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Ecosystem and Ecological Services; Need for Biodiversity Conservation-A Critical Review

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Authors' contributions

This work was carried out in collaboration among all authors. Author CEO designed the study, wrote the protocol and manage the analyses of the study. Author ENOO wrote the first draft of the manuscript. Authors OJU, SEA and CVU managed the literature searches. Author IMS read and edit the final manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Biodiversity and ecosystems are closely related concepts. Biodiversity provides numerous ecosystem services that are crucial and important to human well-being at present and in the future. The review aim to explain the Ecosystem services, and need for conservation of biodiversity. Ecosystem services (also called environmental services or nature's services) are benefits provided by ecosystems to humans, which contribute to making human life both possible and worth living. Human kind fully depends on the earth's ecosystems and the services they provide, such as food, water, disease management, climate regulation, spiritual fulfillment and aesthetic enjoyment. Over the past 50 years, humans have changed these ecosystems more rapidly and extensively than ever before, so that growing demands for food, fresh water, timber, fiber and fuel can be met. Pollution through the discharge of municipal and industrial wastewater and solid waste (e.g.

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plastics) exacerbates the related problems. Environmental pollution results from mishandling, deliberate disposal, spilling and leakage of waste products, such as gasoline, lubricating oils, diesel fuel, heating oil's, used or spent engine oils, animal wastes, human excreta, certain dissolved organic compound (e.g. urea, carbohydrate etc.), and organic salts such as nitrates, soap, phosphates of detergent, sodium, potassium, calcium and chloride ions. Under natural process most of the biodegradable pollutants of sewage are rapidly decomposed, but when they accumulate in large quantities, they create problems, i.e., when their input into environment exceeds the decomposition or disposal capacity. Ecosystem health is inherently linked to water management, sanitation and agriculture as these aspects influence water availability and quality. The loss of biodiversity can reduce the provision of ecosystem services essential for human well-being. Therefore, sustainable sanitation and water management is crucial for a more sustainable ecosystem management in the future.

Keywords: Biodiversity; conservation; ecosystem; ecological services; environment.

ABBREVIATIONS

ES : Ecosystem Services
UN : United Nation
IUCN : International Union for Conservation of Nature
MA : Millennium Ecosystem Assessment
CBN : Convention on Biological Diversity
IUCN : The International Union for the Conservation of Nature (IUCN)

1. INTRODUCTION

Millions of species populate gain energy to support their metabolism either directly from the sun, in the case of plants, or, in the case of animals and microbes, from other organisms through feeding on plants, predation, parasitism, or decomposition [1]. In the pursuit of life and through their capacity to reproduce, organisms use energy, water, and nutrients. Terrestrial plants obtain water principally from soil, while animals get it mainly from free-standing water in the environment or from their food. Plants obtain most of their nutrients from the soil or water, while animals tend to derive their nutrients from other organisms [2]. Microorganisms are the most versatile, obtaining nutrients from soil, water, their food, or other organisms [3]. Organisms interact with one another in many ways, including competitive, predatory, parasitic, and facilitative ways, such as pollination, seed dispersal, and the provision of habitat. These fundamental linkages among organisms and their physical and biological environment constitute an interacting and ever-changing system that is known as an ecosystem. Humans are a component of these ecosystems and are the dominant organism. However, humans depend on ecosystem properties and on the network of interactions among organisms and within and among ecosystems for sustenance, just like all other species.

As organisms interact with each other and their physical environment, they produce, acquire, or decompose biomass and the carbon-based or organic compounds associated with it. They also move minerals from the water, sediment, and soil into and among organisms, and back again into the physical environment. Terrestrial plants also transport water from the soil into the atmosphere [4]. In performing these functions, they provide materials to humans in the form of food, fiber, and building materials and they contribute to the regulation of soil, air, and water quality [5]. These relationships sound simple in general outline, but they are in fact enormously complex, since each species has unique requirements for life and each species interacts with both the physical and the biological environment. Recent perturbations, driven principally by human activities, have added even greater complexity by changing, to a large degree, the nature of those environments.

Biodiversity is being threatened at an unprecedented scale by global environmental change brought about by human societies [6]. In addition to the many moral reasons to preserve it for its own sake, biodiversity provides numerous ecosystem services that are crucial to human well-being at present and in the future. Ecosystem services (also called environmental services or nature's services) are benefits provided by ecosystems to humans, which contribute to making human life both possible and worth living. Biodiversity can affect ecosystem services directly [7]. For example, humans derive most of their essential food and fibers from animals and plants. Certain plants and animals are at the core of traditional knowledge systems. In many areas of the world, fields covered in colorful flowers provide enjoyment to locals and visitors, and support important tourist industries. Particular configurations of vegetation, bird songs, and scents are crucial to human sense of place. In addition, biodiversity can affect the provision of ecosystem services indirectly, through its influence on ecosystem processes that are essential to Earth’s life support systems. By affecting the magnitude, pace, and temporal continuity by which energy and materials are circulated through ecosystems, biodiversity influences the provision of regulating ecosystem services, such as pollination and seed dispersal of useful plants, regulation of climatic conditions suitable to humans and the animals and plants they consider important, the control of agricultural pests and diseases, and the regulation of human health. Also, by affecting nutrient and water cycling, and soil formation and fertility, biodiversity indirectly supports the production of food, fiber, potable water, shelter, and medicines [8].

Biodiversity has several components, such as the number, abundance, composition, spatial distribution and interactions of genotypes, populations, species, functional types and traits, and landscape units in a given system. All these components may play a role in maintaining life support systems in the long term. However, some of these components are more important than others in influencing specific ecosystem services. For example, functional composition, that is, the identity, abundance and range of species traits, appears to be considerably more important than species number in determining the effects of biodiversity on many ecosystem services, such as plant and animal biomass production, soil formation and retention, pollination, climatic regulation, and protection against natural hazards. At least among species within the same trophic level (e.g., plants), rarer species likely have small effects at any given point in time. Therefore, the most dramatic changes in ecosystem services are likely to come from altered functional composition of communities and from the loss, within the same trophic level, of locally abundant species rather than from the loss of already rare species. For example, accelerated land use change in the last decade (e.g. replacement of dry forest by soybean fields in Southern South America, replacement of lowland rainforest by oil palm plantations in South East Asia) will likely increase the risk of total extinction of critically endangered plant and animal species native to those ecosystems [8]. However, most of the ecosystem-service consequences are likely to arise from the decreased abundance of locally dominant species -which are unlikely to become totally extinct- rather than from the complete disappearance of rare species, many of which might be already “functionally extinct”. The presence of several plant species and genotypes within the same trophic level appear to play a significant role in some ecosystem services, for example in the protection against agricultural pests and diseases. Some of the most dramatic examples of effects of biodiversity changes on ecosystem services have been the consequence of the alteration of local food-web diversity through indirect interactions and trophic cascades.

However, over the past 100 years, humans have increased the extinction rate by at least 100 times compared to the natural rate, leading to a net loss of biodiversity. Some 12% of bird species, 23% of mammals, 25% of conifers, and 32% of amphibians are currently threatened with extinction, and similarly alarming threats of extinction may apply to aquatic organisms. Many animal and plant populations have declined in numbers, geographical spread, or both. Genetic diversity has also declined globally, particularly among domesticated plants and animals in agricultural systems. The distribution of species on Earth is becoming more homogeneous. This is caused by the extinction of species or loss of populations that had been unique to particular regions, and by the invasion or introduction of species into new areas [9].

Virtually all of Earth's ecosystems have now been dramatically transformed through human actions. Due to the expansion of agriculture, cities and infrastructure, the conversion of ecosystems is expected to continue and between now to 2050 and the services they provide, many of these services are used in an unsustainable way while humans depend on ecosystems. This has and will have harmful consequences for human well-being. Those that live in poor rural areas are often the first being affected by the lack of these services and its consequences. They are also the least able to acquire substitutes for ecosystem services. It is a major challenge to reverse degradation of ecosystems while meeting increasing demand for their services, but it is a challenge that can be met. Changes in policies, institutions and practices can mitigate some of the negative consequences of pressure on ecosystems, although the changes are large and currently not on the way [10].

Unfortunately, application of strict conservation approaches has not resulted in the achievement of many of the world's global conservation targets: none of the CBD targets for 2010 were met and species and ecosystems are declining more rapidly than ever. Thus, it is clear that in addition to the continued use of proven conservation tools such as protected areas, additional approaches will be necessary to achieve future conservation targets. Ecosystem services approaches have the potential to contribute significantly to achieving many conservation goals. The conservation and ecosystem services communities still have much to learn about the most effective and strategic application of these tools for conserving biodiversity and sustainably managing ecosystem services. But, at this stage, it is important to recognize the potential of ecosystem services approaches to contribute to biodiversity conservation and to complement other conservation tools and methods, while recognizing that there will be limitations to using ecosystem services approaches for achieving certain conservation targets, such as the protection of rare species, endemic species, and species or habitats without utilitarian value. Thus, we will continue to need focused biodiversity conservation approaches alongside new and evolving ecosystem services approaches if we are to conserve the full range of genes, species, and ecosystems that are important for all life on earth. .The loss of biodiversity can reduce the provision of ecosystem services essential for human well-being. Knowledge of the links between biodiversity and ecosystem processes is still incomplete, but existing evidence suggests that a precautionary approach may be prudent and that research should be targeted to assist with the development of appropriate management interventions.

1.1 Biodiversity Services

Biodiversity or Biological diversity is a term that describes the variety of living beings on earth. It is described as degree of variation of life. Biological diversity encompasses microorganism, plants, animals and ecosystems such as coral reefs, forests, rainforests, deserts etc. The United Nations designated 2011–2020 as the United Nations Decade on Biodiversity. In biodiversity, each species, no matter how big or small has an important role to play in ecosystem. Various plant and animal species depend on each other for what each offers and these diverse species ensures natural sustainability for all life forms. A healthy and solid biodiversity can recover itself from variety of disasters [9]. Biodiversity has three essential elements:

- Genetic diversity,
- Ecosystem diversity
- Species diversity
- Molecular diversity
- **A species is a group of living organisms that can interbreed:** Examples of species include blue whales, white - tailed deer, white pine trees, sunflowers and microscopic bacteria that you cannot even see with your eye. Biodiversity includes the full range of species that live in an area.
- **Genetic Biodiversity:** Is the variation in genes that exists within a species. A helpful way to understand genetic diversity is to think about dogs. All dogs are part of the same species, but their genes can dictate whether they are Chihuahua or a Great Dane. There can be a lot of variation in genes – just think about all the colors, sizes, and shapes that make up the genetic diversity of dogs.
- **Ecological Biodiversity:** Is the diversity of ecosystems, natural communities and habitats. In essence, it's the variety of ways that species interact with each other and their environment. The forests of Maine differ from the forests of Colorado by the types of species found in ecosystems, as well as the temperature and rainfall. These two seemingly similar ecosystems have a lot of differences that make them both special [11].

Biodiversity is unevenly distributed. It varies globally and within regions. The various factors that influence biodiversity include -temperature, altitude, precipitation, soils and their relation with other species. For instance, ocean biodiversity is 25 times lesser than terrestrial diversity. Biodiversity also increases its form as it moves from the poles towards the tropics [4].

1.2 Values of Biodiversity

Biodiversity has a number of functions on the Earth. Biodiversity has evolutionary, ecological, economic, social, cultural, and intrinsic values [12]. These are includes:

- **Maintaining Balance of the Ecosystem:** Recycling and storage of nutrients, combating pollution, and stabilizing climate, protecting water resources, forming and protecting soil and maintaining ecobalance.
- **Provision of Biological Resources:** Provision of medicines and pharmaceuticals, food for the human population and animals, ornamental plants, wood products, breeding stock and diversity of species, ecosystems and genes.
- **Social Benefits:** Recreation and tourism, cultural value and education and research.

The role of biodiversity in the following areas will help make clear the importance of biodiversity in human life:

- **Biodiversity and Food:** Biodiversity allows us to live healthy and happy lives. It provides us with an array of foods and materials and it contributes to the economy. Without a diversity of pollinators, plants, and soils, our supermarkets would have a lot less produce. 80% of human food supply comes from 20 kinds of plants. But humans use 40,000 species for food, clothing and shelter. Biodiversity provides for variety of foods for the planet.
- **Biodiversity and Human Health:** The shortage of drinking water is expected to create a major global crisis. Biodiversity also plays an important role in drug discovery and medicinal resources. Medicines from nature account for usage by 80% of the world's population.
- **Biodiversity and Industry:** Biological sources provide many industrial materials. These include fiber, oil, dyes, rubber, water, timber, paper and food.
- **Biodiversity and Culture:** Biodiversity enhances recreational activities like bird watching, fishing, trekking etc. It inspires musicians and artists.
- **Biodiversity Provides Ecosystem Services:** water purification; clean air, fertile soil, climate regulation, flood control, as well as pest regulation and disease resistance, essentially for the cost of letting natural systems function.
- **Biodiversity is Nature's Insurance Policy:** The more variety there is now, the more there can be in the future, and the greater the chances of adapting to major changes in environmental conditions [13].
- Biodiversity is key in sustaining the natural beauty of National and Provincial Parks and green spaces for recreational use and heritage preservation.
- Biodiversity allows for ecosystems to adjust to disturbances like extreme fires and floods. If a reptile species goes extinct, a forest with 20 other reptiles is likely to adapt better than another forest with only one reptile.
- Genetic diversity prevents diseases and helps species adjust to changes in their environment [14].

2. REASON FOR LOSS OF BIODIVERSITY

The earth's biodiversity is in grave danger. In the present era, human beings are the most dangerous cause of destruction of the earth's biodiversity [6]. In 2006, the terms threatened, endangered or rare were used to describe the status of many species. The "evil quartet" identified by Jared Diamond is overkill, habitat destruction, secondary extinctions and introduced species. Factors identified by Edward Wilson are described by the acronym- HIPPO standing for habitat destruction, climate change, invasive species, pollution, human overpopulation and over-harvesting [15]. Habitat destruction is a major cause for biodiversity loss. Habitat loss is caused by deforestation, overpopulation, pollution and global warming. Species which are physically large and those living in forests or oceans are more affected by habitat reduction. Some experts estimate that around 30% of all species on earth will be extinct by 2050. According to the International Union for Conservation of Nature (IUCN), globally about one third of all known species are threatened with extinction. Even it is estimated that 25% of all mammals will be extinct within 20 years.

Even if a small element of an ecosystem breaks down, the whole system's balance is threatened. Fresh water ecosystems are nowadays the most threatened ecosystems. Invasive species refer to those that would normally remain constrained from an ecosystem because of the presence of natural barriers. Since these barriers are no longer existing, invasive species invade the ecosystem, destroying native species. Human activities have been the major cause for encouraging invasive species. Species can also be threatened by genetic pollution- uncontrolled hybridization and gene swamping. For instance, abundant species can interbreed with rare species thus causing swamping of the gene pool. Over exploitation is caused by activities such as over fishing, over hunting, excessive logging and illegal trade of wildlife. Over 25% of global fisheries are being overfished at unsustainable levels.

Global warming is also becoming a major cause for loss of biodiversity. For example if the present rate of global warming continues, coral reefs which are biodiversity hotspots will disappear in 20-40 years. 10% of all species might become extinct by 2015, if global warming continues. Thus we can see that biodiversity which is crucial for the well-being of life on earth, is coming under the threat of many factors related to human activities [6]. There is an urgent need to take action to protect the magnificent biodiversity of our planet. We must create economic policies in order to maintain the Earth's biodiversity and take appropriate measures to protect habitats and species [16].

2.1 Ecological Services

Ecosystem services are the benefits people obtain from ecosystems. This definition is derived from two other commonly referenced and representative definitions:

"Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life. They maintain biodiversity and the production of ecosystem goods, such as seafood, forage timber, biomass fuels, natural fiber, and many pharmaceuticals, industrial products, and their precursors [13]. Ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from ecosystem functions [12].

Ecosystem services have been categorized in a number of different ways [17], including by:

- Functional groupings, such as regulation, carrier, habitat, production, and information services [5].
- Organizational groupings, such as services that are associated with certain species, that regulate some exogenous input, or that are related to the organization of biotic entities [18] and
- Descriptive groupings, such as renewable resource goods, nonrenewable resource goods, physical structure services, biotic services, biogeochemical services, information services, and social and cultural services [18].

For operational purposes, ecosystem services was classified along functional lines within the Millennium Ecosystem Assessment (MA), using categories of provisioning, regulating, cultural, and supporting services.

2.2 Provisioning Services

These are the products obtained from ecosystems, including:

- ***Food and fiber:*** This includes the vast range of food products derived from plants, animals, and microbes, as well as materials such as wood, jute, hemp, silk, and many other products derived from ecosystems.
- **Fuel*:*** Wood, dung, and other biological materials serve as sources of energy.
- ***Genetic Resources:*** This includes the genes and genetic information used for animal and plant breeding and biotechnology.
- ***Biochemicals:*** Natural Medicines, and Pharmaceuticals. Many medicines, biocides, food additives such as alginates, and biological materials are derived from ecosystems.
- ***Ornamental Resources:*** Animal products, such as skins and shells, and flowers are used as ornaments, although the value of these resources is often culturally determined. This is an example of linkages between the categories of ecosystem services.
- ***Fresh water:*** Fresh water is another example of linkages between categories—in this case, between provisioning and regulating services.

2.3 Regulating Services

These are the benefits obtained from the regulation of ecosystem processes,
Including:

- ***Air Quality Maintenance:*** Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality.
- ***Climate regulation:*** Ecosystems influence climate both locally and globally. For

example, at a local scale, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases.

- ***Water Regulation:*** The timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in land cover, including, in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.
- ***Erosion Control:*** Vegetative cover plays an important role in soil retention and the prevention of landslides.
- ***Water Purification and Waste Treatment:*** Ecosystems can be a source of impurities in fresh water but also can help to filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems.
- ***Regulation of Human Diseases:*** Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes.
- ***Biological Control:*** Ecosystem changes affect the prevalence of crop and livestock pests and diseases.
- ***Pollination:*** Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators.
- ***Storm Protection:*** The presence of coastal ecosystems such as mangroves and coral reefs can dramatically reduce the damage caused by hurricanes or large waves.

2.4 Cultural Services

These are the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, including:

- ***Cultural Diversity:*** The diversity of ecosystems is one factor influencing the diversity of cultures.
- ***Spiritual and Religious Values:*** Many religions attach spiritual and religious values to ecosystems or their components.
- ***Knowledge Systems* (Traditional and Formal):** Ecosystems influence the types of knowledge systems developed by different cultures.
- ***Educational Values:*** Ecosystems and their components and processes provide the basis for both formal and informal education in many societies.
- ***Inspiration:*** Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.
- ***Aesthetic Values:*** Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, “scenic drives,” and the selection of housing locations.
- ***Social Relations:*** Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies.
- ***Sense of Place:*** Many people value the “sense of place” that is associated with recognized features of their environment, including aspects of the ecosystem.
- ***Cultural Heritage Values:*** Many societies place high value on the maintenance of either historically important landscapes (“cultural landscapes”) or culturally significant species.
- ***Recreation and Ecotourism:*** People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.

Cultural services are tightly bound to human values and behavior, as well as to human institutions and patterns of social, economic, and political organization. Thus perceptions of cultural services are more likely to differ among individuals and communities than, say, perceptions of the importance of food production.

2.5 Supporting Services

Supporting services are those that are necessary for the production of all other ecosystem services. They differ from provisioning, regulating, and cultural services in that their impacts on people are either indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people. (Some services, like erosion control, can be categorized as both a supporting and a regulating service, depending on the time scale and immediacy of their impact on people.) For example, humans do not directly use soil formation services, although changes in this would indirectly affect people through the impact on the provisioning service of food production. Similarly, climate regulation is categorized as a regulating service since ecosystem changes can have an impact on local or global climate over time scales relevant to human decision-making (decades or centuries), whereas the production of oxygen gas (through photosynthesis) is categorized as a supporting service since any impacts on the concentration of oxygen in the atmosphere would only occur over an extremely long time. Some other examples of supporting services are primary production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat.

2.6 Multisectoral Approach

Every part of Earth produces a bundle of ecosystem services. Human interventions can increase some services, though often at the expense of other ones. Thus human interventions have dramatically increased food provisioning services through the spread of agricultural technologies, although this has resulted in changes to other services such as water regulation. For this reason, a multisectoral approach is essential to fully evaluate changes in ecosystem services and their impacts on people. The multisectoral approach examines the supply and condition of each ecosystem service as well as the interactions among them. The Millennium Ecosystem Assessment (MA) has adopted just such an approach. When assessing ecosystem services, it is often convenient to bind the analysis spatially and temporally with reference to the ecosystem service or services being examined. Thus a river basin is often the most valuable ecosystem scale for examining changes in water services, while a particular agroecological zone may be more appropriate for assessing changes in crop production [11]. When looking at interactions among services, the combination of services provided by an ecosystem, or the variety of services drawn on by a society, the question of boundaries becomes more complex.

3. BIODIVERSITY AND ECOSYSTEM SERVICES

Habitat modification, invasion, and many other factors are leading to changes in biodiversity across many taxa within most ecosystems. Recently, theoretical and empirical work has identified linkages between changes in biodiversity and the way ecosystems function [19]. The Millennium Ecosystem Assessment (MA) will address how ecosystem services are affected by such linkages. Among the most important factors identified is the degree of functional redundancy found within an ecosystem [20]. This indicates the substitutability of species within functional groups in an ecosystem such that the impact created by the loss of one or more species is compensated for by others [21]. For example, in many ecosystems there are several species that fix nitrogen (known as a functional group of species). If the loss of any one of them is compensated for by the growth of others and there is no overall loss in nitrogen fixation, then there is functional redundancy in that ecosystem [22].

Some species make unique or singular contributions to ecosystem functioning, however, and therefore their loss is of greater concern [22]. Small changes in the biodiversity of diverse systems may lead to only small changes in the functioning of an ecosystem, including its production of services, providing no species with unique roles are lost [23,24]. But the possibility of significant losses of function increases as more species are lost and as redundancy is reduced—that is, there is an asymptotic relationship between biodiversity and ecosystem functioning. For example, the high diversity of South African fynbos ecosystems ensures steady rates of production because many plant species can compensate for losses by growing when others cannot [20]. Greater redundancy represents greater insurance that an ecosystem will continue to provide both higher and more predictable levels of services [25]. The Millennium Ecosystem Assessment (MA) will seek to evaluate biodiversity and potential declines in biodiversity for different ecosystems under a set of different scenarios for plausible changes in driving forces. This work will extend previous studies that developed scenarios for biodiversity change. For provisioning and supporting services, the MA will identify which ecosystem functions are associated with these services and link their response to declining biodiversity, using the fundamental asymptotic relationship between biodiversity and ecosystem functioning. Both magnitudes and stability responses to biodiversity loss can be considered using this fundamental relationship [25].

3.1 Ecosystem Condition and Sustainable Use

People seek multiple and different services from ecosystems and thus perceive the condition of an ecosystem in relation to its ability to provide the services desired. The ability of ecosystems to deliver particular services can be assessed separately with various methods and measures [26]. An adequate assessment of the condition of ecosystems, the provision of services, and their implications for human well-being requires an integrated approach. With such an assessment in hand, a decision process can then determine which set of services are valued most highly and can manage the system in a sustainable way. In a narrow sense, the sustainability of the production of a particular ecosystem service can refer simply to whether the biological potential of the ecosystem to sustain the yield of that service (such as food production) is being maintained. Thus a fish provision service is sustainable if the surplus but not the resource base is harvested, and if the fish's habitat is not degraded by human activities. In the MA, we use the term "sustained yield management" to refer to the management and yield of an individual resource or ecosystem service.

More generally, however, sustainability is used in the context of "sustainable development" to refer to a pattern of development that meets current needs without diminishing prospects for future generations. We use sustainability, and sustainable management, to refer to this goal of ensuring that a wide range of services from a particular ecosystem is sustained. The Millennium Ecosystem Assessment (MA) will consider criteria and methods to provide an integrated approach to ecosystem assessment. The condition and sustainability of each category of ecosystem services is evaluated in somewhat different ways, although in general a full assessment of any service requires considerations of stocks, flows, and resilience [27].

3.2 Condition of Provisioning Services

The flows of provisioning services do not accurately reflect their condition, since a given flow may or may not be sustainable over the long term.

The flow is typically measured in terms of biophysical production, such as kilograms of maize per hectare or tons of tuna landings. The provisioning of ecological goods such as food, fuel wood, or fiber, depends both on the flow and the "stock" of the good, just as is the case with manufactured goods. (In economics, "stock" refers to the total merchandise kept on hand by a merchant; in this section, we use "stock" in its economic sense to show how considerations of ecosystem goods can be incorporated into the economic framework of stocks and flows.) The quantity of goods sold by a manufacturer (the flow), for example, is an incomplete measure of a factory's productivity, since it could come from either the production of new goods or the depletion of built-up stocks. Indeed, production of biological resources has often been maintained in the short term at a higher rate than its sustainable yield. In the long term, the production of overharvested resources will fall.

Marine fisheries provide examples of an ecosystem service being degraded even while output has been temporarily maintained or increased by more intensive harvesting. Numerous fisheries around the world have been overharvested, exhibiting a general pattern of rapid growth in landings (production) followed by the eventual collapse of the fishery. Similar patterns can be found with virtually all other provisioning services. Agricultural production, for example, can be maintained through the addition of fertilizers and through new crop varieties even while the productive potential of the ecosystem is degraded through soil erosion. Some 40 percent of agricultural land has been strongly or very strongly degraded in the past 50 years by erosion, salinization, compaction, nutrient depletion, biological degradation, or pollution even while overall global food production has increased. So long as manufactured capital can compensate for losses of the natural capital of the ecosystem, agricultural production can be maintained. In this case, however, manufactured and natural capital are not perfectly substitutable, and once a critical level of soil degradation is reached, agricultural output will decline.

A complete accounting of the condition of food production would reveal that it has been degraded because the underlying capability of the ecosystem to maintain production has been degraded. Historically, it has not been common for environmental or resource assessments to include measures of the productive potential of biological resources when monitoring the condition of the resource. Thus although all countries have considerable information on the production of grain, fisheries, and timber, relatively little is known about the actual condition of these services since the productive potential of the resource has rarely been evaluated. The Pilot Analysis of Global Ecosystems, which was prepared by the World Resources Institute and the International Food Policy Research Institute to assist in the MA design, attempted to provide a more complete assessment of the condition of ecosystem services along these lines [28].

3.3 Condition of Regulating, Cultural, and Supporting Services

In the case of regulating services, as opposed to provisioning services, the level of "production" is generally not relevant. Instead the condition of the service depends more on whether the ecosystem's capability to regulate a particular service has been enhanced or diminished. Thus if forest clearance in a region has resulted in decreased precipitation and this has had harmful consequences for people, the condition of that regulatory service has been degraded [29]. The evaluation of the condition of cultural services is more difficult. Some cultural services are linked to a provisioning service (such as recreational fishing or hunting) that can serve as a proxy measure of the cultural service. But in most cases no such proxy exists. Moreover, unlike provisioning or regulating services, assessing the condition of cultural services depends heavily on either direct or indirect human use of the service. For example, the condition of a regulating service such as water quality might be high even if humans are not using the clean water produced, but an ecosystem provides cultural services only if there are people who value the cultural heritage associated with it.

Information about the condition of cultural services can be obtained by identifying the specific features of the ecosystem that are of cultural, spiritual, or aesthetic significance and then examining trends in those features. For example, salmon are a totemic or revered species in almost all parts of the world where they are found, and thus the degradation of wild salmon stocks represents degradation of a cultural service provided by the ecosystem. But cultural service information such as this would be difficult to obtain and to quantify: tigers, for instance, remain totemic species even in areas where they have been extinct for decades. Recognizing that the concept of cultural services is relatively new, the MA will explore methods for evaluating the condition and value of these services [30]. Supporting services maintain the conditions for life on Earth but may affect people only indirectly (by supporting the production of another service, as soil formation supports food production) or over very long time periods (such as the role of ecosystems in producing oxygen). Because the link to human benefits is indirect, as opposed to the other ecosystem services just discussed, a normative scale for assessing the condition of a service is not always practical. For example, primary production is a fundamental supporting service, since life requires the production of organic compounds. But if global primary production were to increase by 5 percent over the next century, it would be difficult to categorize the change as an enhancement or degradation of the service, though it certainly would be a significant change. In such cases the MA will report on the current biophysical state (production, flux, and stocks) of the supporting service.

4. THE ECOSYSTEM APPROACH: A BRIDGE BETWEEN THE ENVIRONMENT AND HUMAN WELL-BEING

The concept of an ecosystem provides a valuable framework for analyzing and acting on the linkages between people and their environment. For that reason, the ecosystem approach has been endorsed by the Convention on Biological Diversity (CBD) and the Millennium Ecosystem Assessment (MA) conceptual framework is entirely consistent with this approach. The CBD defines the ecosystem approach as follows: The Ecosystem Approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. Thus, the application of the ecosystem approach will help to reach a balance of the three objectives of the Convention: conservation; sustainable use; and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources. An ecosystem approach is based on the application of appropriate scientific methodologies focused on levels of biological organization, which encompass the essential structure, processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of many ecosystems [31].

According to the CBD, the term ecosystem can refer to any functioning unit at any scale. This approach requires adaptive management to deal with the complex and dynamic nature of ecosystems and the absence of complete knowledge or understanding of their functioning. It does not preclude other management and conservation approaches, such as biosphere reserves, protected areas, and single-species conservation programs, or other approaches carried out under existing national policy and legislative frameworks; rather, it could integrate all these approaches and other methodologies to deal with complex situations. As described in the CBD, there is no single way to implement the ecosystem approach, as it depends on local, provincial, national, regional, and global conditions.

The conceptual framework of the MA provides a useful assessment structure that can contribute to the implementation of the CBD's ecosystem approach. By way of analogy, decision-makers would not make a decision about financial policy in a country without examining the condition of the economic system, since information on the economy of a single sector such as manufacturing would be insufficient. The same applies to ecological systems or ecosystems. Decisions can be improved by considering the interactions among the parts of the system. For instance, the draining of wetlands may increase food production, but sound decisions also require information on whether the potential added costs associated with the increased risk of downstream flooding or other changes in ecosystem services might outweigh those benefits.

4.1 Need for Conservation of Biodiversity and Ecosystem Services

Biodiversity and ecosystems are closely related concepts. Biodiversity is defined by the Convention on Biological Diversity (CBD) as "the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" [32]. Diversity thus is a structural feature of ecosystems, and the variability among ecosystems is an element of biodiversity. Decreased provision of ecosystem services as a result of biodiversity loss is not expected to affect all peoples in the same way. People that rely most directly on ecosystem services, such as subsistence farmers and fishers, the rural poor, and traditional societies, face the most serious and immediate risks. This is because they are the ones who rely the most on the "safety net" provided by the biodiversity of natural ecosystems in terms of food security and sustained access to medicinal products, fuel, construction materials, and protection from natural hazards such as storms and floods. Also, because of their low economic and political power, the less privileged sectors cannot substitute purchased goods and services for the lost ecosystem benefits and they typically have little influence on national policy. Therefore the loss of biodiversity-dependent ecosystem services is likely to accentuate inequality and marginalization of the most vulnerable sectors of society.

4.2 Threats of Biodiversity

There is growing scientific concern about the major, rapid decline in biodiversity around the world. The extinction of each additional species and the loss of variation within species brings the irreversible loss of unique genetic diversity [15]. The scientific community has linked human activity to the accelerated rate of recent and current extinctions. Biodiversity is declining because of:

- Deforestation / Habitat loss
- Invasive species
- Pollution
- Population Growth
- Over-consumption (Unsustainable use)
- Climate change

4.3 Signs of Biodiversity Loss

- More than 70 percent wild species are endangered
- More than 70% of wetlands are gone; the loss of wetlands is seen as eroding the protection of our drinking water and leading to further species losses.
- Climate change is significantly affecting some northern Ontario species.
- Increase of at risk species.
- Human cultural diversity and biodiversity are linked. Intact indigenous cultures living traditional lifestyles require an intact, functioning ecosystem, and are threatened by the loss of biodiversity and attendant ecosystem goods and services.
- Human impacts on biodiversity have been accelerating as population growth and consumption rates have increased.
- If the dominant public demand is less expense and more convenience, that is what industry will supply -- often to the

detriment of environmental interests. In short, it is the average consumer that dictates industrial actions that may lead to loss of biodiversity.
- The same principle discussed above for industry applies also to agriculture. The consumer wants cheap fresh food. The farmer delivers.
- Loss of species may mean loss of important but as yet unknown resources for humans.

4.4 Society's Role in Supporting Biodiversity

We depend on biodiversity and have a responsibility to contribute to biodiversity conservation and to use biological resources in a sustainable manner. Government, non-governmental organizations, community groups, academic institutions and individuals use a variety of means to protect plants and animals [33].

- Preservation of local natural areas (woods, old fields, wetlands, etc) allows the plants and animals that depend on these areas to continue to live.
- Restoration of habitat that has been lost (school yard naturalization, naturalized gardening, and removal of invasive species) can increase the number of different species found in an area [34].
- Development and institution of recovery plans for species at risk.
- Zoos and botanical gardens and other facilities can participate in captive breeding with the intent of reintroducing the species when habitat problems have been solved through processes such as ecological restoration [34].

Conservation efforts often focus on maintaining biodiversity as measured by the number of species present at a particular place. Since threats to biodiversity are distributed unevenly, the spatial limits of biodiversity is recognized, spawning a group of terms - α, β and γ diversity - differentiating between local species richness (α diversity, the number of species at a location), the regional species pool (γ diversity, the number of different species that could be at a location) and variability between localities (β diversity). In the long term, however, persistence of species requires not only maximizing their representation in places where they are currently present, but crucially also minimizing the probability of their being lost [35]. The International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (www.iucnredlist.org) is the accepted standard for species global extinction risk. Both governmental and non-governmental organizations increasingly rely on the IUCN Red List to inform priorities, influence legislation, and guide conservation investment [35]. Concentrating on the number of species and taking threat rankings at face value to define conservation priorities reduces biodiversity to a simple metric which is easy to comprehend; however when it comes to the link between biodiversity and ecosystem functioning, much evidence points to a strong role for species identity [36]. That is, the composition of ecological communities and even the presence of individual dominant species (e.g., keystone species or ecosystem engineers) can play a key role in controlling ecosystem function, rather than the number of species per se [29].

5. CONCLUSION

The management of biodiversity is a complex matter that needs the involvement of many different partners ranging from governmental organizations to private companies, NGO's and volunteers. This aside, national and international commitment, legislation and enforcement offer an essential framework for promoting and maintaining biodiversity. Species extinction is a natural part of Earth's history. Many ecosystem services approaches represent new opportunities for the sustainable management of species and ecosystems. However, it is important to recognize that while biodiversity is intimately connected to ecosystems services through various relationships ecosystem services approaches and biodiversity conservation approaches may be complementary, but are not always identical pathways for achieving conservation or sustainable natural resource management. In many cases, the two approaches will be compatible and mutually reinforcing, delivering positive results for conservation targets, even if biodiversity was not the original or primary objective, and vice versa. However, it is important to understand the conditions in which these two approaches do not lead to the same outcomes so that increasingly scarce resources for biodiversity conservation may be used to target those elements of biodiversity that may not be conserved otherwise. This divergence in outcomes is most concerning with respect to species, ecosystems, and ecological process that may fall through the cracks of ecosystem services frameworks, particularly very rare or endemic species that may not play important functional roles in an ecosystem. When utilising ecosystem services approaches for conservation, planners and managers must be realistic and recognise that these approaches are not all-encompassing and there are going to be gap species, ecosystems, and ecological processes whose conservation will require tools tailored to address those issues.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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