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Received and accepted 2 May 2002

Balancing the approaches of environmental conservation by considering ecosystem services as well as biodiversity

S. P. Singh

In recent years, most plans for conservation have focused on biodiversity, ignoring the importance of the ecosystem services. This paper discusses limitations of the biodiversity-centred approach to conservation and reasons why ecosystem services need to be included to provide a balanced approach to conservation. To achieve this objective, there is need to improve the identification and valuation of ecosystem services. By focusing on biodiversity conservation, we may ignore many areas that are not rich in biodiversity but are important to human welfare and are under the threat of environmental degradation.

RECENT initiatives of environmental conservation, particularly in tropical parts of the world, are unduly oriented towards biodiversity, ignoring ecosystem services, though conserving biodiversity is often justified on the ground that it contributes to ecosystem services[1]. Recent exercises on the prioritization of creatures and places deserving most attention for conservation, and on developing national biodiversity conservation plans in several Asian countries, may further increase this imbalance. These also include India's National Biodiversity Strategy and Action Plan (NBSAP), regarded as one of the greatest exercises on conservation ever taken place in the developing world. Because conservation is tightly connected with funding, attempts are being made to find ways to reduce costs and maximize benefits of biodiversity conservation. For example, Myers *et al.*[2] argue that by protecting 25 top hot spots, comprising only 1.4% of the earth's surface, 44% of all plant species and 35% of vertebrate species worldwide can be saved. It is important to develop strategies to conserve as high a proportion of the species on the planet as possible, but a balanced approach of conservation should also consider other environmental issues such as carbon sequestration, waste dissipation, the hydrological balance, soil formation, health of local ecosystems, and others not intimately connected with biodiversity.

S. P. Singh is in the Botany Department, Kumaun University, Nainital 263 002, India.
e-mail: surps@yahoo.com

In this article, a plea is made for taking corrective measures to produce a balanced approach to environmental conservation, by giving due consideration to the unrecognized but essential services provided by ecosystems. As described by Daily[3], these include all ecosystem processes that sustain and fulfil human life. The specific objectives of this paper are: (i) to discuss the limitations of the biodiversity-centred approach and the usefulness of ecosystem-oriented approach to conservation, and (ii) to emphasize the need for understanding the great variability that occurs in ecosystem properties due to subtle variations in biotic and abiotic components, and their effects on the kind and magnitude of ecosystem services generated.

Definition

For the present purpose, ecosystem services are defined as services generated due to the interaction and exchange between biotic and abiotic components of an ecosystem (Figure 1). Accordingly, ecosystem services do not include ecosystem products such as food. Ecosystem services are generated by ecosystem functions (such as production and nutrient cycling), but the functions and services do not necessarily show a one-to-one correspondence[4]. There are numerous ways through which interactions among the community, energy flow and cycling of materials generate services to humans. The ecosystem services commonly listed are carbon sequestration, purification of water and air, soil formation and renewal of fertility, regulation of water and nutrient movement from one ecosystem to another, dissipation of wastes and removal of toxins, control over climate, dampening of fluctuations in physical factors of the environment, and providing recreation and scenic beauty. Since ecosystem services are considered in the context of humans (Figure 1), their importance would largely depend on the size of the population that utilizes them.

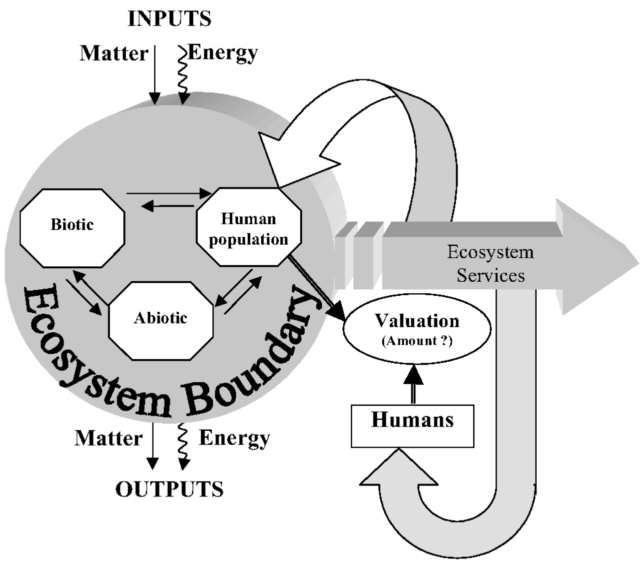

Figure 1. Representation of connections between the components of a circumscribed ecosystem, and between ecosystem services and humans. Within an ecosystem, human population is separated from the biotic component to focus on its extraordinary impact. A circumscribed ecosystem is an open system with inputs and outputs of energy and matter. Outputs such as cleansed water and air are part of ecosystem services. Ecosystem services are always in flow; their use and valuation depend on humans living both inside and outside the ecosystem. Valuation, however, is greatly influenced by human perception, which in turn is influenced by education and institutional context.

Limitations of biodiversity-centred approach

The biodiversity-centred approach to conserving nature has some serious limitations. It is primarily based on giving the highest priority to areas of highest diversity, and identifying hot spots and other species-rich areas, generally located in the tropics. Many rare and restricted species occur outside species-rich areas[5], and it is not necessary that areas rich in one kind of organism are also rich in others[6]. This approach neglects the areas not so rich in biodiversity, but important from the standpoint of the ecosystem services they generate for humans. To cite an Indian example, the Western Himalayan Ecoregion (WHE) in India is not as species-rich as the Eastern Himalayan Ecoregion (EHE), and the latter along with the Western Ghats is among the major hot spots of the world. However, the importance of WHE as the provider of ecosystem services is clearly greater than that of the two Indian hot spots. Associated with the WHE is the Gangetic plain, easily one of the most productive and robust agricultural zones on the planet, supporting nearly 400 million people[7]. Though the Gangetic plain owes its origin and development largely to geological processes, the nursing effect of the forests of WHE, in terms of regulated supply of soil fertility and water, has played an important role in continued food production from the region for at least 6000 years. An ecosystem subsidy such as this was recognized long ago by Odum[8] as accounting for the high productivity of estuaries. Also, the alpine meadows of WHE, spread over about 70,000 km^2, may prove to be critical for the woody species of lower altitudes, that would be forced to migrate upward in the event of global warming. There are reasons to conserve refugia that may be important in the changing future, irrespective of the amount of diversity they have, particularly in view of the fact that origins of biodiversity are poorly understood[6]. If all values were considered, both WHE and EHE should get attention from conservation planners, but if a conservation plan is centred around biodiversity alone, WHE may be neglected. At least certain ecosystem services are not related to biodiversity. For example, boreal peat lands are among the most species-poor ecosystems, but storing about 23–26% of all terrestrial organic carbon they play a significant role in the control of regional and global climate through internal ecosystem control of energy fluxes[9].

It is important to create and align diverse incentives for conservation, particularly because opportunity costs of conservation, especially of biodiversity, are perceived to be too high[10]. In poor countries, it is difficult to motivate people to protect species by arguing that useful products from them await discovery. In contrast, ecosystem services are already in use; they need only to be identified and to have people educated about them.

The limitations of the biodiversity-oriented approach to the conservation of nature in poor countries become particularly apparent outside protected areas, where an economic rationale is generally sought for forest conservation[11]. The basis of a market-oriented conservation is that the extraction of useful species from the natural ecosystem is sustainable and economically profitable. Such requirements would focus attention only on ecosystems in which economically important species occur in high densities. The concentration of biomass in a few economically useful species means the promotion of a system with low biodiversity. Therefore, areas of high biodiversity will require non-market mechanisms to ensure their protection[11], unless values of ecosystem services are connected with market mechanism. Thus, even to justify the conservation of biodiversity-rich areas economically, there may be a need to take the support of ecosystem services as incentives. Valuation of ecosystem services improves the economics of both species-rich and species-poor ecosystems.

It may be needed to expand the list of components of conservation further. For example, in a watershed there may be a need to conserve geological material also, that has little biota but filters or/and stores water for drinking. Porous limestone rocks and debris deposited at the bottom of a catchment are good examples of natural water filters. Such watershed components also play a significant role in regional biogeochemical cycles, in linking ecosystems, and generating services in the context of a greater spatial scale. The New York City water department decided to allocate $ 1.5 billion to preserve the Catskill and Delware watersheds, rather than spending $ 6 billion to construct a new water-treatment system (see Shwartz[12]). The high valuation is not because of high diversity of vegetation in the watershed, but because of the other ecosystem properties. In central Himalaya, a valley-fill located in the watershed of Lake Nainital is shown to contribute significantly to its health by providing filtered water, and diluting pollutants and controlling siltation[13].

An ecosystem approach is more effective even for protecting biodiversity. Developing economic enterprises based on the sustainable use of biodiversity is suggested for the conservation of biodiversity. However, the 50-year history of fisheries with the paradigm of sustainability of a single species is associated with numerous and repeated collapses of fish populations and alteration of marine ecosystems irreversibly. Pitcher[14] suggests that to conserve fish species the goal of the management should be rebuilding the marine ecosystems, including the creations of no-take marine reserves. The conservation strategy that focuses on biodiversity-rich areas, though it may ensure protection of a high proportion of global biodiversity, ignores large areas low in diversity such as arid regions and high mountains. However, it is essential to conserve the ecosystems of such areas (i) because of the day-to-day dependence of the people on local ecosystem services, and (ii) because they maintain a wide range of variation in life. It is important to recognize and conserve the ecosystems of extreme habitats, as such areas extend the global gradients of environment, communities and ecosystems.

The question of whether diversity improves ecosystem services is still unresolved. A number of experiments based on terrestrial conditions, generally carried out during the last seven years, suggest a direct relationship between species diversity and ecosystem functioning, measured variously (productivity, nutrient retention, resistance to invasion of other species, and stability measured over several years[15–18]), but the debate continues as strong doubts have been raised about the experimental designs[19,20]. Any attempt to seek a relationship between species diversity and ecosystem services appears to be futile in the case of freshwaters, where the medium, water, is the principal determinant of ecosystem functioning[21]. Here, ecosystem functioning is not at all synonymous with the absolute preservation of all species. In fact, many freshwater ecosystem services decline with the increase in species diversity. For example, for recreation purposes, a species-poor oligotrophic lake has far more value than a species-rich eutrophic lake. There are several examples of comparative studies indicating a negative correlation between diversity and phytoplankton biomass or productivity in lakes[22,23]. In freshwaters, the whole system must be considered from the point of view of conserving a particular species. Aquatic ecosystems in general are evaluated higher than terrestrial ecosystems for their services to humans[4], though some of the latter type may be exceptionally rich in biodiversity.

Expanding the scope of ecosystem services

Most studies describe ecosystem services of a general nature, attributable to any ecosystem. For example, a forest is associated with services such as landscape and watershed stabilization, soil protection, water and nutrient retention within the soil or the entire ecosystem, and regulation of water flows, thereby preventing flood-and-drought regimes in downstream territory, returning water from the ground into the atmosphere, buffering against the spread of pests and diseases, modulating climate through regulation of rainfall regimes and albedo, and reducing global warming by sequestering carbon and controlling dry-land salinity[24]. However, to develop a conservation plan for a region and to harness the ecosystem services sustainably, we need to realize that even the ecosystems of an area developed under similar climates show a wide range of attributes, depending on the species composition and plant functional type, the developmental stage of the ecosystem, connections with other ecosystems and the spatial pattern. There is a need to go beyond the stage of generalized ecosystem characters, and (i) consider services that emanate from a stand or other units of a particular forest type, (ii) determine how ecosystems of a region or landscape vary in their attributes, and how such variations affect the quality and quantity of services that humans receive and can harness, (iii) identify linkages across ecosystems, and their effects on ecosystem services in a regional context, (iv) identify and map areas generating ecosystem services and people consuming them or taking advantage of them, and (v) undertake economic valuation of ecosystem services and develop a suitable payment mechanism to assure their continued availability.

To cite a few examples, an alder (*Alnus*) forest is particularly useful for supplying nitrogen to plantations or croplands located downstream[25,26]. In the Western Himalaya, an oak (*Quercus leucotrichophora*) forest serves most effectively in terms of soil development, protection of nutrients, water retention, and the life of connected springs in a watershed[27], while pine (*Pinus roxburghii*) conserves nutrients efficiently on steep slopes by employing a high proportional retranslocation of nutrients from senescing leaves, slow litter decomposition[28,29], and microbial immobilization of nutrients[30]. Studies on the relationship between hydrology, nutrient supply and plants show that they can affect the spatial pattern of services significantly even in simpler tundra ecosystems[31]. The relationships between recharge and discharge areas, and forest functioning and services in terms of nutrient supply are not adequately described, with a few exceptions, even for forests occurring on an easily identifiable topographic gradient. Discharge areas in Fennoscandian boreal forests, in which low N and low pH are limiting to productivity, play an important role in providing a relatively stable environment and lead to the formation of productive communities, requiring high soil pH and nutrients. Attributes such as these can be harnessed profitably[32]. Though soil formation along with nutrient cycling is considered to be one of the premier ecosystem services, almost no information is available on how the rate of soil formation varies across different terrestrial ecosystems of a region under the influence of the same climate, or how the rate of soil formation is affected by subsequent deforestation. Forests may vary in numerous other features, such as the retrieval of nutrients from deeper soil layers, influence on hydrology and fire regimes, which may be suitably harnessed to generate services. Services of these ecosystems can be seen at various scales – local, regional, inter-regional and global. A study on a northern hardwood forest indicates how a complex interplay among vegetation, topography, soil factors and soil microbes determines the characteristics of N-cycling. The form of fungi and their ability to form a mat in the forest soil and to release organic acids, affect the rate of mineral weathering of forest soils, enhancing mobility of important nutrients and their uptake by trees and other plants. Griffiths *et al.*[32] showed that in Douglas-fir forest (*Pseudotsuga menziesii*) in the Pacific Northwest of USA, the concentrations of soluble phosphates and sulphates were significantly higher in fungal mats than in non-mat soils. We know little about the subtle variations that occur in ecosystem functioning, and their implications for ecosystem services. A study based on more than 2700 soil profiles indicated how ecosystems vary widely in distribution of carbon with soil depth and carbon sequestration ability because of differences in only two or three parameters such as plant functional type, allocation pattern to below-ground plant parts, and clay content in soil[33]. Ecosystems with deeper plant roots and more clay particles in soil (through protecting and stabilizing organic matter) are more effective as a long-term carbon sink than those with shallower roots. Soil organic carbon is important in relation to climatic change, as on a global scale soil stores 2344 Pg C, with 842 Pg C distributed in deeper soils (1–3 m depth) alone, which is more than carbon in the global atmosphere. An effective ecosystem pattern can be determined for a region to ameliorate rising atmospheric CO_2 levels.

To enable these services of great intrinsic value to command price calls for a radical change in thinking. As described earlier, the WHE of India is speculated to have a high ecosystem service value, partly because of its connection with a large territory down below. There is no such receiver territory of services in the case of EHE. In the case of the Western Himalayan croplands, the maintenance of genetic diversity of crops and fodder plants, soil microbes, and organically produced food grain or pulses can also be recognized as ecosystem services. The production of food grain and pulses largely depends on services generated by the adjoining forests[34]. There is a need to work out details of ecosystem services. For example, though vegetation is said to affect soil formation, how ecosystems of an area differ in this regard is hardly known. Some processes such as nitrogen fixation are considered to be a character of a species, but N-fixation occurs within the ecosystem arena, involving the interaction of the photosynthesis of host species, bacterial population, shade cast by plants, soil nutrients and soil moisture. Retention of nutrients and water within an area, involving contributions of mycorrhizae, tree growth, retranslocation of nutrients from senescing leaves, microbial immobilization of nutrients and a host of other processes, is also a form of ecosystem service. For example, the age-old practice of shifting agriculture in the tropics depends on soil fertility developed by forests over several years.

A given ecosystem attribute can be put to various uses. For example, the property of decomposition of a natural area such as forest stand could be used to take care of orange peels by a juice company or for preparing manure from forest litter, as is done in the Himalaya.

It is not easy to document all services precisely, and to make people perceive their roles. Equally difficult is the identification of providers and users of ecosystem services. We need data to analyse these, educate people and make them perceive the importance of ecosystem services. In democratic societies, it is the perception of individuals that determines the valuation of services provided, and individuals' preferences depend on how much they know about the environment and its significance to their lives. For example, people in the Himalaya would prefer to have forests if they knew enough about the total balance sheet of costs and benefits. The balance sheet may include, for example, productivity of different systems, such as forest and cropland, and services supplied from forest to maintain fertility of cropland[34], its role in crop yield, soil water storage, and carbon sequestration.

Conclusions

To conserve biodiversity is good for the environment, but by ignoring innumerable variations in ecosystem attributes and the resultant services, an imbalanced approach is promoted for environmental conservation. The concept of hot spots, largely based on concentration of species in an area, underplays the role of natural services that result from the exchanges between biotic and abiotic components in various ecosystems and the services that result from ecosystem connections. The diversity in ecosystem attributes somehow has been ignored worldwide in management practices.

Hot spots and other species-rich areas as a framework for management are inadequate. They give an impression that humans and biodiversity (and natural ecosystems) are isolated compartments. This message may be misread in developing countries, where even highly educated people consider forest litter as waste matter, and not a part of nutrient cycling. It is good that protected areas are doing well even in developing countries, but the problem is that not much wilderness is left in them. For example, in India the forest cover is below 20% of the geographical area, and much of it is under anthropogenic stress. In such a situation, a strategy is required to conserve whatever remains and restore areas where it is possible, rather than spending time and resource on selecting biodiversity-rich areas.

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ACKNOWLEDGEMENTS. I thank Prof. Don B. Zobel, Oregon State University, USA and Dr Nicholas Polunin, UK for their suggestions and encouraging me to take up issues relating to ecosystem services; Mukund Kumaiyan of Nainital for interacting with me and improving the manuscript and Dr Ashish Kothari of *Kalpvriksh*, Pune for providing support of NBSAP. I also thank Dr Anil Bisht, Kumaun University for help.

Received 18 October 2001; revised accepted 28 February 2002