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# Ecosystem services and biodiversity in developing countries

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**Abstract** The concept of ecosystem services has become important for our understanding of the role of nature for maintaining human livelihoods. But is biodiversity essential to maintain ecosystem services? Many studies suggest that higher biodiversity allows a higher level of ecosystem services, but others argue that there is little hard evidence, especially from tropical environments, to document the necessity of high biodiversity for provision of most ecosystem services. Thus, effective valuation of biodiversity for ecosystem services and long-term studies and monitoring are needed to fully understand the complex biodiversity-ecosystem service interface. This introduction briefly reviews some of the main arguments in this debate and provides an overview of the other five special issue papers. Exploring biodiversity and ecosystem interactions in the context of the provision of ecosystem services, these papers address population and biodiversity coexistence, the importance of dung beetles in agricultural landscapes, the knowledge and use of palms by local

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communities, bioprospecting for drugs and how biodiversity conservation may have added benefits in terms of improved watershed functions and health.

**Keywords** Biodiversity · Ecosystem services · Valuation · Ecological economics · Sustainable financing · Monitoring · Bioprospecting · Local knowledge · Conservation · Population · Environment

## Introduction

In the last decades, humans have more than ever been changing the world's ecosystems to meet the growing demands for food, freshwater, timber, fibre, fuel and minerals (MA 2005). A range of ecosystem services are needed to satisfy these demands, some of which can be derived from highly transformed ecosystems (e.g. soil fertility for intensive agriculture) whereas others require quasi natural ecosystems to be maintained (e.g. steady and high quality water supply). Biodiversity in itself provides a range of services, including aesthetic, cultural and recreational values as well as goods that have direct use value and enhances many other ecosystem services on which humans depend (Bulte et al. 2005).

Loss of biodiversity, degradation of ecosystems and subsequent reduction in goods and services are, therefore, by many seen as major barriers to the achievement of the United Nations' Millennium Development Goals. Conservation International noted that 19 out of 25 biodiversity "hotspots" had population growth rates higher than the global average and 16 of these hotspots account for one quarter of all undernourished people in the developing world (Cincotta and Engelman 2000). While being a source of concern over the future of the biodiversity in these areas, it also reflects the mere fact that people and biodiverse ecosystems have always co-existed (Fjeldså and Burgess in press; Fjeldså this volume). Whether poor people are marauders or managers of the ecosystems has been eagerly debated during the late 1980s and 1990s, and empirically based accounts have been made in support of both perceptions. While both situations exist, it is becoming increasingly clear that overwhelmingly it is the non-poor who possess not only the legal access to biodiversity rich areas but also the economic and political means making resource extraction possible and economically attractive in these biodiversity rich areas. (DFID UK et al. 2002; Ravnborg et al. 2006).

Research on the importance of biodiversity for the rural poor, who tend to depend on natural resources for their survival, has a long history (Beer and McDermott 1989; Burkill 1935; Byg et al. 2007; Christensen 2002; Dalziel 1937; Mertz et al. 2001; Peters et al. 1989; Vantomme 1998; Wadley and Colfer 2004), whereas studies on the functional role of biodiversity for ecosystem services have emerged in the 1990s (Cork and Shelton 2000; Loreau et al. 2001; McCann 2000). There is a large body of research suggesting that natural ecosystem properties greatly depend on biodiversity and that the functioning of ecosystems is associated with biodiversity (Esteban et al. 1998; Hooper et al. 2004; Loreau et al. 2001; Tilman et al. 2005). Others argue that it is "surrounded by intricacies, uncertainties and questions" whether biodiversity really matters, not least because many studies are on experimental plots in developed countries (Fjeldså this volume). Moreover, some studies argue that agricultural intensification - though usually causing deliberate reduction of biodiversity - does not necessarily reduce the necessary ecosystem functions of a given area, provided that key functional species are not removed (Swift et al. 2004).

The key questions for this special issue are therefore: to what extent is conservation of biodiversity an essential element for maintaining ecosystem services and how can conservation of biodiversity and ecosystem services contribute to improving the living conditions for the poor in developing countries? These questions were raised at the ReNED Conference in Copenhagen in 2005, where the material in this special issue was initially presented (Mertz 2005). We will proceed with an overview of current research on the relationships between biodiversity and ecosystem services, discuss some important approaches to understanding these relationships - including economic valuation and monitoring - and conclude by a brief overview of the five papers included in the special issue.

## Biodiversity and ecosystem functioning

The concept of biodiversity – or biological diversity – is well defined in the literature (MA 2005; Pearce and Moran 1994; UNEP 1995). Ecosystem goods and services is a more recent concept and denote that ecosystems produce outputs to human societies that are – directly or indirectly – useful to people (Constanza et al. 1997; Kremen 2005). Ecosystem goods are typified by products, such as food, fibre, medicinal plants etc. Ecosystem services include carbon storage, water supply and soil fertility, resilience to climate and other environmental changes, recreation, and the maintenance of ecological conditions favourable for human health (Bulte et al. 2005). Table 1 shows three examples of classification of ecosystem services in relationship to four categories identified by the MA (2005).

As indicated above, there is a general lack of empirical evidence of the role of biodiversity for maintaining ecosystem services. Effects of species loss or changes in species composition differ among ecosystem properties, ecosystem types, and pathways of potential community change (Hooper et al. 2004). Some ecosystem properties are initially insensitive to species loss because ecosystems may have different species that carry out similar functional roles and some species may contribute little to ecosystem properties or properties may be primarily controlled by abiotic environmental conditions (Hooper et al. 2004; Pearce and Moran 1994). Most ecosystem processes are non-additive functions of the traits

**Table 1** Examples of classifications of ecosystem (goods and) services

| MA (2005) | Constanza et al. (1997) | Daily et al. (1997) |
|---|---|---|
| Provisioning services | Water supply | Production of ecosystem goods |
| | Food production | |
| | Raw materials | |
| Regulating services | Gas regulation | Climate and life |
| | Climate regulation | Mitigation of floods and droughts |
| | Disturbance regulation | |
| | Water regulation | Natural pest control services |
| | Erosion control & sediment retention | |
| | Biological control | |
| | Waste treatment | |
| Cultural services | Recreation services | Aesthetic beauty and intellectual and spiritual stimulation. |
| | Cultural services | |
| Supporting services | Soil formation | Generation and maintenance of biodiversity |
| | Nutrient cycling | |
| | Genetic resources | Services supplied by soil |
| | Pollination | Pollination |
| | Refugia and habitat | Seed dispersal |

of two or more species, because interactions among species (rather than simple presence or absence) determine ecosystem characteristics (Chapin et al. 2000). Certain combinations of species are complementary in their patterns of resource use and can increase average rates of productivity and nutrient retention, although evidence from experimental studies is not conclusive (Chapin et al. 2000). Species interactions, which include mutualism, trophic interactions (predation, parasitism, herbivory), and competition may affect ecosystem processes directly by modifying pathways of energy and material flow or indirectly by modifying the abundances or traits of species with strong ecosystem effects (Chapin et al. 2000).

A key mechanism in the relation between biodiversity and ecosystem functioning is biodiversity's contribution to ecosystem resilience and stability (Chapin et al. 2000; Hooper et al. 2004; Loreau et al. 2001; McCann 2000). The "diversity-stability" hypothesis states that diversity provides a general insurance policy that minimizes the chance of large ecosystem changes in response to global environmental change (Chapin et al. 2000). Increase in diversity raises the odds that at least some species will tolerate new conditions and perturbations, thus stabilizing ecosystem processes and insuring a stable supply of ecosystem services. Greater diversity also increases the odds that an ecosystem has functional redundancy by containing species that are capable of functionally replacing other important species (Kremen 2005). A third mechanism, also mentioned by Kremen (2005), relates to functional compensation or the increase in the efficiency of individuals as aggregate abundance declines or community compensation changes.

Evidence of the influence of biodiversity on ecosystem services at the level of individual services exists, but is sometimes anecdotal rather than research based. Higher species diversity within an ecosystem obviously implies (potentially) more ecosystem goods to be used (for example, medicinal plants). Despite the note of caution raised by Pearce and Moran (1994), mentioning a "hit chance" of 1 in 10,000 plant species when searching for a plant of value to the pharmaceutical industry, more than 35% of new medicines during the past 20 years have been derived from natural products, and considerable research still goes into screening living organisms for drug discovery (Kursar et al, this issue). In general, the linkages between biodiversity and human health have been the focus of recent research and reviews on biodiversity and ecosystem services (Chivian 2002; Chivian and Bernstein 2004), and Pattanyak and Wendland (this issue) argue that indirect positive effects of biodiversity conservation efforts on water quality, and thus on health, may be very important.

The importance of biodiversity to agriculture is explored by Esteban et al. (1998), and exemplified by the need for diversity in decomposers, pollinators, natural enemies of pests and diseases, genetic material, and so forth. Nielsen (this issue) provides a specific example of dung beetles in East Africa. Dung beetles (Coleoptera, Scarabeidae) improve soil fertility and structure, and although existing in larger numbers in bush land, they also provide these ecosystem services in farmland. Biodiversity is also important for eco-tourism, where areas of high diversity (e.g. tropical rainforests, coral reefs) and with the presence of rare species (e.g. mountain gorillas) have attracted increasing numbers of tourists (Grieg-Gran and Bann 2003; Myers 1996). Eco-tourism was identified as a major priority needing further research at the ReNED Conference (Mertz 2005).

## Valuation of biodiversity and ecosystem services

Valuation of biodiversity and ecosystem services is an essential tool not only to assess the relative importance of different components in the system, but also to inform decision-makers, who are often unaware of the value and importance of ecosystem services, particularly if they accrue to people far from the ecosystem (Cork and Shelton 2000; Gutman 2003). Valuation can take different perspectives, for example according to more anthropocentric or biocentric approaches (Lockwood 1999). Within biodiversity conservation, there is a long tradition of ecologically-oriented valuation. Nunes et al. (2001), for example, discuss the use of various biodiversity and ecological indicators under the headings of biological richness and ecosystem health or integrity. In the biological richness approach, genetic, species, and community diversity are measured. Ecosystem health or integrity approaches are more relevant than other forms of ecologically-oriented valuations from the point of view of ecosystem functioning and services, as they assess ecosystem performance and integrity (Constanza 1992). In general, ecological evaluation can help decision-making, for example by means of protected species lists, biological value indices, species population modelling and presenting different scenarios and thus contributes to form the basis for the economic valuation of such scenarios.

Biodiversity and ecosystem services are often structurally undervalued from an *economic perspective* (Pearce and Moran 1994), mainly because of the manifold problems related to valuation: many services do not pass through the market; services such as clear air and clean water have been considered public goods, for all to enjoy with no price attached; suppliers of ecosystem services are either not adequately organized to sell their service provision or do not find a market willing or able to buy; and government failures may cause wrong or absent government intervention (Katoomba Group 2006; Pearce and Moran 1994; Ravnborg et al. 2007).

Valuation studies can be divided into (1) valuation of entire biomes or ecosystems; and (2) valuation of one or more particular ecosystem goods or services. Probably the most cited valuation of the total economic value of ecosystems is the study by Constanza et al. (1997) who estimated the values of 17 ecosystem services for 16 different biomes using results of existing studies as well as some new analysis. The authors' estimate exceeded the sum of total global income. As an alternative, authors such as Balmford et al. (2002) and Pagiola et al. (2004) find it more useful to estimate the marginal rather than the total value. Thus, Balmford et al. (2002) reviewed 300 case studies, searching for matched estimates of the marginal values of goods and services delivered by a biome when relatively intact, and when converted to typical forms of human use. Other weaknesses of this and other studies, often acknowledged by the authors themselves, include partial coverage of services, unreliable benefit transfers, possible "double counting" of services, and non-inclusion of services due to lack of previous studies.

The second group of studies focuses on the value of particular ecosystem goods and services, such as watershed services, carbon storage, non-timber forest products, recreation, and landscape beauty, biodiversity for medicinal or industrial uses, natural crop pollination and cultural benefits (Pagiola et al. 2004; Pearce and Moran 1994; Rausser and Small 2000). Values identified are often very significant. Crops pollinated by wild bees and honey bees in the United States, for example, represent a value of USD 30 billion (Myers 1996).

Economic valuation should never be applied as a single basis for decision making (Brown and Moran 1993) and achieving sustainable solutions requires integrated assessment of ecological, social and economic systems and negotiation among stakeholders taking into account a wider range of objectives than economic efficiency (Bulte et al. 2005; Constanza and Folke 1997; Nunes et al. 2001; Turner et al. 1999). Economic valuation of biodiversity and ecosystem services is, however, an essential element in making conservation efforts financially sustainable over longer periods of time as it stimulates the perceived need for investing in conservation, be it through the establishment and management of protected areas, through traditional economic instruments such as taxation, license fees, etc. or through the development of markets and agreements on payments for environmental services. An overview of the relatively large and emerging literature on sustainable financing mechanisms and payments for environmental services is beyond the scope of this paper, but is provided by several other studies (Grieg-Gran and Bann 2003; Gutman 2003; Landell-Mills and Porras 2002; Wunder 2005).

## Monitoring of biodiversity and ecosystem services

The best way to obtain a better understanding of the complex interactions between biodiversity and ecosystem services is to establish long-term studies and effective monitoring systems (Constanza et al. 1997; Cork and Shelton 2000). A key challenge, however, is to find criteria and indicators to measure such broad and multidimensional concepts as biodiversity and ecosystem services in a meaningful and useful way (Eiswerth and Haney 2001; Purvis and Hector 2000). The choice of biodiversity indicators can substantially influence decisions about conservation priorities and planning. Counting species is not enough; functional aspects need to be incorporated and comprehensive assessment of environmental, economic and social indicators is needed to ensure that the resources are conserved (Gullison 2003).

This brings us to the importance of involving stakeholders – especially local communities – in management, valuation and monitoring (Adamowicz and Beckley 1998; Wilson and Howarth 2002; Zambrana et al., this issue). Locally-based monitoring, incorporating for example traditional and ethno-botanical knowledge, can offer an important complement to more conventional monitoring, or even offer an alternative where more formal schemes run by professional scientists are hard to sustain because of the high cost involved, lack of capacity and logistics, or irrelevance as perceived by local managers and communities (Danielsen et al. 2005). Topp-Jørgensen et al. (2005) demonstrate the success of community-based forest monitoring schemes in a part of Tanzania, where 23 local villages have been monitoring resource extraction and disturbance, and several of the papers in this special issue address the importance of ownership and local capacities in managing local and national resources (Kursar et al. this issue; Zambrana et al. this issue).

## Overview of papers

The use, valuation and assessment of biodiversity as a key component in the provision of ecosystem services are further discussed in the five remaining papers of this special issue. The papers range from specific case studies to broader analyses of key concepts. Together, they provide insights into the range of studies available on the ecosystem-biodiversity interface in developing countries.

With a case study in the Andean Highland, Fjeldså demonstrates that biodiversity can remain relatively high in densely populated areas, particularly in so-called old population centres. In more recently settled areas, the diversity of small-range birds – used as a proxy for biodiversity – is smaller, and Fjeldså argues that past strategies for coexistence of people and nature are difficult to maintain. He goes on to propose that integrated conservation and development efforts must focus on populated areas rather than pristine wilderness areas as the former often have a higher and more threatened biodiversity.

The paper by Nielsen analyses biodiversity in an intensively used agricultural landscape of Tanzania. Here, the diversity of dung beetles is used as an indicator to show the importance of bush land fragments for maintaining the population of beetles, which are much less prevalent in the farmlands. The dung beetles are important for maintaining soil fertility and Nielsen concludes that complete clearing of all bush lands for agriculture would most likely result in impoverished soils and negative impacts on agriculture.

The last three papers analyze ecosystem services more directly used by humans, though the analyses take place at different levels and under different conditions. Zambrana et al. map the knowledge and use of palms by small communities in the western Amazon (Peru and Bolivia) and correlate use patterns with socio-economic parameters. Longer education and wealth were both positively correlated with knowledge on palms, thus emphasizing the need for accompanying conservation and sustainable management efforts with socio-economic development. Kursar et al. present an overview of locally based bioprospecting activities in Panama and the benefits of such drug discovery programmes in developing countries. The programme in Panama resulted in training, infrastructure improvement, locally based patents and development of research capacity, used a modest amount of funds, and had a direct, positive impact on the conservation of biodiversity areas in the country.

The final paper by Pattanayak and Wendland takes a critical look at economic valuation of biodiversity and ecosystem services, and applies various approaches and frameworks to a case study area in Indonesia. The authors argue that valuation is a necessary tool to capture the total value of a conservation area, but that too many valuation studies are not empirically well-founded. They show that the conservation of a highland forest area has significant positive impacts on diarrhoea incidence in the buffer zone communities, and argue that secondary effects of biodiversity conservation can be economically just as or even more important than protecting the biodiversity for its own sake.

## Conclusion

It is clear both from the papers in the special issue and from the review of the literature that there are still considerable needs for research to understand and assess the benefits of biodiversity for maintaining ecosystem services, especially under tropical conditions in developing countries where few studies have been made so far. While many of the direct use benefits of plants and animals are fairly easily evaluated, the more indirect influence of biodiversity on other services such as clean water, clean air, human health, carbon sequestration, eco-tourism and ecosystem stability, are less well understood. We therefore hope that this special issue can provide inspiration for further research into the complexities of the biodiversity-ecosystem services relationships.

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