ecosystem enhancement, e.g. through tackling pollution or adopting 'nature based solutions'.

Current status

Over the last two decades, the concept of ecosystem management has been taken up in a range of situations, though there still does not appear to be a universally accepted definition or set of guidelines for implementation. Sustainable Forest Management (SFM) is now widely practised, building on the Forest Principles that were adopted at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992. Ecosystem Management can be seen as a logical progression from SFM: it is applied to a wider range of goods and services (as it is not restricted to forests), but it is still an operational approach linked to a set of tools and methodologies (Sayer and Maginnis, 2009). It was adopted by the US Forest Service in the late 1980s, generating a large body of literature in the 1990s, and is enshrined in the 2008 Planning Rule[2]. Ecosystem-based management has also been applied to coasts and oceans (McLeod and Leslie, 2009) including in the 2008 EU Marine Strategy Framework Directive. More recently, the concept was incorporated into the EU Biodiversity Strategy (sustainable management of agriculture is mentioned in Target 3a; SFM in Target 3b) and SFM is mentioned in the EU Forest Strategy. At a broader level, twelve general principles and five points of operational guidance for the 'Ecosystem Approach' have been developed by the Convention on Biological Diversity (CBD), which has also provided a sourcebook of guidelines for applying the approach, and a database of case studies[3]. SEM is related to the CBD's Aichi Targets, especially Strategic Goals C and D. Concepts and approaches to SEM will be key in the delivery of the post-2015 SDGs adopted by the UN General Assembly and accepted by the EU and all member states (ecosystem integrity is an over-arching principle for all 17 SDGs).

Open Problems/Issues to be discussed

1. Should we offer guidance on how to perform sustainable ecosystem management as part of the OpenNESS tools?

---

[2] http://www.fs.usda.gov/planningrule

[3] https://www.cbd.int/ecosystem/about.shtml

2. What type of sustainability should we aim for? Management for strong sustainability might place more emphasis on maintaining ecosystem integrity, whereas management for weak sustainability (which assumes that resources are substitutable) might be willing to sacrifice integrity provided that the supply of ES is maintained, though this carries a greater risk that resilience will be lost.
3. Can ES valuation be used to set priorities for sustainable ecosystem management? Can techniques for assessing cultural and social values (e.g. PPGIS; photoseries analysis) help to ensure that ES with no market value receive due attention?
4. How can we evaluate resilience in practice, especially given the lack of data on tipping points and thresholds?
5. How can we reconcile the need to reach an agreement that is accepted by all stakeholders (as far as possible) with the need to maximise ecosystem integrity in order to provide long term resilience to future change? Could the process be vulnerable to exploitation by powerful stakeholders who favour short term exploitation of resources?
6. Does biodiversity offsetting have a role to play in sustainable ecosystem management?
7. Do payments for ES schemes (PES) have a role to play in sustainable ecosystem management?

Significance to OpenNESS and specific Work Packages[4]

The concepts of Natural Capital and Ecosystem Services are fundamental to SEM, which aims to deliver essential ES while maintaining a resilient NC base to continue to supply those ES into the future. Mapping supply and demand of ES and monitoring ecosystem condition as part of the SEM process will help to indicate whether ES are being used sustainably or whether they are being over-exploited, and where there is a need to restore particular ecosystems to ensure that they will be able to meet future demand for ES.

WP1 (Key challenges and conceptual frameworks): This briefing note aims to contribute to the conceptual understanding of this challenge, which is to: '*examine the contribution of the ES and NC concepts to strategies for sustainable ecosystem management and, in particular, to improve our understanding of biophysical thresholds and tipping-points and the uncertainties associated with them'*.

WP2 (Regulatory frameworks and drivers of change): SEM hinges on effective and equitable governance of natural resources. Regulatory frameworks can be used to make sustainable ecosystem management mandatory, as with the US Forestry Service Planning Rules. They can also play a part in maintaining ecosystem health and integrity, e.g. by minimising pollution and enforcing protected areas.

WP3 (Biophysical control of ecosystem services): The database of NC-ES links (task 3.1) can guide selection of sustainable management techniques by providing information on how to maximise delivery of different ES and how to minimise trade-offs. The review highlights the lack of data on thresholds and tipping points, which is a fundamental barrier to SEM. However, the section on 'human impacts' contains some useful examples of actions to restore or enhance the ability of ecosystems to provide ES sustainably. The concept is also relevant to task 3.2 (methods for mapping and modelling ES supply), because supply depends on condition, which depends on management; and to task 3.3 – synergies and conflicts – because the stakeholder negotiation element of SEM is key to resolving these.

WP4 (Valuation of the demand for ecosystem services): Valuation can guide prioritisation of ES, and hence guide the setting of management goals, but there are limitations due to the difficulty in determining accurate ES values.

WP5 (Place-based exploration of ES and NC concepts): It would be useful to explore the experience of case study participants with different ecosystem management approaches, what indicators and methods they currently use, and whether specific guidance or enhanced knowledge of the approach could help them to apply SEM in the future.

---

[4] For a brief description of the OpenNESS Work Packages see: http://openness-project.eu/about/work-packages

WP6 (Integration: Synthesis and Menu of Multiscale Solutions): Guidance for ecosystem management could be offered as part of the menu of multi-scale solutions.

Relationship of Sustainable Ecosystem Management to four challenges[5]

Human well-being: Sustainable ecosystem management is necessary to preserve the long term ability of ecosystems to deliver the services that underpin human well-being. This may involve trade-offs between short term wellbeing and long term resilience. It will also involve trade-offs between different ES, which in turn depends (partly) on the benefits of each ES for human well-being, including the cultural value of managing an area for particular species. We should be aware of the need to use a range of approaches for ES valuation, and avoiding over-reliance on monetary values, and we need to explore ways of maximising synergies and minimising trade-offs.	**Sustainable Ecosystem Management:** N/A
Governance: Effective governance is critical for the negotiation and management process, and this will require a high degree of co-ordination between stakeholders and administrative agencies. Key governance needs include: inclusion of all stakeholders in the negotiation process; regular monitoring and review of goals to enable adaptive management; enforcement of protected areas; regulation to protect ecosystems from pollution, development and over-exploitation; managing offsets (if appropriate); incentives for sustainable use (e.g. PES, organic farming, eco-tourism).	**Competitiveness:** Choice of ecosystem management techniques (e.g. restoration, enforcement of protected areas): how much will they cost? What is the value of ES benefits and the wider social and economic impacts, e.g. for long term sustainability of agricultural production (soil erosion and fertility, water availability, genetic resources, pollination, pest regulation), employment, social cohesion, health and well-being (reduced health care costs, impacts on productivity of work force), education, innovation?

Recommendations for the OpenNESS consortium

Sustainable ecosystem management is a useful concept and offers a framework for balancing competing human needs and long term ecosystem sustainability through a process of stakeholder negotiation and adaptive management. However, because the goals are, by definition, set on a case-by-case basis, there is no guarantee that the goals and strategy that emerge from the negotiation process will safeguard biodiversity and provide resilience to long term social and environmental change. Ecosystem integrity and resilience will still be at risk, especially if there are power imbalances between stakeholders. ES valuation may be useful in setting priorities, but it is important to use a broad range of valuation approaches, including cultural and social values, as well as monetary values for marketable goods and services. . The consortium should consider whether we can provide clear guidance for a process of sustainable ecosystem management that will be helpful to practitioners.

Three 'Must Read' Papers

Volume 40 of Landscape and Urban Planning (1998) is a special issue on Ecosystem Management, and contains many useful papers.

[5] There are certainly more societal challenges; the reduced number presented here is due to the four major challenges mentioned in the work programme of FP7 to which OpenNESS responded.

Brussard, P.F, Reed, J.M., Tracy, C.R. (1998): Ecosystem management: what is it really? *Landscape and Urban Planning* **40**: 9-20.

Grumbine, R. E. (1994): What is Ecosystem Management? *Conservation Biology* **8**:27-38.

Szaro, R.C., Sexton, W.T. and Malone, C.R. (1998): The emergence of ecosystem management as a tool for meeting people's needs and sustaining ecosystems. *Landscape and Urban Planning* **40**: 1-7.

Further Literature or Cited References

Binder, C.R., Feola, G. and Steinberger, J.K. (2010): Considering the normative, systemic and procedural dimensions in indicator-based sustainability assessments in agriculture. *Environmental Impact Assessment Review* **30:** 71–81

Chapin, F.S., Matson, P.A. and Mooney, H.A. (2011): *Principles of Terrestrial Ecosystem Ecology*. 2nd Edition. New York: Springer. ISBN 0-387-95443-0.

Doak, D.F, Bakker, V.J., Goldstein, B.E. and Hale, B. (2014): What is the future of conservation? *Trends in Ecology and Evolution*, 29: 77–81.

Hunter, M. L., Redford, K. H. and Lindenmayer, D. B. (2014): The Complementary Niches of Anthropocentric and Biocentric Conservationists. *Conservation Biology*, **28**: 641–645.

Kandziora, M., Burkhard, B. and Müller, F. (2013): Interactions of ecosystem properties, ecosystem integrity and ecosystem service indicators—A theoretical matrix exercise. *Ecological Indicators* **28:** 54–78.

Lackey, R.T. (1999): Radically Contested Assertions in Ecosystem Management. *J. Sustainable Forestry*, **9**:1-2, 21-34.

McLeod, K. and Leslie, H. (eds): *Ecosystem-Based Management for the Oceans.* Island Press, Washington DC.

Palmer, M.A. and Febria, C.M. (2012): The Heartbeat of Ecosystems, Science 336: 1393-4.

Rapport, D.J., Costanza, R. and McMichael, A.J. (1998): Assessing Ecosystem Health, *TREE* **13**: 397-402.

Sayer, J.A. and Maginnis, S. (2005): *Forests in Landscapes: Ecosystem approaches to sustainability.* IUCN/Earthscan, London.

Slocombe, D.S. (1998): Lessons from experience with ecosystem-based management. *Landscape and Urban Planning* **40**: 31-39.

Tallis, H., Levin, P.S., Ruckelshaus, M., Lester, S.E., McLeod, K.L., Fluharty, D.L. and Halpern, B.S. (2010): The many faces of ecosystem-based management: Making the process work today in real places. *Marine Policy* **34**:340-348.

Tansley, A.G. (1935): The Use and Abuse of Vegetational Concepts and Terms. *Ecology* **16**: 284-307.

Williams, B.K. (2011): Adaptive management of natural resources: framework and issues, Journal of *Environmental Management* **92**: 1346-1353.

Review Editor: Sander Jacobs (INBO)

Suggested Citation: Smith, A.C.; Berry, P.M. and Harrison, P.A. (2016): Sustainable Ecosystem Management. In: Potschin, M. and K. Jax (eds): *OpenNESS Ecosystem Services Reference Book*. EC FP7 Grant Agreement no. 308428. Available via: www.openness-project.eu/library/reference-book

Acknowledgements: The following OpenNESS partners have contributed to the consultation: Joachim Maes (RC), Raktima Mukhopadhyay (IBRAD), Sander Jacobs (INBO), Jari Niemelä (UH), Camino Liquete (JRC), Berta Martín-Lopéz (UAM), David Odee (KEFRI), Heli Saarikoski (SYKE), Eeva Furman (SYKE), Conor Kretsch (UNOTT), Roy Haines-Young (UNOTT)

Disclaimer: This document is the final version of the Synthesis Paper on the topic within the OpenNESS project. It has been consulted on formally within the consortium in 2015 and updated in 2016.