UNEP

CONVENTION ON BIOLOGICAL DIVERSITY

Distr.
GENERAL

UNEP/CBD/SBSTTA/10/INF/5
17 December 2004

ENGLISH ONLY

SUBSIDIARY BODY ON SCIENTIFIC, TECHNICAL AND TECHNOLOGICAL ADVICE
Tenth meeting
Bangkok, 7-11 February 2005
Item 5.2 of the provisional agenda*

MILLENNIUM ECOSYSTEM ASSESSMENT: REVIEW OF THE DRAFT REPORTS, IN PARTICULAR THE DRAFT SYNTHESIS REPORT PREPARED FOR THE CONVENTION ON BIOLOGICAL DIVERSITY

Draft Synthesis Report for the Convention on Biological Diversity

Note by the Executive Secretary

1. The Executive Secretary is circulating herewith, for the information of the participants to the tenth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA), the Synthesis Report for the Convention on Biological Diversity prepared by the Millennium Ecosystem Assessment.

2. The Millennium Ecosystem Assessment (MA) was carried out between 2002 and 2005 to assess the consequences of ecosystem change for human well-being and to analyse options available to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being. The Assessment responds to requests for information received through the Convention on Biological Diversity and other international conventions and is also designed to meet needs of other stakeholders including business, civil society, and indigenous peoples.

3. The Assessment has been carried out through four working groups (Condition and Trends; Scenarios; Responses; and Sub-Global) and includes sixteen sub-global assessments in addition to the global assessment. Approximately 1,300 experts from 95 countries have participated as authors of the working group reports, review editors, or authors of the sub-global assessments. During 2004, the draft technical assessment reports of the four working groups underwent two rounds of review by Governments and experts. Approximately 50 countries, 800 experts, and 10 national academies of sciences (and other scientific institutions) provided review comments on the draft reports. An independent review board provided oversight for the review process and ensured that all review comments were appropriately addressed by the authors.

4. The reports of the four working groups, which provide the technical foundation for the assessment, comprise approximately 73 chapters and 2000 printed pages. A number of synthesis reports are being prepared to summarize the findings most relevant to for particular decision-maker audiences. These include a General Synthesis and a Synthesis for the Convention on Biological Diversity.

* UNEP/CBD/SBSTTA/10/1.

For reasons of economy, this document is printed in a limited number. Delegates are kindly requested to bring their copies to meetings and not to request additional copies

5. A number of national focal points for the Convention on Biological Diversity, other national experts and Secretariat staff members have contributed to the Assessment process as chapter authors and reviewers. Secretariat staff members and the Chair and Chair-elect of SBSTTA have also participated in the preparation of the Synthesis for the Convention on Biological Diversity. In addition, the Executive Secretary serves on the Board of the Assessment. The Assessment secretariat and Co-Chairs have regularly reported to Conference of the Parties and to SBSTTA, and have organized a number of briefing sessions for delegates to these meetings.

6. At its seventh meeting, the Conference of the Parties, in its decision VII/6, took note of the progress of the Millennium Ecosystem Assessment and the outline for the synthesis report that would be prepared for the Convention on Biological Diversity, and encouraged national focal points to participate in the review of the Millennium Ecosystem Assessment reports. The Conference of the Parties also requested SBSTTA to review the findings of the Millennium Ecosystem Assessment, including the synthesis report on biodiversity, to be taken into account by the Millennium Ecosystem Assessment in finalizing its reports, and to prepare recommendations to the eighth meeting of the Conference of the Parties.

7. Accordingly, the draft synthesis report on biodiversity is being made available to SBSTTA in this information document. It is being provided in the language and form in which it was received by the Secretariat of the Convention. The Summary for Decision Makers, which summarizes the main findings of the full synthesis report, is available separately, in all official languages, as a working document for the tenth meeting of SBSTTA (UNEP/CBD/SBSTTA/10/6).

8. The Summary for Decision Makers and the full synthesis report were also made available for expert and government review on 15 December 2004, and the national focal points of the Convention are encouraged to participate in this review.

9. The draft will be revised based on comments of SBSTTA, as well as those received during the expert and government review, and finalized by the Panel of the Millennium Ecosystem Assessment. Along with the other reports of the Millennium Ecosystem Assessment, the synthesis report will be formally reviewed and approved by the Assessment Board in March 2005.

10. The final versions of the synthesis report and its Summary for Decision Makers, and the other Assessment reports, will be available to SBSTTA at its eleventh meeting, in order that it may prepare recommendations for the consideration of the Conference of the Parties at its eighth meeting.

Millennium Ecosystem Assessment

www.millenniumassessment.org | Strengthening Capacity to Manage Ecosystems Sustainably for Human Well-Being

Synthesis Report for the Convention on Biological Diversity

Review Draft – Not for Citation

15 December 2004

Send review comments to review@MAreview.org by 4 Feb. 2005

Synthesis Team Co-chairs: Anantha Duraiappah, Shahid Naeem

Synthesis Team Members:[1] Tundi Agardy, Neville Ash, David Cooper, Sandra Diaz, Daniel Faith, Georgina Mace, Jeff McNeely, Harold Mooney, Alfred A. Oteng-Yeboah, Henrique Pereira, Steve Polasky, Christian Prip, Walter Reid, Cristian Samper, Peter Johan Schei, Bob Scholes, Frederik Schutyser, Albert van Jaarsveld

Table of Contents

[1] All of the MA authors and Review Editors have contributed to this draft through their contributions to the underlying assessment chapters on which this material is based.

Summary for Decision-makers

Note: The Summary for Decision-makers is not included in this Information Document since it is being made available in UNEP/CBD/SBSTTA/10/6. The pagination of the rest of this document is identical to the review draft made available to governments on December 15, 2004 in order to avoid discrepancies in page and line number references during the review process.

Introduction

The goal of the Millennium Ecosystem Assessment (MA) is to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to meeting human needs. Because the heart of all ecosystems is a dynamic complex of plants, animals, and microorganisms, biological diversity, or "biodiversity" for short, has been a key component of the MA. The MA recognizes that interactions exist between people, biodiversity and ecosystems; and the changing human condition drives, both directly and indirectly, changes in biodiversity, changes in ecosystems, and ultimately changes in the services ecosystems provide. Thus, biodiversity and human well-being are inextricably linked. (See Box 1) The MA also understands that many other factors independent of changes in biodiversity affect the human condition, while biodiversity is influenced by changes in many natural forces which are independent of human conditions.

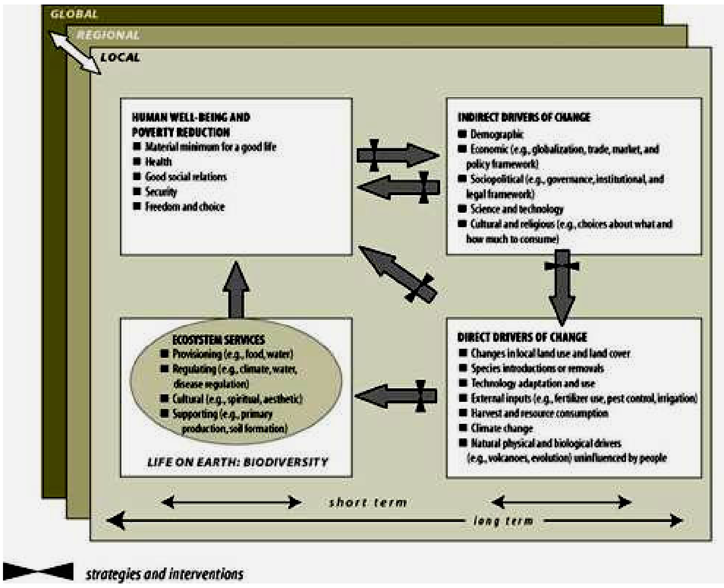
The MA places human well-being as the central focus for assessment, while recognizing that biodiversity and ecosystems also have intrinsic value and that people take decisions concerning ecosystems based on considerations of well-being as well as intrinsic value. (CF1-ES[1]) (See Box 1.) The human-focused nature of the assessment, however, does not undermine its utility for understanding and responding to ecosystem changes based on considerations of intrinsic value as well as human well-being.

A full assessment of the interactions between people and biodiversity requires a multi-scale approach, as this better reflects the multi-scale nature of decision-making, allows the examination of driving forces from outside particular regions, and provides a means of examining the differential impact of changes in biodiversity, ecosystem services, and policy responses on different regions and groups within regions (CF1-ES). The MA thus was comprised of a global assessment and 16 sub-global assessments carried out at sub-global scales. (Box 2) The sub-global assessments were not intended to serve as scientific samples of local ecosystems, but rather to: a) meet the needs of decision-makers at the scales where they were conducted; and, b) strengthen and enrich the findings of the global assessment and, in turn, to be strengthened by the findings of the global assessment.

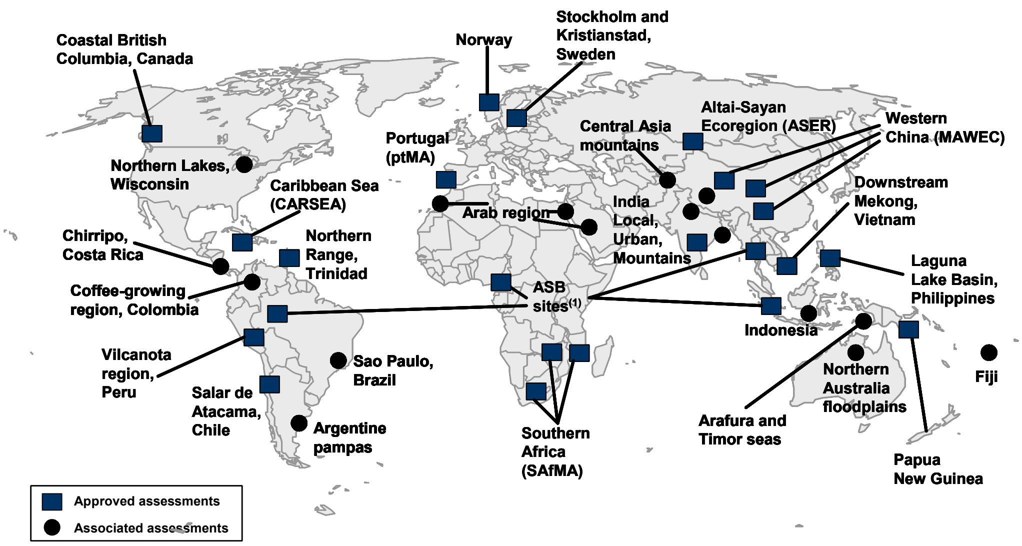
This report synthesizes findings from the MA global and sub-global assessments on biodiversity and human well-being.

[1] References are to the source chapter for this information in the underlying MA technical assessment reports. The Tables of Contents for the MA Assessment reports are provided in Annex 1.

Box 1: Integrated Assessment Framework Used in the Millennium Ecosystem Assessment. Changes in drivers that indirectly affect ecosystems, such as population, technology, and lifestyle (upper right corner of figure), can lead to changes in drivers directly affecting ecosystems, such as the catch of fisheries or the application of fertilizers to increase food production (lower right corner). The resulting changes in the ecosystem (lower left corner) cause ecosystem services to change and thereby affect human well-being. These interactions can take place at more than one scale and can cross scales. For example, a global timber market may lead to regional loss of forest cover, which increases flood magnitude along a local stretch of a river. Similarly, the interactions can take place across different time scales. Actions can be taken either to respond to negative changes or to enhance positive changes at almost all points in this framework (black cross bars).



Box 2. MA Sub-Global Assessments. Sixteen assessments have been approved as components of the MA. The Sub-global assessments were not designed to provide a scientific sample of any feature of ecosystems or human well-being. Instead, the choice of assessment locations was determined by a combination of interest in undertaking the assessment, interest in using the findings, and availability of resources to undertake the assessment. These assessments thus are primarily designed to meet needs of decision-makers in the locations where they are conducted but they also informed the global MA findings with information and perspectives from the sub-global scale and visa versa.



1. Biodiversity: What is it, where is it, and why is it important?

Biodiversity is the variability among living organisms from all sources including 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.

Biodiversity forms the foundation of the vast array of ecosystem services that critically contribute to human well-being.

Biodiversity is important in human-managed as well as natural ecosystems.

Decisions humans make that influence biodiversity affect the well-being of themselves and others.

1.1 Biodiversity – What Is It?

Biodiversity is the foundation of ecosystems that, through the services they provide, impact human well-being. No feature of Earth is more complex, dynamic, and varied than the layer of living organisms that occupy its surfaces and its seas, and no feature is experiencing more dramatic change at the hands of humans than this extraordinary, singularly unique feature of Earth. This layer of living organisms, the biosphere, through the collected metabolic activities of its innumerable plants, animals, and microbes, physically and chemically unites the atmosphere, geosphere, and hydrosphere into one environmental system within which millions of species, including humans, have thrived. Breathable air, potable water, fertile soils, productive lands, bountiful seas, the equitable climate of Earth's recent history, and other ecosystem services (Box 1.1; see also chapter 2) are manifestations of the workings of life. It follows then, that large-scale human influences over this biota have tremendous impacts on human well-being. It also follows then, that the nature of these impacts, good or bad, is within the power of humans to govern (CF2).

1.1.1 *Defining biodiversity*

Biodiversity is defined 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" (United Nations 1992:Article 2). The importance of this definition is that it draws attention to the many dimensions of Earth's biological diversity. It explicitly recognizes that every biota can be characterized by its taxonomic, ecological, and genetic diversity and by the way these dimensions of diversity vary over space and time is a key feature of biodiversity. By this definition, for example, a heterogeneous landscape whose ecosystems are made stable by a web of compensatory interactions among its species is readily recognized as more biodiverse than a homogenous landscape made up of unstable ecosystems that consist largely of non-interacting species. By this definition, the former could readily be considered more biodiverse even if the latter contained twice as many species. Taxonomic diversity is important, but only one component of biodiversity. Thus, only a multidimensional assessment of biodiversity can provide insights into the relationship between changes in biodiversity and changes in ecosystem functioning and ecosystem services. (see 1.3.1.1 and CF2).

Biodiversity includes all ecosystems, managed, or unmanaged. Sometimes biodiversity is presumed to be a relevant feature of only unmanaged ecosystems, wild lands, nature preserves, or national parks. This is incorrect. Managed systems, be they plantations, farms, croplands, aquaculture sites, rangelands, or even urban parks and urban ecosystems have their biodiversity. Given that agroecosystems alone now account for 34% of the Earth's surface, it is critical that any decision concerning biodiversity or ecosystem services address the maintenance of biodiversity in these largely anthropogenic systems. (C26.3.1)

1.1.2 *Measuring Biodiversity: Species Richness and Indicators*

In spite of many tools and data sources, biodiversity remains difficult to quantify precisely, but precise answers are seldom needed to devise an effective understanding of where biodiversity is, how it is changing over space and time, what drivers are responsible for such change, what the consequences of such change are for ecosystem services and human well-being, and what response options are available. Ideally, to assess the trends and conditions of biodiversity either globally or sub-globally, one must measure the abundance of all organisms, the visible and invisible, over space and time, using taxonomy (e.g., the number of species), functional traits (e.g., the ecological type such as woody versus herbaceous plants), and the interactions among species that affect their dynamics and function (e.g., predation, parasitism, competition, and facilitation such as pollination, and how strongly such interactions affect ecosystems). Even more important would be to estimate turnover, not just point estimates in space or time. Currently, it is not possible to do this with much accuracy because the data are lacking. Even for the taxonomic component of biodiversity, where information is the best, considerable uncertainty remains about the true extent and changes in taxonomic diversity. (C4)

There are many measures of biodiversity of which species richness represents a single, but important metric that is valuable as the common currency of the diversity of life – but it must be integrated with other metrics to fully capture biodiversity. Because the multidimensionality of biodiversity (1.1.1) poses formidable challenges to the measurement of biodiversity (1.1.2), a variety of surrogate or proxy measures are often used. These include the number of species or species richness of specific taxa, the number of distinct plant functional types (e.g., grasses, forbs, bushes, or trees), or the diversity of distinct gene sequences in a sample of microbial DNA taken from the soil. Species- or other taxon-based measures of biodiversity, however, rarely capture key attributes of biodiversity, such as variability, function, quantity, and distribution, all of which provide insight into the roles of biodiversity (Box 1.2). Thus, wherever possible, attributes other than taxonomic diversity should and are often measured along with species richness. (C4)

Ecological indicators form a critical component of monitoring, assessment, and decision making, but may not serve as adequate indicators of biodiversity. An ecological indicator is a scientific construct that uses quantitative data to measure aspects of biodiversity, ecosystem condition, services, or drivers of change, but no single ecological indicator captures all the dimensions of biodiversity (Box 1.3) (C2.2.4). Ecological indicators are designed to communicate information quickly and easily to policy makers. For example, economic indicators, such as GDP, are highly influential and immediately understood by decision makers. Similarly, some environmental indicators, such as global mean temperature and atmospheric carbon dioxide concentrations, are becoming widely accepted as measures of anthropogenic effects on global climate. Ecological indicators are founded on much the same principles and therefore carry with them similar pros and cons (Box 1.4). (C2.2.4).

1.2 Where Is Biodiversity?

Biodiversity is essentially everywhere, in every surface, crevice, and pore of Earth's lands and in every drop of its bodies of water. The virtual omnipresence of life on Earth is seldom appreciated because most organisms are small (<5 cm), their presence sparse, ephemeral or cryptic, or, in the case of microbes, invisible to the unaided human eye. (CF2)

Documenting spatial patterns in biodiversity is difficult because taxonomic, functional, trophic, genetic, and other dimensions of biodiversity have been relatively poorly quantified. Even taxonomic diversity, the best known dimension of biodiversity, is incomplete and strongly biased towards the species level, megafauna, temperate systems and components used by people (Fig. 1.1). This results in significant gaps in knowledge, especially regarding the status of tropical systems, marine and freshwater biota, plants, invertebrates, micro-organisms and subterranean biota. These shortcoming mean that estimates that the total number of species on Earth range from 5 to 30 million. This number could be higher than 30 million if poorly known groups such as deep sea organisms, fungi, and micro-organisms including parasites, have more species than currently estimated. Irrespective of the true value of global species richness, however, it is clear that the 1.7 – 2 million species that have been formally identified represent only a small portion of total species richness. Biotic inventories are badly needed to correct for this deficiency (C4)

1.2.1 *Spatial patterns of biodiversity: hotspots, biomes, biogeographic realms, ecosystems, and ecoregions.*

While the data to hand are often insufficient to provide accurate pictures of the extent and distribution of biodiversity, there are many patterns and tools that decision makers or the public can use to derive useful approximations of biodiversity in a given ecosystem. Each country or region will have different information about their biota, north-temperate regions often having the best data, but for some groups, usually vertebrates, plants, and some invertebrates such as butterflies and dragonflies, there is frequently some information. There are also some basic principles about biodiversity distributions or indicators that can be used to supplement what biotic inventories are to hand. For example, species richness is associated with NPP, temperature, salinity, and water depth. Global maps and sub-global maps of species richness, several of which are provided in the Condition and Trends and Scenarios Biodiversity chapters, provide valuable insights into what biodiversity might look like if it could be visualized.

Most macroscopic organisms have small, often clustered, geographical ranges, leading to diagnosable centers of both diversity and endemism, and frequently concentrated in isolated or topographically variable regions (islands, mountains, peninsulas). A large proportion of the world's terrestrial biodiversity at the species level is concentrated in a small area of the world, mostly in the tropics. Such hotspots are frequently concentrated in isolated or topographically variable regions (islands, mountains, peninsulas). The neotropics and afrotropics show the highest species richness and considerable endemism, but biodiversity hotspots are found in most biomes. Even among the larger and more vagile species such as the terrestrial vertebrates, more than one third of all species have ranges less than 1000 km^2. In contrast, local and regional diversity of micro-organisms tends to be more similar to large-scale and global diversity, indicating greater dispersal, larger range sizes and lower levels of regional species clustering (C4.3.3).

Biomes and biogeographic realms provide broad pictures of the distribution of functional diversity. Functional diversity (the variety of different ecological types of species, such as woody or herbaceous, annual or perennial plant species, rather than taxonomic diversity) shows patterns of associations (e.g., biota typical of wetlands, forests, grasslands, estuaries, and so forth) with geography and climate known as biomes (Fig. 1.2), with ecosystems, and ecoregions being smaller divisions within biomes. These can be used to provide first-order approximations of both expected functional diversity as well as possible changes in the distribution of these associations should environmental conditions change. In conjunction with biogeographical realms (e.g., geographical regions that share a biota united by a common history among its species) (Fig. 1.3) (C3).

1.2.2 *Temporal patterns of biodiversity: Background rates of extinction and biodiversity loss.*

Patterns of biodiversity over time allow for only qualitative assessments of background rates of extinction or how fast species have become extinct over geological time in the absence of human activities. Life on earth arose approximately 3,800 million years ago, only 200 million years after the formation of Earth itself, thus the history of In general, rates of origination (the generation of new species) has outpaced the rate of extinction such that Earth now holds many millions of species. Except for the last 1000 years, global biodiversity has been relatively constant over most of human history, but the history of life is characterized by considerable change. The exact pattern of this history is uncertain, which poses challenges for deriving a comprehensive picture of rates of origination and rates of extinction. Key to origination is biological variation at all levels (i.e. genes, populations, and species) without which origination or speciation cannot occur (C4.4.2). The estimated magnitude of background rates of extinction is roughly 0.1 – 1.0 extinctions per million species per year. Most measurements of this 'background' extinction rate have come from assessing the length of species' lifetimes through the fossil record: these range over 0.5–13 million years, possibly 0.2–16 million years. These data probably underestimate background extinction rates, because they are necessarily largely derived from taxa that are abundant and widespread in the fossil record; increasing use of molecular data and techniques should allow more accurate calibration. Nevertheless, converting these data into a relative extinction rate (more meaningful than an absolute one, given the uncertainties over the number of species on the planet) (C4.4.2).

The complexity and non-linear characteristics of ecosystems make ecological impacts difficult to monitor and predict, resulting in rapid ecosystem transitions and/or considerable inertia and time lags in management responses. A mismatch exists between the dynamics of natural systems and human responses to those changes, with inertia and lag times in both natural systems and social systems complicating the ability of humans to anticipate and develop adaptation strategies to cope with change. Anticipating major changes is complicated by lags in ecological responses, complex feedbacks between socio-economic and ecological systems, and the difficulty of predicting thresholds prior to such thresholds being overshot. Multiple impacts (especially the addition of climate change to the mix of forcing functions) can cause thresholds to change, and monitoring methods are often inadequate due to poor choice of indicators, inappropriate periodicity of monitoring, and infrequent analysis of results. (C28, S3.4.1)

Regime shifts in ecosystems cause rapid substantial changes in biodiversity, ecosystem services and human well-being. Regime shifts are common in pelagic fisheries, where thresholds are surmised to be related to temperature regimes but which are also influenced by over-exploitation (C19.2.1). Some regime shifts are essentially irreversible**,** for instance coral reef ecosystems that undergo sudden shifts from coral-dominated to algal –dominated reefs (C19.6). The trigger for such phase shifts is usually multi-faceted and includes increased nutrient inputs leading to eutrophied conditions and removal of herbivorous fishes that maintain the balance between corals and algae. Once the thresholds for the two ecological processes of nutrient loading and herbivory (one upper and one lower) are passed, the phase shift occurs suddenly (within months) and the resulting ecosystem, though stable, is less productive and less diverse. Consequently, human well-being is affected not only by reductions in food supply and decreased income from reef-related industries (e.g. diving and snorkeling, aquarium fish collecting, etc.), but also by increased costs accruing from decreased ability of reefs to protect shorelines (algal reefs are more prone to being broken up in storm events, leading to shoreline erosion and seawater breaches of land) (C19.3). Such phase shifts have been documented in Jamaica, elsewhere in the Caribbean, and in Indo Pacific reefs (SG). (C19; S3.2.1) Introduced invasive species can act as a trigger for dramatic changes in ecosystem structure, function, and delivery of services. For example, the introduction of the carnivorous ctenophore *Mnemiopsis leidyi* (a jellyfish-like animal), in the Dead Sea, caused the loss of 26 major fisheries species, and has been implicated (along with other factors) in the subsequent growth of the oxygen deprived “dead” zone. (C28.6)

1.3 Biodiversity – Why is it important?

Humans depend on biodiversity to provide food, medicine, clothing and other necessities of life. In a basic sense, the total value of biodiversity is essentially infinite because it is essential for human survival. Of greater practical significance are estimates of value for smaller changes in biodiversity. What is the value of particular components of biodiversity? What values would be lost if a species goes extinct either locally or globally, or important ecosystem functions change? Illustrating the importance of biodiversity in value terms that can be compared with the value of development or other activities that pose a threat to biodiversity can demonstrate that conserving biodiversity may be beneficial for the health and well being of people. Many ecosystems yield higher net benefits with less intensive management that maintains a greater portion of the original biodiversity in the system. (CWG)

Biodiversity may have value apart from what it provides to people in the way of provisioning, cultural, regulating or supporting ecosystem services to humans (intrinsic value). For some, biodiversity has intrinsic value: it is valued as an end in itself. The intrinsic value of biodiversity would be measured in its own terms without reference to human well being. By its very nature, it is difficult to weigh intrinsic value vis-à-vis the values of ecosystem services or other values. Cultural, spiritual, and religious belief systems may place intrinsic value on elements of biodiversity so that cultural, spiritual and religious values may blur the line between cultural ecosystem service value and intrinsic value.

Humans depend on plant and animal species for their food supply and much of their material for clothing and housing. Agriculture is the single largest economic sector in many developing countries. In 2000, for example, agriculture represented 24% of total GDP in low income developing countries (C8.5.5.2). In 2000, the agricultural labor force comprised 1.3 billion people globally; that is, approximately a fourth (22 percent) of the world's population and half (46 percent) of the total labor force. (C8.5.5.2). Most of the world's poorest people are almost completely dependent for their livelihoods on what they grow and crop failure can bring on extreme hardship. Agriculture is important in developed countries as well. Agricultural products generate over $2 trillion dollars in sales annually in the United States. Biodiversity is important to maintaining agricultural production. Wild relatives of domestic crops provide genetic variability that can be crucial for overcoming outbreaks of pest and pathogen, and new environmental stresses. Increased local diversity can increase productivity. For example, interweaving multiple varieties of rice in the same paddy has been shown to increase productivity by lowering the loss from pests and pathogens. Estimates of the annual monetary value of pollination—a direct service from biodiversity—exceed $100 billion per year.

Biodiversity contributes to a range of other industries such as pharmaceutical, cosmetics, and horticulture. Market trends vary widely according to the industry and country involved but many bioprospecting activities and revenues are expected to increase over the next decades. (C10) Some kinds of bioprospecting are notoriously cyclical but several major new industries are well established and appear set to increase while others have a less certain future although their markets are present. The current economic climate suggests that pharmaceutical bioprospecting will increase, especially as new methods that utilize evolutionary and ecological knowledge enhance productivity.

Biodiversity plays an important role in ecosystem functions that provide regulating and supporting services, without which the other services would not be provided. These services are essential for human well being. However, at present there are few studies that link changes in biodiversity with changes in ecosystem functioning to changes in human well being. Protecting the Catskill watersheds that provide drinking water for New York City, is one case where protecting ecosystem services paid a dividend of several billion dollars. Further work that demonstrates the links between biodiversity, regulating and supporting services, and human well being is needed to show this vital but often unappreciated value of biodiversity.

The value of cultural, spiritual, religious, educational and aesthetic values that people have for elements of biodiversity are significant. These values may provide the core reason for caring about biodiversity conservation for many. These values, however, are notoriously difficult to measure in any objective fashion. Economists have conducted a number of contingent valuation surveys on the willingness to pay to protect endangered species and other elements of biodiversity. Estimates of existence values for endangered species can be quite significant.

Nature-based tourism ("ecotourism") is one of the fastest growing segments of tourism worldwide. Ecotourism is a particularly important economic sector in a number of countries. For example, the aggregate revenue generated by nature-based tourism in Southern Africa was estimated to be $3.6 billion in 2000, roughly 50% of total tourism revenue (SG-SAfMA p. 55 and table 9.1). Nature-based tourism has generated over $100 million in revenue in Botswana, Kenya, Namibia, South Africa, Tanzania, Uganda, and Zimbabwe. In Tanzania, tourism contributed 30% of the total GDP of the country. In Costa Rica, there were approximately 1 million ecotourists spending $1 billion in 2000.

1.3.1 *Biodiversity, Ecosystem Function, and Ecosystem Services*

Species composition matters as much or more than species richness when it comes to regulating ecosystem services. Ecosystem functioning, and hence ecosystem services, at any given moment in time, is strongly influenced by the ecological characteristics of the most abundant species, not by the number of species. What determines the relative importance of a species to ecosystem functioning is its traits and its relative abundance. For example, the traits of the dominant or most abundant plant species, such as how long they live, how big they are, how fast they assimilate carbon and nutrients, how decomposable their leaves are, or how dense their wood is, are usually the key species drivers of an ecosystem's processing of matter and energy. Thus, conserving or restoring the composition of communities, rather than simply maximizing species numbers, is critical to maintaining ecosystem services. (C11.2.1, C7, C11.3, C19).

Local or functional extinction, or the reduction of a population to the point that they no longer contribute to ecosystem functioning, can have dramatic impacts on ecosystem services. Local extinctions (i.e. the loss of a species from a local area) and functional extinctions (i.e., the reduction of a species is such that they no longer play significant roles in ecosystem function) have received little attention compared to global extinctions (i.e. loss of all individuals of a species from its entire range in the planet). Loss of ecosystem function, and the services derived from them, however, occurs long before global extinction. Often, when the functioning of a local ecosystem has been pushed beyond a certain limit by direct or indirect biodiversity alterations, the ecosystem-service losses may persist for a very long time. (C11.3)

Changes in biotic interactions among species (i.e., predation, parasitism, competition, facilitation) can lead to disproportionately large, irreversible, and often negative alterations of ecosystem processes, causing large monetary and cultural losses (high certainty). In addition to direct interactions, such as predation, parasitism, or facilitation, the maintenance of ecosystem processes depends on indirect interactions as well, such as a predator preying on a dominant competitor such that the dominant is suppressed and permits subordinate species to coexist. Interactions with important consequences for ecosystem services include pollination, links between plants and soil communities, including mycorrhizal fungi and nitrogen-fixing microorganisms, between plants and herbivores and seed dispersers, interactions involving organisms that modify habitat conditions (e.g. beavers that build ponds, tussock grasses that increase fire frequency), and indirect interactions involving more than two species (e.g. top predators, parasites or pathogens that control herbivores and thus avoid overgrazing of plants or algal communities). (C11.4.2).

As in terrestrial and aquatic communities, the loss of individual species involved in key interactions in marine ecosystems can also influence ecosystem processes and the provisioning of ecological services. For example, coral reefs and the ecosystem services they provide are directly dependent on the maintenance of some key interactions between animals and algae. As one of the most species rich communities on earth, coral reefs are responsible for maintaining a vast storehouse of genetic and biological diversity. Substantial ecosystem services are provided by coral reefs, such as habitat construction, nurseries and spawning grounds for fish, nutrient cycling and carbon and nitrogen fixing in nutrient-poor environments, and wave buffering and sediment stabilization. The total economic value of reefs and associated services is estimated as hundreds of billions of dollars (C11.5.2). Yet, all coral reefs are dependent on a single key biotic interaction - symbiosis with algae. The dramatic effects of climate change and variability (e.g. El Niño oscillations) on coral reefs are mediated by the disruption of this symbiosis.

Many unpleasant "ecological surprises" are brought about by the removal or introduction of organisms in ecosystems that disrupt biotic interactions or ecosystem processes. Because the network of interactions among species and the network of linkages among ecosystem processes are complex, the impacts of either the removal existing species or the introduction of new species are difficult to anticipate (Table 1.1). (C11.4.2).

1.3.2 *Biodiversity and Some Key Ecosystem Services in Terrestrial, Aquatic, and Marine Ecosystems*

1.3.2.1 <u>Supporting services</u>

Biodiversity impacts key ecosystem processes in terrestrial ecosystems such as biomass production, nutrient and water cycling, and soil formation and retention, all of which govern supporting services (high certainty). The relationship between biodiversity and supporting ecosystem services depends on composition, relative abundance, functional diversity, and to a lesser extent, taxonomic diversity. If multiple dimensions of biodiversity are driven to very low levels, especially trophic or functional diversity within an ecosystem, both the level and stability supportive services may decrease. (CF2; Box 1.2; Fig. 1.4).

Region-to-region differences in ecosystem processes are driven mostly by climate, resource availability, disturbance, and other extrinsic factors, and not by differences in species richness (*high certainty*). In natural ecosystems, the effects of abiotic and land-use drivers on ecosystem services are usually more important than those of biodiversity. Plant productivity, nutrient retention, and resistance to invasions and diseases sometimes increase with increasing species number in experimental ecosystems that have been reduced to low levels of biodiversity. In natural ecosystems, however, these direct effects of biodiversity are usually overridden by the effects of climate, resource availability or disturbance regime. (C11.3)

Even if losses of biodiversity have small short-term impacts on ecosystem function, such loss may reduce the capacity of ecosystems for adjustment to changing environments (i.e., ecosystem resilience, resistance, and biological insurance). (*medium certainty*). Although the stability of an ecosystem depends to a large extent on the characteristics of the dominant species (e.g. lifespan, growth rate, regeneration strategy), less abundant species also contribute to the long-term preservation of ecosystem functioning. There is evidence that a large number of resident species, including those that are rare, may act as 'insurance" that buffers ecosystem processes in the face of changes in the physical and biological environment (e.g. changes in precipitation, temperature, pathogens) (C11.3.2). As tragically illustrated by social conflict and humanitarian crisis over droughts, floods and other ecosystem collapses, stability of ecosystems underpins most components of human well being, including health, security, satisfactory social relations, freedom and choice (C6; Ch. 2).

1.3.2.2 Regulating services

1.3.2.2.1 Invasion resistance

The preservation of the number, types, and relative abundance of resident species can enhance invasion resistance in a wide range of natural and semi-natural ecosystems, but species-rich habitats should be subjected to particularly close monitoring to avoid species invasion. (medium certainty) Areas of high species richness (e.g., hot spots) are more susceptible to invasion than species-poor areas. On the other hand, within a given habitat, the preservation of its natural species pool appears to increase its resistance to invasions by non-native species (C11.4.1).

There is now evidence in several marine ecosystems that species richness increases invasion resistance. Although there are few studies of the effects of biodiversity in marine ecosystems, in experimentally assembled sea-floor communities, decreasing the richness of native taxa was correlated with increased survival and percent cover of invading species.

1.3.2.2.2 Pollination

Pollination, the transfer of pollen between flowers, without which many plants cannot achieve sexual reproduction, is essential for the provision of plant-derived ecosystem services, yet world wide declines in pollinator diversity suggest this regulating service is in jeopardy. (*medium certainty*) Many fruits and vegetables require pollinators, thus pollination services are critical to the production of a considerable portion of the vitamins and minerals in the human diet. Although there is no assessment at the continental level, documented declines in more restricted geographical include mammals (e.g. lemurs, bats) and birds (hummingbirds, sunbirds), bumblebees in Britain and Germany, honeybees in the US and some European countries, and butterflies in Europe (C11, Box 11.2). The causes of these declines are multiple, but habitat destruction and the use of pesticide are especially important. Estimates of the global annual monetary value of pollination vary widely, but they are in the order of hundreds of billions of dollars. (C11.4.2, Box 11.2).

1.3.2.2.3 Climate regulation

Biodiversity influences climate at local, regional, and global scales, thus changes in land use and land cover that affect biodiversity can affect climate. The important components of biodiversity include plant functional diversity and the type and distribution of habitats across landscapes. These components of biodiversity influence the capacity of terrestrial ecosystems to sequester carbon, albedo (proportion of incoming radiation from the Sun that is reflected by the land surface back to space), evapotranspiration, temperature, and fire regime, all of which influence climate, especially at the landscape, ecosystem, or biome levels. For example, forests have higher evapotranspiration than other ecosystems, such as grasslands, because of their deeper roots and greater leaf area, thus forests have a net moistening effect on the atmosphere and becomes a moisture source for downwind ecosystems. In the Amazon, for example, 60% of precipitation comes from water transpired by upwind ecosystems. (C11.4.3)

In addition to biodiversity within habitats, the diversity of habitats in a landscape exerts additional impacts on climate across multiple scales. Landscape-level patches (>10 km in diameter) that have lower albedo and higher surface temperature than neighboring patches create cells of rising warm air above the patch (convection). This air is replaced by cooler moister air that flows laterally from adjacent patches (advection). Climate models suggest that these landscape-level effects can substantially modify local-to-regional climate. In Western Australia, for example, the replacement of native heath vegetation by wheatlands increased regional albedo. As a result, air tended to rise over the dark (more solar-absorptive and therefore warmer) heathland, drawing moist air from the wheatlands to the heathlands. The net effect was a 10% increase in precipitation over heathlands and a 30% decrease in precipitation over croplands. (C13.4.2)

Some components of biodiversity affect carbon sequestration and thus need to be considered in carbon-based climate change mitigation where afforestation, reforestation, reduced deforestation, and biofuel plantations are involved. (*high certainty*) Biodiversity affects carbon sequestration primarily through its effects on species characteristics which determine how much carbon is taken up from the atmosphere (assimilation) and how much is released into it (decomposition, combustion). Particularly important are how fast can plants grow, which governs carbon inputs, and woodiness, that enhances carbon sequestration because woody plants tend to contain more carbon, live longer, and decompose more slowly than smaller herbaceous plants. Plant species also strongly influence carbon loss via decomposition and their effects on disturbance. Plant traits also influence the probability of disturbances such as fire, wind-throw, and human harvest, which temporarily change forests from accumulating carbon to releasing it. (C11.4.3).

The major importance of marine biodiversity in climate regulation appears to be via its effect on biogeochemical cycling and carbon sequestration. The ocean through its sheer volume and links to the terrestrial biosphere plays a huge role in cycling of almost every material involved in biotic processes. Of these, the anthropogenic effects on carbon and nitrogen cycling are especially prominent. If there were no life in the ocean, transfer of carbon dioxide from atmosphere to seafloor would cease and atmospheric CO2 concentrations would rise. Biodiversity influences the effectiveness of the biological pump that moves carbon from the surface ocean and sequesters it in deep waters and sediments. Some of the carbon that is absorbed by marine photosynthesis and transferred through food webs to grazers sinks to the deep ocean as fecal pellets and dead cells. The efficiency of this trophic transfer and therefore the extent of carbon sequestration is sensitive to the species richness and composition of the plankton community. Some phytoplankton in the southern ocean, for example, are more palatable than others, so an increase in their abundance increases grazing, the formation of fecal pellets, and the export of carbon to depth (C19).

1.3.2.2.4 Pest, disease, and pollution control.

The maintenance of natural pest control services, which benefits food security, rural household incomes, and national incomes of many countries, is strongly dependent on biodiversity. Yields of desired products from agroecosystems may be reduced by attacks of animal herbivores and microbial pathogens, above and below ground, and by competition with weeds. Increasing associated biodiversity with low-diversity agroecosystems, however, can enhance biological control and reduce the dependency and costs associated with biocides. Moreover, high-biodiversity agriculture has cultural and esthetic value, and can reduce many of the externalized costs of irrigation, fertilizer, pesticide and herbicide inputs associated with monoculture agriculture. (C11.4.4. and Boxes C11.3 and C11.4)

The marine microbial community provides critical detoxification services, but how biodiversity influences them is not well understood. There is very little information on how many species are necessary to provide detoxification services, but these services may critically depend upon one or a few species. Some marine organisms provide the ecosystem service of filtering water and reducing effects of eutrophication. For example, American oysters in Chesapeake Bay were once abundant, but have sharply declined, and with them their filtering ecosystem services. Areas like the Chesapeake might have much clearer water if large populations of filtering oysters could be reintroduced. Some marine microbes can degrade toxic hydrocarbons, such as those in an oil spill, into carbon and water, using a process that requires oxygen. Thus, this service is threatened by nutrient pollution, which generates oxygen deprivation.

TABLES

Table 1.1. Ecological surprises caused by complex interactions. Voluntary or involuntary introductions or deletions of species often trigger unexpected alterations in the normal provision of ecosystem services by terrestrial, freshwater and marine ecosystems. In all cases, the community and ecosystem alterations have been the consequence of indirect interactions among three or more species (C11, Table 11.1).

Study case	Nature of the interaction involved	Ecosystem-service consequences
Top predators		
Introduction of brown trout (*Salmo trutta*) in New Zealand for angling	Trophic cascade, predator increased primary producers by decreasing herbivores	**Negative** – Increased eutrophication
Introduction of bass *(Cichla ocellaris)* in Gatun Lake, Panama	Trophic cascade, top predator decreased control by predators of mosquito larvae	**Negative** – Decreased control of malaria vector
Introduction of pine marten (*Martes martes*) in the Balearic Islands, Spain	Predator of frugivorous lizards (main seed dipersers)	**Negative** – Decreased diversity of frugivorous lizards due to extinction of native lizards on some islands. Changes in dominant shrub (*Cneorum tricoccon*) distribution because marten replaced the frugivorous – dispersing role
Intraguild Predators		
Potential egg parasitoid (*Anastatus kashmirensis*) to control gypsy moth (*Lymantria dispar*)	Hyperparasitism (parasitoids that may use parasitoids as hosts)	**Negative** – Disruption of biological control of pests. Introduced parasitoid poses risk of hyperparasitism to other pest-regulating native parasitoids
Gambusia and *Lepomis* fish in rice fields to combat mosquitoes	Intraguild predator (adult fish feed on juveniles as well as on mosquito larvae)	**Opposed to goal** – Decreased control of disease vector (mosquito)
Intraguild preys		
Opossum shrimp (*Mysis relicta*) in Canadian lakes to increase fish production	Intraguild prey depletes shared zooplankton preys	**Opposed to goal** – Decreased salmonid fish production
Apparent competitors		
Rats (*Rattus* spp) and cats (*Felis catus*) in Steward Island, New Zealand	Rats induced high cat densities and increased predation on endangered flightless parrot (*Strigops habroptilus)*	**Negative** – Reduced diversity
Herbivores		
Zebra mussel (*Dreissena polymorpha*) in Great Lakes, USA	Zebra mussel reduced phytoplankton and outcompeted native bivalves	**Negative** – Reduced diversity **Positive** – Increased water quality
Mutualists		
Myna bird (Acridotheres tristis) for worm pest control in Hawaiian sugarcane plantations	Myna engaged in the dispersal of the exotic woody weed *Lantana camara*	**Negative** – Increased invasion by *Lantana* produced impenetrable thorny thickets, reduces agricultural crops and pasture carrying capacity and sometimes increases

		fire risk. Displaces habitat of native birds
Ecosystem engineers		
Earthworm (*Pontoscolex corethrurus*) in Amazonian tropical forests converted to pasture	Dramatically reduces soil macroporosity and gas exchange capacity	**Negative** – Reduces soil macrofaunal diversity and increases soil methane emissions
C_4 perennial grasses *Schizachyrium condesatum, Melinis minutiflora* in Hawai'i for pasture improvement	Increased fuel loads, fuel distribution and flammability	**Negative** – Increases fire frequency affecting fire sensitive plants, reduced plant diversity, positive feedback for further invasion of flammable exotic species on burned areas
N-fixing firetree (*Myrica faya*) in Hawai'i	Increases soil N levels in newly formed N-poor volcanic soils.	**Negative** – Increased fertility, increased invasion by other exotics, reduced regeneration of native *Metrosideros* tree, alteration of successional patterns

Deletions/Harvesting

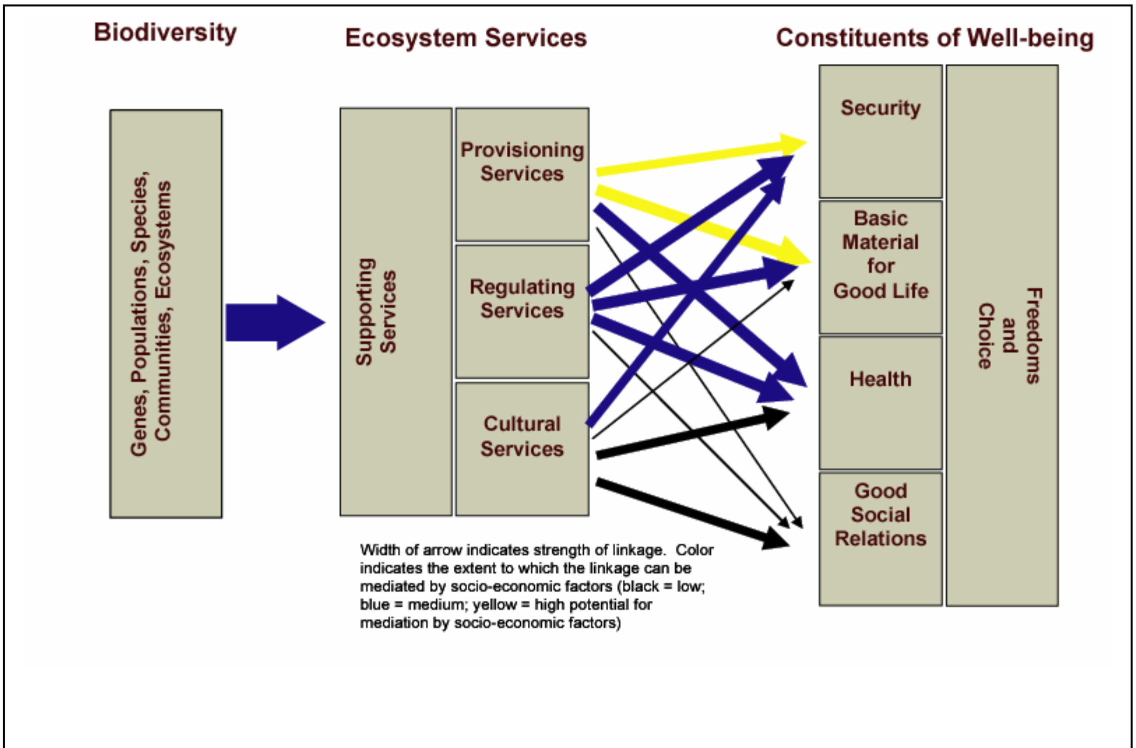
Study case	Nature of the interaction involved	Ecosystem-service consequences
Top predators		
Selective harvesting-of piscivorous fishes in Canadian lakes	Piscivorus fishes promote *Daphnia* that effectively suppresses 1^{ary} production	**Negative** - Shifts from net carbon sinks in planktivorous-dominated to equilibrium or net carbon sources in piscivorous-dominated lakes
Sea otter (*Enhydra lutris*) harvesting near extinction in southern California	Cascading effects produced reductions of kelp forests and the kelp-dependent community	**Negative** – loss of biodiversity of kelp habitat users
Pollution-induced reductions in predators of nematodes in forest soils	Heavy metal bioaccumulation produced reductions nematophagous predators and increased herbivorous nematodes	**Negative** - disruption of forest soil food webs - increases in belowground herbivory – decrease in forest productivity
Intraguild predators		
Declining populations of coyote (*Canis latrans*) in southern California	Releases in raccoons (*Procyon lotor*) and feral house cats	**Negative** - threat to native bird populations
Overhavesting of seals and sea lions in Alaska	Diet shifts of killer whales increased predation on sea otters	**Negative** – conflict with other restoration programs. Failure of reintroduction of sea otters to restore kelp forest ecosystems
Keystone predators		
Harvesting of triggerfish (*Balistaphus*) in Kenyan coral reefs	Tiggerfish declines release sea urchins which outcompete herbivorous fish	**Negative** – increased bioerosion of coral substrates – reduced calcium carbonate deposition
Herbivores		
Voluntary removal of sheep and cattle in Santa Cruz Is., USA, for restoration	Release of the exotic plant component from top-down control	**Opposite to goal** - explosive increases in exotic herbs and forbs and little recovery of native plant species
Overfishing in the	Lack of fish grazers allowed	**Negative -** Coral cover was reduced from

Caribbean reduced herbivorous and predatory fish and reduced fish biomass	macroalgae to outcompete coral following disturbances	52% to 3%, and macroalgae increased from 4% to 92%.
Ecosystem engineers		
Voluntary removal of exotic tamarisk (*Tamariscus* sp.) for restoration of riparian habitats in Mediterranean deserts	Long-established tamarisk has replaced riparian vegetation and serves as habitat to endangered birds	**Opposite to goal** – reduction in biodiversity – structural changes in riparian habitats

BOXES

Box 1.1: Linkages among Biodiversity, Ecosystem services, and Human Well-Being

Biodiversity represents the foundation of ecosystems that, through the services they provide, impact human well-being. These include *provisioning services* such as food, water, timber, and fiber; *regulating services* such as the regulation of climate, floods, disease, wastes and water quality; *cultural services* such as recreational, aesthetic, and spiritual benefits; and *supporting services* such as soil formation, photosynthesis and nutrient cycling. (CF-2). The MA considers human well-being to consist of five main components; the basic material needs for a good life, health, good social relations, security, and freedom and choice. Human well-being is the result of many factors, some directly or indirectly linked to biodiversity and ecosystem services while others are independent of these.



Box 1.2. Measuring and Estimating Biodiversity: More than Species Richness

Measurements of biodiversity seldom capture all its dimensions and the most common measure, species richness, is no exception. There are several limitations, however, associated with an emphasis on species. First, what constitutes a species is not often well defined. Second, species richness and ecosystem function rarely correlate well. Third, species may be taxonomically similar (i.e. in the same genus), but may be ecologically quite distinct. Fourth, species vary extraordinarily in abundance, often exhibiting a pattern in which only a few are dominant while many are rare. Thus, to simply count species does not take into consideration how variable each species might be in its contribution to ecosystem properties.

Simply counting the number of species in an ecosystem does not take into consideration how variable each species might be or its contribution to ecosystem properties. For every species, several properties other than its taxonomy (e.g., species richness), especially those concerning the ecology of a species, are more valuable for assessment and monitoring. These properties include measures of:

- Variability (loss of genetic and ecological variability limits species function, creates more challenges for conservation)
- Distribution (specialists, generalists, broadly distributed, narrowly distributed – important for conservation, understanding role in ecosystem functions/services)
- Dynamics (species have tremendous powers to recover due to exponential or geometric growth provided habitat and resources are in place – conservation works)
- Trophic position (producers, consumers, decomposers, a mix)
- Functional traits (response and effect traits – refer to sections below)

In practice, however, variability, dynamics, trophic, and functional attributes of many species are poorly known, thus it is both necessary and useful to use surrogate, proxy, or indicator measures based on the taxonomy or genetic information.

Measures of biodiversity are therefore frequently of genes, populations, species or ecosystems, even though they provide little insight into the ecological properties of a biological community. Important attributes missed by species or taxon-based measures of diversity include:

- **Quantity**, reflecting how much there is of any one type. Variation on its own will only rarely meet individual needs. For example for many provisioning services (food, fresh water, fiber) it is the quantity that matters more than the presence of a particular genetic variety, species, or ecosystem type.
- **Variation**, reflecting the number of different types over space and time. For example, for understanding population persistence, the number of different varieties or races in a species or variation in genetic composition among individuals in a population, provide more insight than species richness.

- **Distribution,** reflecting where quantity or variation in biodiversity occurs. For many purposes, distribution and quantity are closely related and are therefore generally treated together under the heading of *quantity*. However it is important to bear in mind that quantity may not always be sufficient for services: the location, and in particular its availability to the people that need it will frequently be more critical than the absolute volume or biomass of a component of biodiversity.

Finally, the importance of variability and quantity varies depending on the level of biodiversity measured. These are outlined in the table below.

Level	Importance of Variability	Importance of Quantity and Distribution
Genes	Adaptive variability for production and resilience to environmental change, pathogens, etc.	Local resistance and resilience
Populations	Different populations retain local adaptation	Local provisioning and regulating services, food, fresh water,
Species	The ultimate reservoir of adaptive variability, representing option values	Community and ecosystem interactions are enabled through the co-occurrence of species
Ecosystems	Different ecosystems deliver a diversity of roles	The quantity and quality of service delivery depends on distribution and location

Box 1.3. Ecological Indicators and Biodiversity

The United States National Research Council identifies three categories of ecological indicators, none of which adequately assess the many dimensions of biodiversity. These categories are:

1) Ecosystem condition or the extent and status of ecosystems (e.g. land cover and land use) indicates the capacity of ecosystems to continue to provide services.
2) Ecological capital, further divided into biotic raw material (e.g. total species richness) and abiotic raw materials (e.g. soil nutrients), indicate the amount of resources available for providing services.
3) Ecological functioning (e.g. lake trophic status) measures the performance of ecosystems.

Care must therefore be taken not to apply ecological indicators to uses they were not intended for, especially when assessing biodiversity. For example, biotic raw ecological capital measures the amount and variability of species within a defined area (C2.2.4). This may seem related to biodiversity, but it measures only taxonomic diversity. As such, this indicator does not necessarily capture many important aspects of biodiversity that are significant for the delivery of ecosystem services. The most common ecological indicator, total species richness (TSR), is a case in point. TSR only partially captures ecosystem services. TSR does not differentiate among species in terms of sensitivity or resilience to change nor does it distinguish between species that fulfill significant roles in the ecosystem (e.g., pollinators, decomposers) and those that play lesser roles. That is, all species are weighted equally which can lead assigning equal values to areas that have quite different biota. Moreover, the value of TSR depends on the definition of the area over which it was measured and may scale neither to smaller nor larger areas. Finally, TSR does not differentiate between native and non-native species, the latter often including exotic, introduced, or invasive species that frequently disrupt key ecosystem services. Ecosystem degradation by human activities may temporarily increase species richness in the limited area of the impact due to an increase in exotic or weedy species – but this is not a relevant increase in biodiversity. (C2.2.4)

Given the limitations of ecological indicators to serve as adequate indicators of biodiversity, work is urgently needed to develop a broader set of biodiversity indicators that are aligned against valued aspects of biodiversity. With the exception of diversity indices based on taxonomic or population measures, little attention has been paid to the development of indicators that capture all the dimensions of biodiversity. (C4.6.1).

Box 1.4. Criteria for effective ecological indicators

An effective ecological indicator should answer in the affirmative the following questions:

- Does the indicator provide information about changes in important processes?
- Is the indicator sensitive enough to detect important changes but not so sensitive that signals are masked by natural variability?
- Can the indicator detect changes at the appropriate temporal and spatial scale without being overwhelmed by variability?
- Is the indicator based on well-understood and generally accepted conceptual models of the system to which it is applied?
- Are reliable data available to assess trends and is data collection a relatively straightforward process?
- Are monitoring systems in place for the underlying data needed to calculate the indicator?
- Can policymakers easily understand the indicator?

FIGURES

Figure 1.1: Estimates of Proportions and Numbers of (A) Named Species in Groups of Eukaryote Species and Estimates of Proportions of (B) the Total Number of Species in Groups of Eukaryotes. (C4.2.3)

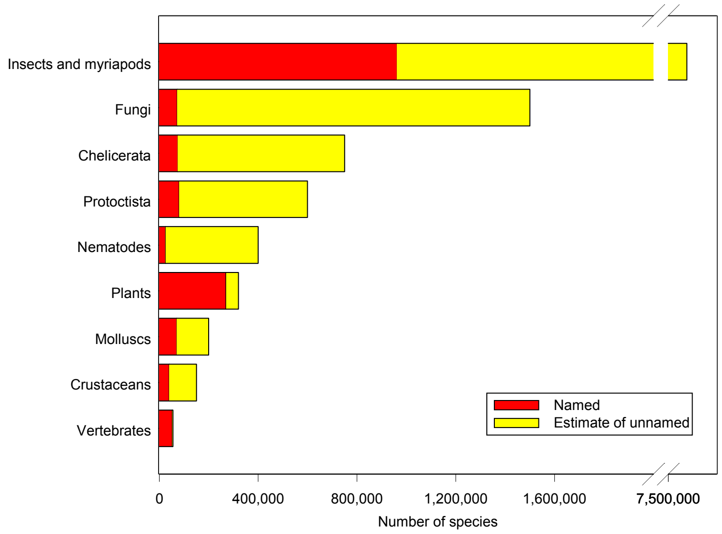


Figure 1.2 Diversity comparisons for the 14 terrestrial biomes of the world: a) species richness; b) family richness; c) endemic species. Biome codes as in Fig 1.3. (C4 Figure 4.7)

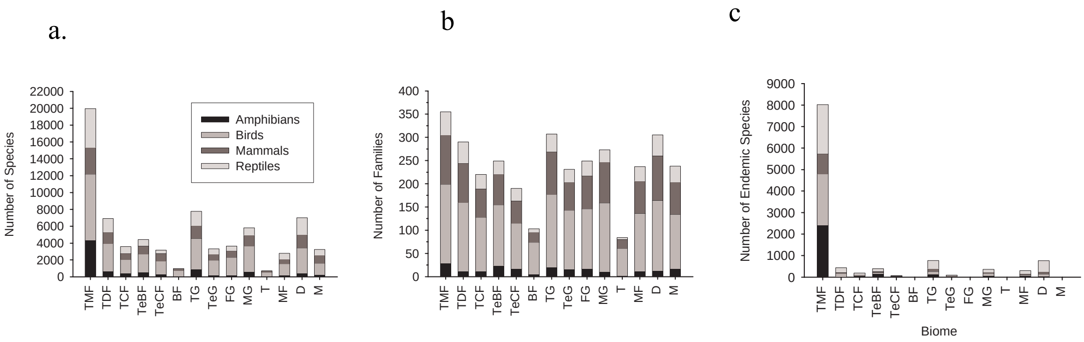


Figure 1.3. The world's 8 biogeographical realms and 14 biomes as used in the MA. (C4 Figure C4.3). Biogeographic realms are large spatial regions, within which ecosystems share a broadly similar biological evolutionary history. Eight terrestrial biogeographic realms are typically recognized, corresponding roughly to continents. Although similar ecosystems (e.g. Tropical Moist Forests) share similar processes and major vegetation types wherever they are found, their species composition varies markedly depending on the biogeographic realm in which they are found. Assessing biodiversity at the level of biogeographic realms is important because they display substantial variation in the extent of change, they face different drivers of change, and there may be differences in the options for mitigating or managing the drivers. Terrestrial biogeographic realms reflect freshwater biodiversity patterns reasonably well, but marine biogeographic realms are poorly known and largely undefined. (C4.3.1)

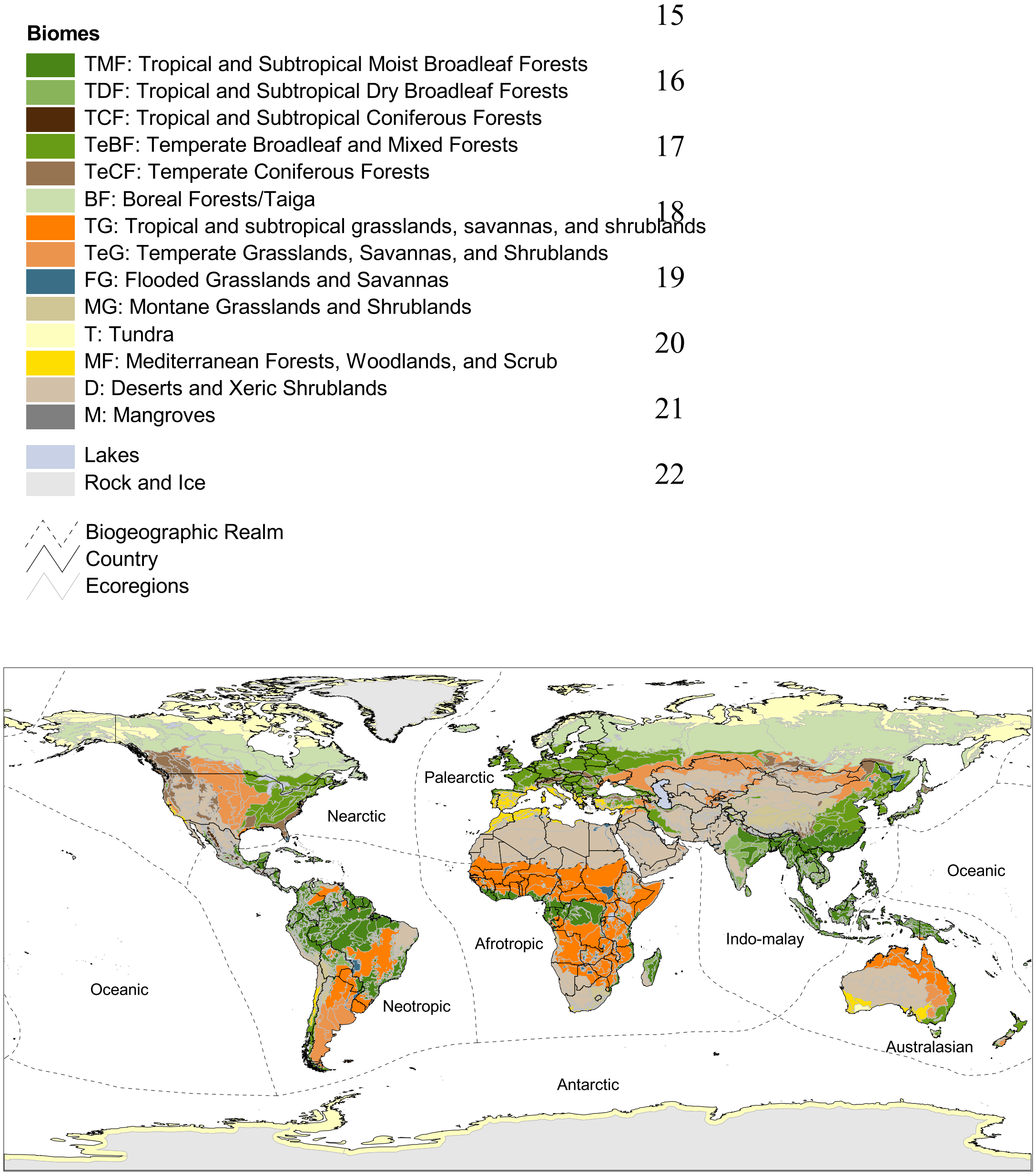
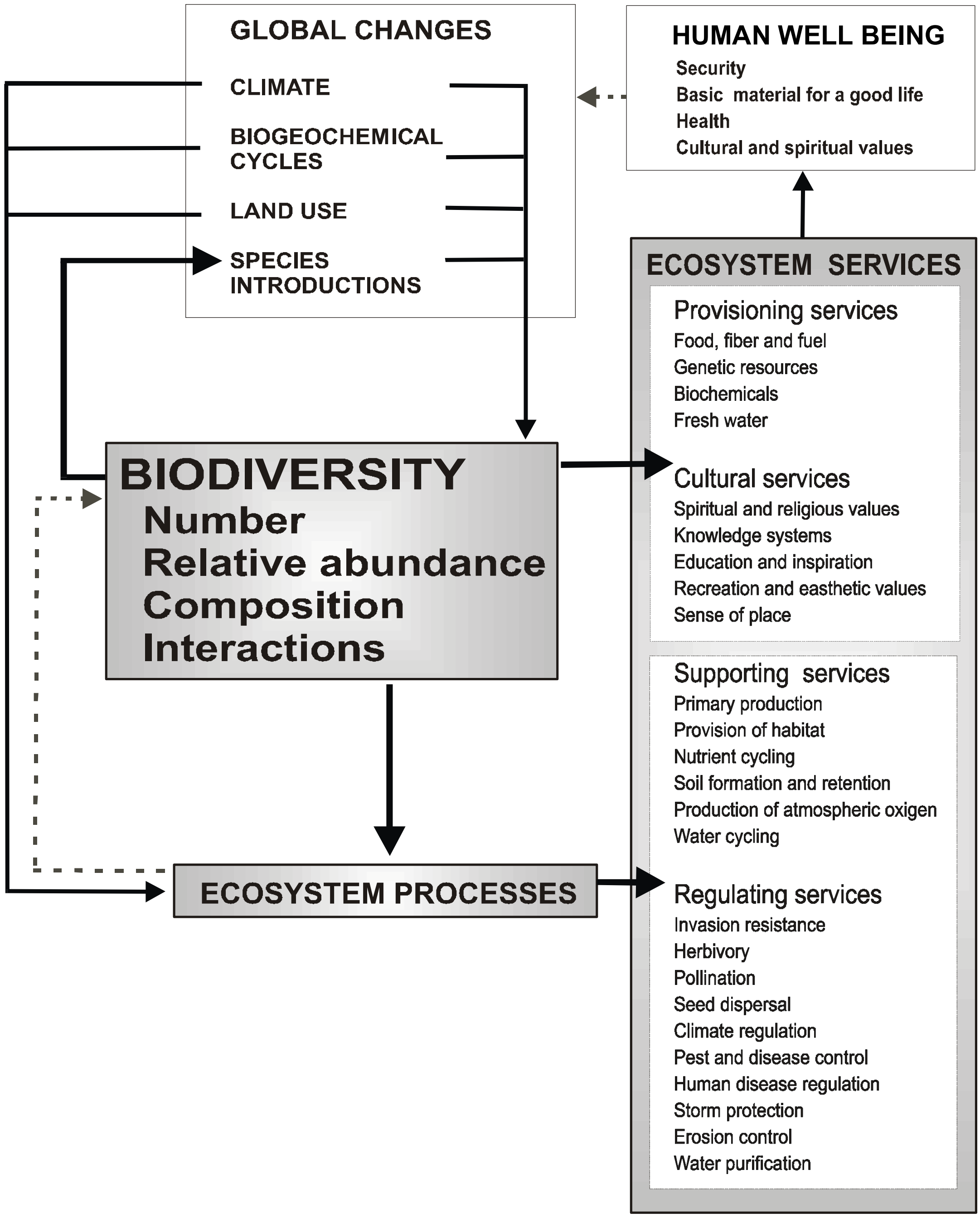


Figure 1.4. Biodiversity, ecosystem functioning and ecosystem services. (C11 Fig 11.1) Biodiversity is both a response variable affected by global change drivers and a factor modifying ecosystem processes and services and human well-being. Solid arrows indicate those links that are the focus of this chapter. Supporting services are the benefits obtained from the regulation of ecosystem processes. Regulating services are those that are necessary for the production of all other services. Provisioning and cultural services are also considered fundamental ecosystem services, but they are not addressed in this chapter.



2. Why is biodiversity loss a concern?

We know with certainty that biodiversity is essential for ecosystem services and hence for human well-being. This goes beyond material welfare but also contributes to security, social relations, health, freedom of choices and personal happiness. Some people have benefited significantly from the conversion of natural ecosystems to human dominated ecosystems and from the exploitation of biodiversity over the last century. However, other people have suffered decreased well-being with some being pushed into poverty.

2.1 Overview of main links among biodiversity, ecosystem services and various constituents of human well-being

Not all of the multiple components of human well-being are dependent on biodiversity and/or ecosystem services. And, for those that are, there are several challenges to assessing and attributing the links between ecosystem services and well-being. One is multiple causality: for example, human health depends on health services, education *and* ecosystem services (and probably several other factors as well). Thus an improvement in health, as measured by rising life expectancy, could occur in the face of a moderate decline in ecosystem services, if the other factors were positive - including the efficiency of conversion of ecosystem 'capital' to human 'income'. This is also true in the case of poverty. Poverty has many causes and trying to isolate biodiversity and ecosystem service loss as a main cause for poverty is a non-trivial task and we would be naïve to say that poverty will be reduced if we are able to conserve biodiversity and ecosystem services. The nexus is much more complicated and is governed by social, economic and political variables in addition to the ecological factors we focus on in this report.

Nevertheless, this report finds biodiversity as an important means as well as an end to a number of key constituents and determinants of human well-being. If we keep all other variables constant, we can say *with medium certainty* that biodiversity loss and deterioration in ecosystem services will contribute—directly and/or indirectly—to worsening health, higher food insecurity, increasing vulnerability, lower material wealth, less freedoms and choices and personal unhappiness. However, there are insufficient data globally to allow rigorous estimations of the full consequences for human well-being of biodiversity loss and deteriorating ecosystem services.

Food Security. Biological diversity is used by many rural communities directly as insurance, a coping mechanism, increasing flexibility, and risk spreading strategy in the face of increasing uncertainty. The availability of this biological "safety net" has increased the security and resiliency of some local communities to external economic and ecological perturbations or shocks. (C6; C8.4). In a world where fluctuating commodity prices are more the norm than the exception, economic entitlements of the poor are increasingly becoming precarious. The availability of an ecosystem based food security net during times when economic entitlements are insufficient to purchase adequate nourishment in the market provides an effective insurance program (C8.1; C6.8)

Investigations of two dryland sites in Kenya and Tanzania found that wild indigenous plants provided alternative sources of food when harvests failed or sudden expenses had to be met (such as a hospital bill). Coping mechanisms based on indigenous plants are particularly important for the most vulnerable who have little access to formal employment, land and/or market opportunities. (C6). Table 2.1 illustrates the high degree of dependency households in Kenya and Tanzania have on biodiversity for their food sources.

<<Insert Table 2.1>>

Another pathway through which biodiversity was found to improve food security is through the adoption of agro biodiversity farming practices vis-à-vis mono cash cropping systems. The preservation of a large number of species, crop varieties, and their wild relatives, and a high degree of spatial heterogeneity are considered by many agrarian communities to be crucial for the long-term viability of their agricultural systems (C11). The more diverse farms were found to have the higher probability of meeting food needs (C6.8).

Vulnerability. The world is experiencing an increase in human suffering and economic losses from natural disasters over the past several decades. Destruction of mangrove forests and coral reefs, which act as natural buffer against floods and storms, has increased the severity of flooding on coastal communities. Floods affected more people across the globe (140 million per year on average) than all other natural or technological disasters put together. Over the past four decades, the number of "great" disasters has increased by a factor of four while economic losses have increased by a factor of ten. For the period of the 1990s, countries of low human development experienced about 20% of the hazard events and reported over 50% of the deaths and just 5% of economic losses. High human development countries account for over 50% of the total losses and less than 2% of the deaths (C6; R11; C4).

Health. An important component of health is a balanced diet. About 7000 species of plants and several hundred species of animals have been used for human food at one time or another. Some indigenous and traditional communities presently use 200 or more species for food use. Wild sources of food in general remain particularly important for the poor and landless—especially important during times of famine or conflict—to provide a somewhat balanced diet (C6). Even at normal times wild foods are often important in complementing staple foods to provide a balanced diet (C6). Overexploitation of marine fisheries worldwide, and of bushmeat in many areas of the tropics, has lead to a reduction in the availability of wild-caught animal protein, with serious consequences in many countries for human health (C4).

Human health, particularly risk of exposure to many infectious diseases, may depend on the maintenance of biodiversity in natural ecosystems. On the one hand, a greater diversity of wildlife species might be expected to sustain a greater diversity of pathogens that can infect humans. However, evidence is accumulating that greater wildlife diversity may decrease the spread of many wildlife pathogens to humans. The spread of Lyme disease, the best studied case, seems to be decreased by the maintenance of the biotic integrity of natural ecosystems. (C11)

Wood fuel is one of the services supplied by forests and woodlands. Even in highly developed nations such as Sweden and the USA, wood supplies 17 and 3 percent of total energy consumption, respectively. Wood provides more than half the energy consumed in developing countries; in some African countries, such as Tanzania, Uganda and Rwanda, it accounts for 80% (Southern Africa Regional Assessment; Scholes and Biggs, 2004). In the Kafue basin of Zambia wood provides 96 % of household energy consumption. In rural areas, 95% is consumed in the form of firewood, while in urban areas 85% is in the form of charcoal. Shortage of wood fuel occurs in areas with high population density without access to alternative and affordable energy sources. In those provinces of Zambia where the population densities exceed the national average of 13.7 persons per km^2, the demand for wood has already surpassed local supply. In such areas, people are vulnerable to illness and malnutrition because it is too expensive to heat homes, not possible to cook food, and consumption of unboiled water facilitates the spread of waterborne diseases such as cholera. Women and children in rural poor communities are the most affected by wood fuel scarcity. They must walk long distances searching for firewood, and therefore have less time for tending crops, cooking meals or attending school. However, it should also be acknowledged that the use of wood fuel in badly ventilated homes is also one of the main causes of respiratory illness.

Provision of Clean Water. The continued loss of cloud forests and destruction of watersheds reduce the quality and availability of water supplied to household use and agriculture. The availability of clean drinking water is a concern in dozens of the world's largest cities (C4). In one of the best documented cases, New York City took steps to protect the integrity of watersheds in the Catskills to insure continued provision of clean drinking water to 9 million people. Protecting the ecosystem was shown to be far more cost-effective than the alternative of building and operating a water filtration plant. New York City avoided $6 to 8 billion in expenses by protecting the ecological integrity of the watersheds. (C27; R17).

Personal Happiness and Social Relations. The values people place for the mere existence of biodiversity other than just for instrumental values contributes directly to individual's personal sense of happiness. This is usually reflected in the existence value individuals place on preserving biodiversity.

Does biodiversity loss translate to cultural loss and what does this means for human well-being? The traditional wisdom, embedded in the concept of the sacred species, ecosystems and landscapes, and its revivalism in the contemporary context of biodiversity conservation is something to be taken note of. Rather than merely taking a mechanistic view of the earth processes, where humans are continually struggling for unlimited material progress through economic growth, mediated by technological innovations, a greater appreciation of the interconnectedness leading to an organic and ecological world view, akin to the views of the ancient seers - the sages and mystics - is emerging. (C17)

Does the notion of a global village imply a more homogenous global community and would the conservation of biodiversity automatically also lead to cultural preservation? The present level of information does not permit us to have definite answers to these questions but are worth consideration in our deliberations for the conservation of biodiversity that just goes beyond the utilitarian use of biodiversity.

Many cultural systems incorporate environmental features (S11). For example, many religions attach spiritual and religious values to ecosystems or their components such as a tree, hill, river or grove. Thus, loss or damage to ecosystems can harm social relations; for example by impeding religious and social ceremonies that normally bind people (see Box 2.1 which provides some of the main findings from the MA South African sub-global assessment). Damaged ecosystems, highly valued for their aesthetic, recreational or spiritual value can harm social relations, both by reducing the bonding value of shared experience, and also by causing resentment towards groups that profit from their damage. As well, of course, lost ecosystems can cause profound material loss, which in turn can also damage social relations. (S11; SG10)

<<Insert Box 2.1 here: Consequences of degradation in SAfMA>>

Freedom and Choice. Freedom and choice within the MA context refers to having control over what happens and being able to achieve what individuals value (MA-CF). Local shrimp farmers lose a valuable source of wild shrimp fry when mangrove forests are destroyed or converted. This leads many of them to depend solely on commercial shrimp fry with no real choices on fry selection. Similarly, local fishermen depend on the mangroves as breeding grounds for local fish populations. Loss of mangroves translates to a loss in control over the local fish stock and a livelihood they have been pursuing for many generations and which they value. Another example is high diversity agricultural systems. These systems normally produce less cash than mono-crop cash crops but farmers have some control over their entitlements because of risk spreading through diversity. High diversity of genotypes, populations, species, functional types and spatial patches decreases the negative effects of pests and pathogens on crops, and keeps open possibilities for agrarian communities to develop crops suited to future environmental challenges (C11).

Another dimension of choices relates to the future. The loss of biodiversity in some instances is irreversible and the value individuals place on keeping biodiversity for future generations—the option value—can be significantly high. Having choices available irrespective if some of the choices will be chosen is an essential constituent of well-being. However, putting a monetary figure on option values is notoriously difficult. We can only postulate on the needs and desires of future generations, some of which can be very different from the present generation's aspirations. The type of environment society wants to leave for a future generation is a difficult question to answer but a question no doubt that needs to be seriously considered in environmental decision making.

Basic material for a good life and Livelihoods. Biodiversity offers directly the various goods individuals need in order to earn an income and secure livelihoods. However, unlike the other constituents of well-being, livelihoods by itself pays less attention to the preservation of biodiversity and is more focused towards the maximization of net gains from the use of biodiversity. In other words, biodiversity and the ecosystem services it supports are treated as a capital asset which can, in principle, be substituted with other forms of capital.

However, a growing body of evidence suggests that the preservation of biodiversity offers opportunities to preserve or improve human well-being while at the same time saving money. When all costs are taken into account, the economic losses brought about by agricultural intensification through pollution, degradation, and erosion are enormous. By having greater biodiversity, agriculture can positively affect soil fertility, pest control, human and animal health, and water and climate regulation. The monetary value of pollination services has been estimated to be \$100 to \$200 billion per year. All of these represent new income opportunities for farmers.

In aquatic ecosystems, resource over-exploitation and coastal degradation undermines subsistence use of coastal ecosystems. However, small rural populations are not the only ones to suffer from over-exploitation and mismanagement – national economies are affected as well. For instance, potential net benefits from coral reefs including fisheries, coastal protection, tourism, and biodiversity total \$29.8 billion annually (C19).

Studies of contemporary losses of biodiversity reveal that these too can impose very substantial costs, at local and national scales. For example, the collapse of the Newfoundland cod fishery in the early 1990's cost tens of thousands of jobs, as well as at least \$2B in income support and re-training. Recent evidence suggests that the preservation of the integrity of local biological communities, both in terms of the identity and the number of species, is important for the maintenance of plant and animal productivity, soil fertility, and their stability in the face of a changing environment (C11; SG7.2). Recent estimates from the MA Portugal sub-global assessment indicate that environmental expenses are increasing at a rate of three percent a year and are presently 0.7 percent of Gross Domestic Product (GDP) (SG7).

The evidence of links between biodiversity and the various constituents of well-being is compelling and leads us to conclude that the conservation of biodiversity is important for reducing poverty and improving well-being. However, we still do not have sufficient data and information to establish a precise relationship between the loss of biodiversity and declines in human well-being.

2.2 Are there trade-offs among biodiversity conservation, human well-being and poverty reduction?

When society has multiple goals, many of which are dependent on the high degree of complexity and inter-dependency among the biodiversity, ecosystem services and the many constituents of well-being, difficult decisions involving trade-offs among competing goals have to be made. The most common trade-off is between exploiting ecosystems for production of commodities and conservation. For example, conversion of wetlands and forests to croplands helps to ensure stable food supplies, but also causes pollution of waterways, disruption of hydrology, reduced fish yields, loss of biodiversity and loss of scenic places.

The value of the services lost to human society, in the long term, may greatly exceed the short-term economic benefits that are gained from those transformative activities. Consider, for example, the draining of swamps. This may reduce mosquito-borne infectious disease risks, while at the same time destroying the wetland system and its flow of ecosystem services. Similarly, creating roads within forests facilitates the contact with, and movement of, infectious diseases such as malaria and viral hemorrhagic fevers, while also providing remote communities with access to health care and to other facilities. Tradeoffs can also occur over time. In Sri Lanka, for example, the clearing of tropical forest for agriculture initially reduced the habitat for forest-adapted anopheline mosquito vectors of malaria. However, in due course, other vector species occupy the changed habitat, contributing to the resurgence of malaria (SG2).

In many instances, the feedback loop between declining ecosystem services and human well-being is slow, or operates at a distance, and this result in the warning signals being missed. Ecosystem transformation is undertaken, of course, because of real or anticipated benefits that will accrue at least in the short term. Indeed, our present societies are dependent on such transformation. Agriculture, forestry and fishing provide one in every two jobs worldwide; and crops, timber and fish contribute more to the global economy than do industrial goods.

The importance of biodiversity and natural processes in producing ecosystem services upon which people depend remains largely invisible to decision-makers and the general public. Unlike goods bought and sold in markets, most ecosystem services do not yet have markets or readily observable prices. However, just because a good or service has no price does not mean that the good or service has no value. A substantial body of research in economics on non-market valuation is now available, though applying these methods to biodiversity and ecosystem services is not fully developed. Methods exist for establishing relatively objective and defensible estimates of value for some ecosystem services, including the value of providing clean drinking water, recreation, or commercially harvested species. Existence value of species, intrinsic values and other "non-use" values pose a greater challenge to those who would try to measure the complete value of conserving biodiversity and natural processes. The fact that ecosystems are dynamic and complex, as well as the fact that human preferences change through time, also present difficulties for attempts to value natural systems. Combinations of irreversible actions, such as species extinction, and uncertainty give rise to option value (e.g., the value of maintaining flexibility, keeping options open, until uncertainty is resolved). Though clear in theory, getting reasonable estimates of option value are difficult in practice. Despite the difficulty, it is worth gathering better evidence about benefits created by natural systems. One goal of such research could be to establish a system of biodiversity accounts to track changes in the status of biodiversity, in much the same way that national income accounts are used to track the status of national economies. Whether such accounts need to be put in monetary terms or whether biological or physical measures are sufficient is an open question. Better quantification of the benefits created by natural systems would provide greater impetus for biodiversity protection.

There is often a large divergence between the private and social value of conserving biodiversity and natural systems. Private value of conservation for individuals will typically ignore the "external" benefits of conservation that accrue to others. For example, a farmer may benefit from intensive use of her land but generally does not bear all of the consequences caused by leaching of excess nutrients and pesticides leaching into ground or surface water, or the consequences of loss of habitat for native species. People around the globe may value a species existence and ecosystem services, such as flood control and nutrient retention, would provide benefits further downstream. If private decision-makers do not perceive the larger social benefits of conservation then their decisions will often result in inadequate conservation.

The key question is how to understand and quantify the current and future benefits, costs and risks involved in all cases. There is much human well-being at stake, both now, and in the future. Formal trade-off analysis (as shown in figure 2.1) can help decision-makers make intelligent decisions among competing goals. Such analysis can identify management strategies which generate efficient outcomes in which it is not possible to increase one objective without decreasing another objective. Second, it can show the extent to which current decisions are inefficient and help identify opportunities for improving upon the status quo. Third, it illustrates the nature of the trade-offs between goals once the efficiency frontier has been reached.

<<Insert Figure 2.1 here: Efficiency frontiers>>

The value of biodiversity can be expressed in economic terms on the basis of the fact that humans derive benefit (or "utility") from the use of ecosystem services that it underpins. The concept of total economic value (TEV) is widely used by economists. This framework typically disaggregates the utilitarian value of biodiversity into various types including direct, and indirect use values (for services that are used by humans, directly and indirectly, respectively), option values (for services that may be used in the future), and non-use or existence values (where people value a resource even if they may never use it). (Note that "total" refers to the sum of the types of value, and does not mean "global"). In addition, it is recognized that biodiversity has intrinsic value, which, not being anthropocentric, cannot be valued in conventional economic terms. (C2.3.3).

Only a few of the ecosystem services are routinely valued in economic terms. Valuation is usually relatively simple in the case of direct use value, and then increasingly difficult as one moves on to indirect use value, option value, and non-use value. Thus, despite the existence of various valuation methods to estimate the different values of biodiversity only provisioning ecosystem services are routinely valued. Most supporting and regulating services are not valued at all, because they bear the characteristics of public goods and are not traded in markets. The value of biodiversity and related ecosystem is usually calculated *at the margin;* that is, for assessing the value of changes in ecosystem services resulting from management decisions or other human actions or for assessing the value of the biodiversity of, or service provided by, an area that is small compared to the total area. Economic valuation studies has also been used to extrapolate the global value of all ecosystem services at a given time but these approaches are generally problematic, since few of the assumptions made (explicitly or implicitly) in such valuations are likely to be valid when aggregated to the global level. (C2.3.3).

The value derived from biodiversity can be highly significant in comparison with other values derived from a particular area. In existing economic studies of changes in the total economic value of changes to biodiversity in specific locations (such as the conversion of mangrove forests, degradation of coral reefs, and clear-felling of forests) the costs of ecosystem conversion is often found to be significant, and sometimes exceeds the benefits of the habitat conversion. Despite this, in a number of these cases, conversion was promoted because the value of the lost ecosystem services was not internalized, and sometimes also because subsidies distorted the relative costs and benefits. Often, the majority of local inhabitants were disenfranchised by the changes. (C5.4.1). See Box 2.2.

The depletion and degradation of many ecosystem services represents a loss of a capital asset that is poorly reflected in conventional indictors of economic growth or

growth in human well-being. (C5.4.1) This loss is poorly reflected in conventional economic indicators of well-being such as GDP. A country could cut its forests and deplete its fisheries, and this would show only as a positive gain to GDP, despite the loss of the capital asset. (GDP measures the flow of economic benefits from the use of these resources, but the depletion of the capital asset is not reflected.) Moreover, many ecosystem services are available freely to those who use them (freshwater in aquifers, the use of the atmosphere as a sink for pollutants) and so again their degradation is not reflected in standard economic measures. When changes to these natural capital assets are factored in to measures of the inclusive wealth of nations, they significantly change the balance sheet for countries with economies significantly dependent on natural resources. Some countries that appeared to have positive growth in the 1970s and 1980s, for example, actually experienced a net loss of capital assets, effectively undermining the sustainability of the gains that they may have achieved.

2.3 Trends in Ecosystem Services

Many of the changes that have been made in biodiversity and ecosystems have occurred to enhance the production of specific ecosystem services such as food production. However, only four of the 22 ecosystem services examined in this assessment have been enhanced: crops, livestock, aquaculture, and (in recent decades) carbon sequestration while 14 services have been degraded. (Table 2.1) Degraded services include capture fisheries, timber production, water supply, waste treatment and detoxification, water purification, natural hazard protection, regulation of air quality, regulation of regional and local climate, regulation of erosion, and many cultural services (spiritual, aesthetic, recreational and other benefits from ecosystems). Modifications of ecosystems to enhance one service generally have come at a cost to other services that the ecosystem provided. The impacts of these trade-offs among ecosystem services affect people in different ways. For example, an aquaculture farmer may gain material welfare from management practices that increase soil salinization and thereby reduce rice yields and threaten food security for nearby subsistence farmers.

2.4 What are the distributional impacts arising from biodiversity loss and ecosystem change?

Biodiversity use, change and loss has improved well-being for many social groups and individuals; however, populations with low resiliency[1] to ecosystem changes—mainly the disadvantaged—have been the biggest losers and witnessed the biggest increase in not only monetary poverty but also in relative, temporary poverty and the depth of poverty (R17). See Box 2.3 for a description of the various type of poverty.

<<Insert Box 2.3 here>>

Local communities depend on a range of biological products for their material welfare. Appropriations of the rights to these products through formal copyright or patent laws

[1] Resilience is defined as (a) the amount of disturbance an individual or group can absorb and still remain within the same state or domain of attraction, (b) the degree to which the individual is capable of self-organization, and (c) the degree to which the system can build and increase its capacity for learning and adaptation.

adversely impact the economic welfare of local communities by shifting benefits of biodiversity from the communities to international corporations or other entities. Provisions for ensuring the equitable distribution of monetary benefits from the use of biological products are an issue of major concern. Even in cases where equitable provisioning has been made, implementation is being impaired by weak and ineffective institutions.

Poor people have historically lost access to biological products and ecosystem services disproportionately as demand for those services has grown. Coastal habitats are often converted to other uses, frequently for aquaculture ponds or cage culturing of high-valued species such as shrimp and salmon. Despite the fact that the area is still used for food production, local residents are often displaced and the fish produced are usually not for local consumption but for export. Coastal residents often no longer have access to cheap protein or sources of income (C18.5.2.3). In Ecuador, the development of shrimp aquaculture along its coast displaced coastal residents and reduced their standard of living. The situation was much better whereby local communities—with particular focus on the poor and the disadvantaged—were involved and made partners in the access, use and management of biodiversity.

Changes in the equity structure of societies can have impacts on ecosystem services. Differential access to resources may also explain why some people living in environmental resource-rich areas nevertheless have low human well-being. For example, economic liberalization in Vietnam resulted in the development of a class of entrepreneurs with markedly greater access to capital. The poorer fishermen were unable to enter the capital and technology-intensive shrimp fishery that developed. Furthermore, the ecological changes precipitated by the expansion of shrimp aquaculture reduced the capacity of the ecosystem to support the traditional fish stocks, further exacerbating the inequity (SG2).

The increase in international trade of biological products has increased the well-being for many social groups and individuals, especially in countries with well developed markets and trade rules and also of those in the developing countries who have access to the biological products. However, many groups have not benefited from such trade. Evidence from this assessment indicates that people who live near biodiversity have experienced a drop in their well-being rather than an increase. Examples include the many indigenous groups and local communities who have relied on these products and the ecosystem services they support for many of the constituents of well-being. Weak and inefficient institutional structures which oversee the equitable distribution of benefits are observed as key reasons for the inequitable distribution of benefits at the national and local levels. Another reason which emerges is the way international agreements related to the use of biodiversity products have been designed and implemented. There is a contention that many of the international agreements are designed by experts from the developed countries and that officials from developing countries do not have either the capacity to negotiate effectively or are over-burdened with too many negotiations. Furthermore, many of these agreements are not legally binding, do not have clear objectives and definitions, lack a clear elaboration of rights and obligations, and seldom have mechanisms for implementation; especially when it comes to related issues of well-being and poverty reduction (R17).

Conflicts between competing social groups and/or individuals over access and use of biological products and ecosystem services have contributed to declines in well-being for some groups and improvements for others. Sometimes different social groups have a conflict over how a given bundle of ecosystem services or biological products ought to be used and shared. Although many such conflicts have been managed cooperatively, it is also common for one side to impose its preferred outcome on the other, and this can lead to an improvement in well-being for one group at the expense of another. If mountain communities convert forests to agricultural lands, for example, that may reduce downstream ecosystem services to low-lying areas in the form of increased siltation and declining water quality. If wetlands are converted to human settlement in one area of a watershed, other communities in the watershed may experience diminished flood buffering capacities. When ecosystem change is linked to well-being change through this mechanism, one observes both winners and losers – some groups improve and other groups decline (C5). Box 2.4 provides an illustration of some of these conflicts which had emerged in Chile over the mining industry and local communities.

<<<<< Insert Box 2.4 >>>>>

One of the main reasons why some countries, social groups or individuals—especially the disadvantaged—are more severely affected by biodiversity and ecosystem changes is because of limited access to substitutes or alternatives. The creation of seed banks in many developed countries has been used in response to the rapid rate of biodiversity loss. However, for many developing countries, the maintenance of gene banks is a major problem as electricity supplies are unreliable and fuel costs expensive (R6).

Equity – the distribution of well-being among people – is an important issue. Averages often hide large disparities in distribution and often mask or hide the disadvantaged. Most poverty statistics are only available at an aggregate level. These tend to hide pockets of poverty existing sometimes within traditionally defined "rich" regions or provinces. Therefore, using aggregate data to understand and establish links between biodiversity loss, ecosystem changes and well-being can be quite misleading (C5). For example, Figure 2.2 shows the spatial distribution of the poor at various scales of aggregation in Ecuador. At the aggregate level, poverty shows up very clearly in eastern Ecuador while central Ecuador shows little evidence of poverty. However, if the data are disaggregated pockets of poverty appear even in Central Ecuador. Further disaggretation to the municipal level reveals high levels of poverty in particular municipalities. The people most affected by biodiversity and ecosystem changes as noted earlier are those communities living near the resources. The highest species diversity in Ecuador occurs in the western part of the country (not the most impoverished region), however, pockets of very high poverty do exist in this region. Place-based or micro level data and not macro level or aggregated data provides more useful information to use to identify disadvantaged communities being affected by biodiversity and ecosystem changes.

<<Insert Figure 2.2: Spatial distribution of the poor>>

Box 2.1 Social consequences of biodiversity degradation (SG-SAfMA)

The basic needs of the AmaXhosa people of the Great Fish River, represented by four Xhosa villages, are met by resources in the natural environment, including fuel wood, medicinal plants, building materials, cultural species, food supplements and species of economic value. Consequently local AmaXhosa people experience a strong dependence and place high utilitarian and cultural value on their local natural environment as expressed in the following two respondents quotes: "*I am entirely dependent on the environment. Everything that I need comes from this environment*" and "*it* (the environment) *will be important for ever because if you have something from the environment it does encourage you to love the environment*."

A result of this connection between the AmaXhosa and the natural environment is that individual well-being is closely related to a healthy environment. Respondents often described positive emotional and physical symptoms when the bush was healthy: "*When the environment is healthy, my body and spirit is also happy*," and when describing people's feelings towards a healthy environment, a respondent stated that "*people love such an environment. They really adore it. Such an environment makes them feel free*." In addition respondents described the feelings of peace when walking in the bush and how they would go to the natural environment to pray. This compares to experiences of de-motivation, a lack of hope and disrespect when the environment becomes degraded.

Coupled with this high dependence on the local environment is the experience of continuity to place, where many villagers born in a village, plan to die there, emulating the practice of their forefathers. Abandoning their respective villages would mean abandoning the ancestors. There is also a fear that they would soon die in the new place, as experienced by many other people, and they feel a close connection and place high value on the place where they were born.

The beliefs and traditions, i.e. cosmology of the AmaXhosa in the Great Fish River play an important role in guiding resource use and management and encouraging values to be place-centered. The ancestors are central to this cosmology where the very identity of a Xhosa person is based on performing traditions and rituals for the ancestors. The majority of respondents stated that practicing one's traditions and thus communicating with the ancestors is what is of value to a Xhosa person.

The reason for their importance is twofold. Firstly, it is a way of emulating their forefathers' way of life, the significance of which is expressed in the following informants quote: "*the traditions are important to us as amaXhosa people because they were being preformed by our forefathers. If we don't perform them there is a saying that we are calling death to us.*" Secondly, respondents draw many parallels between ones health and quality of life and the satisfactory performance of traditions; i.e. following the correct procedures which, as demonstrated below, is intimately tied to use of the natural environment.

A number of sites and species are fundamental to the performance of rituals and maintaining a relationship with the ancestors. When respondents were asked what would happen if these sites were to be destroyed, they replied "It means that the ancestors would be homeless". "That can't happen here at this village because our health depends entirely on these sites" and "It means that our culture is dead."

Box 2.2: Economic Costs and Benefits of Ecosystem Conversion. Relatively few studies have compared the marginal values of ecosystems before and after conversion across a wide range of ecosystem services. One review article found only five examples of such studies and in each case the converted ecosystems were found to have a lower total economic value than the original habitat (C5):

- **Logging of a tropical forests (Selangor, Malaysia).** While high-intensity, unsustainable logging provided large private benefits through timber harvesting ($11,200 per ha), reduced-impact logging provided greater total benefits when a range of social and global benefits (Non-wood forest products, flood protection, carbon stocks, and endangered species) are factored in as well as the benefits from timber (total benefits of $1,300 per ha).

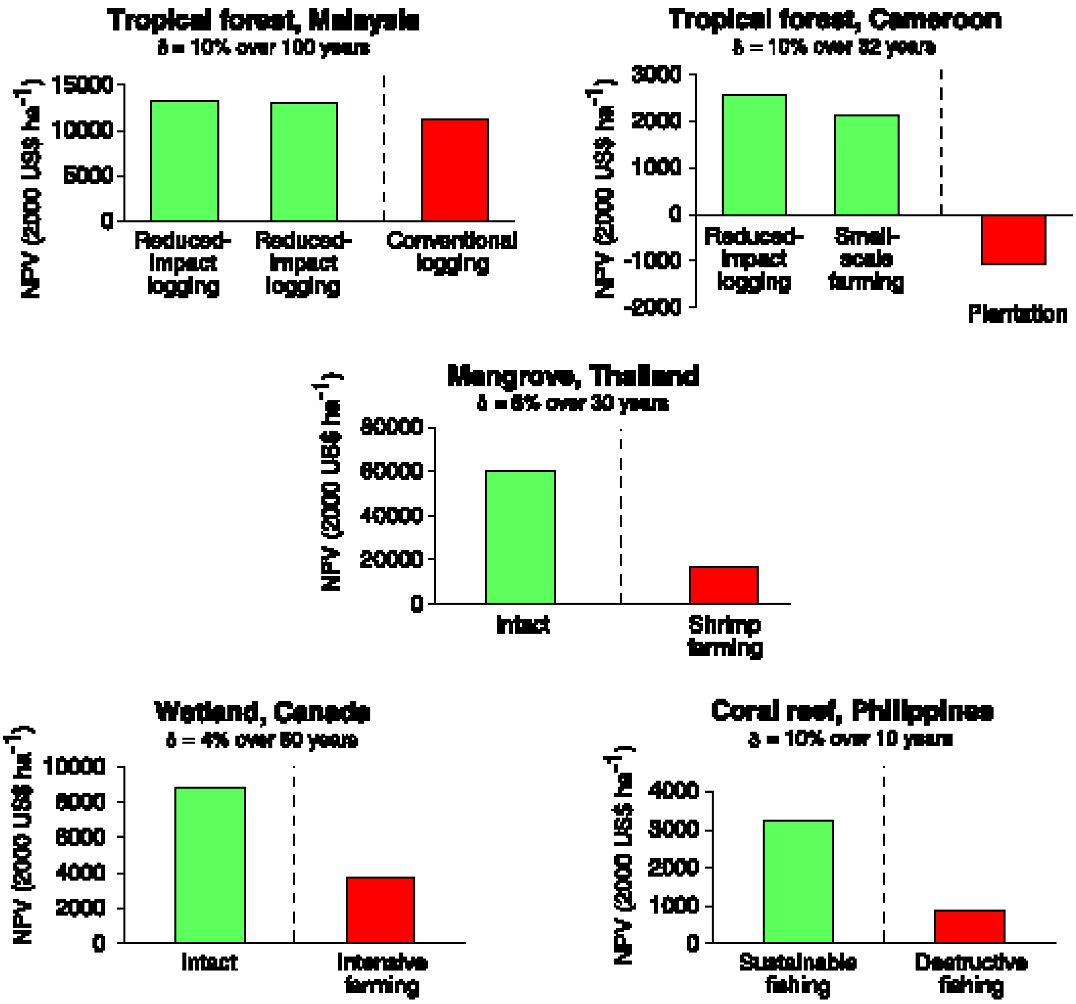
- **Conversion of tropical forest to small scale agriculture or plantations (Mount Cameroon, Cameroon).** Maintenance of the forest with low-impact logging provided social benefits (Non-wood forest products, sedimentation control, and flood prevention) and global benefits (carbon storage plus option, bequest, and existence values), totaling some $2,570 per ha. Conversion to small-scale agriculture yielded private benefits (food production) of about $2110 per ha. Conversion to oil palm and rubber plantations resulted in net costs (negative benefits). Private benefits from cash crops were only realized in this case because of market distortions.

- **Conversion of a mangrove system to aquaculture (Thailand).** Although conversion for aquaculture made sense in terms of short-term private benefits, it does not once external costs are factored in. The global benefits of carbon sequestration were considered to be similar in intact and degraded systems. However, the substantial social benefits associated with the original mangrove cover - from timber, charcoal, non-timber forest products (NTFPs), offshore fisheries, and storm protection -fell to almost zero following conversion. Summing all measured goods and services, the Total Economic Value (TEV) of intact mangroves exceeded that of shrimp farming by around 70% (~$60,400 compared with $16,700 per ha).

- **Unsustainable exploitation of coral reefs (Philippines).** Economic studies of Philippine reef exploitation demonstrated that despite high initial benefits, destructive techniques such as blast fishing had a far lower Net Present Value (NPV) of private benefits than did sustainable fishing. The social benefits of sustainable exploitation, arising from coastal protection and tourism, were also lost upon dynamiting reefs. As a consequence, the TEV of retaining an essentially intact reef was almost 75% higher than that of destructive fishing (at ~$3,300 compared with $870 per ha).

- **Draining freshwater marshes for agriculture (Canada).** Draining freshwater marshes in one of Canada's most productive agricultural areas yielded net private benefits (in large part because of substantial drainage subsidies). However, the social benefits of retaining wetlands, arising from sustainable hunting, angling, and trapping, greatly exceeded agricultural gains. Consequently, for all three marsh types considered, TEVs were higher when the wetlands remained intact, exceeding figures for conversion by a mean of around 60% (~$8800 compared with $3700 per ha).

Figure Box 2.2. The marginal benefits of retaining and converting natural habitats, expressed as Net Present Value calculated using the discount rates and time horizons presented. Values of measured goods and services delivered when habitats are relatively intact and when converted are plotted as green and red columns respectively.



Box 2.3 – Concepts and Measures of Poverty

Relative Poverty is the state of deprivation defined by social standards. It is fixed by a contrast between those others in the society who are not considered poor. Poverty is then seen as lack of equal opportunities. It is based on subjective measures of poverty.

Depth of Poverty is a measure of the average income gap of the poor in relation to a certain threshold. It defines how poor are the poor. It gives the amount of resources needed to bring all poor to the poverty line level.

Temporary Poverty is the poverty characterized by a short-term deprivation, usually seasonal. It could be due to a shortage of water or food that is occasional.

Monetary Poverty is the poverty expressed as an insufficiency of income or monetary resources. Most indicators like US$1 or national poverty lines are defined in those terms.

Multidimensional Poverty is the poverty conceived as a group of irreducible deprivations that cannot be adequately expressed as income insufficiency. It combines basic constituents of well-being in a composite measure, such as the HPI (Human Poverty Index).

Other characteristics of poverty are commonly used in the literature such as those of rural and urban poverty, extreme poverty (or destitution), female poverty (to indicate gender discrimination), food-ratio poverty lines (with calorie-income elasticities), etc. Other indices such as the FGT (Foster, Greer and Thorbecke) or the Sen Index that combine both dimensions of incidence and depth of poverty are also widely used.

Box 2.4 Conflicts between the mining sector and local communities in Chile

The Salar de Atacama, Chile, is a salty wetland within the driest desert in the world. Surface water is limited. The present major concern is over groundwater usage, and the extent to which its exploitation is sustainable. The economic activities in this region include mining, agriculture and tourism, all of which depend on the quantity and quality of available water. The Salar de Atacama holds over 40 % of world lithium reserves; mining provides 12 % of the local employment and two thirds of the regional GDP. It also consumes 65 % of the water used in the region. Tourism is the second largest source of employment and income, and needs freshwater for its facilities. Local communities rely on water for subsistence agriculture and livestock raising. Two-thirds of subsistence farmers do not have enough resources to buy water rights, when bidding against the mining companies. Hence the shortage of water is generating major conflicts over access and ownership rights among the competing users. (SG 2)

Table 2.1. Trends in the human use of ecosystem services and enhancement or degradation of the service over the past 50 years.

Legend

↑ = Increasing or enhanced

↓ = Decreasing or degraded

+/- = Mixed (trend increases and decreases over past 50 years or some components/regions increase while others decrease

* = indicates low to medium confidence. All other trends are medium to high certainty.

Service	Human Use[1]	Enhanced or Degraded[2]	Notes	MA Chapter source
Provisioning Services				
Food – Crops	↑	↑	Significant increase in area devoted to agriculture and in production per unit area	**C8**
Food – Livestock	↑	↑	Significant increase in area devoted to livestock and increase in production per unit area	**C7**
Food – Capture Fisheries	↓	↓	Marine fish harvest increased until the late 1980's and has plateaued or been declining since that time. The only areas that are not currently overfished are the deep ocean systems. Freshwater capture fisheries have also declined.	**C18**
Food – Aquaculture	↑	↑	Aquaculture has become a globally significant source of food in the last 50 years, and now contributes 30 percent of total fish production and one third (by volume) of all fish consumed as food.	**C8.2.2.3.4**
Timber	↑	↓	Global timber production has increased by 60% in the last four decades. Plantations are providing an increasing volume of harvested roundwood, currently accounting for 35% of the global harvest.	**C9.ES**
Fiber (cotton, etc.)	+/-	+/-	Cotton and silk production have doubled and tripled respectively in the last four decades. Production of other agricultural fibers has declined.	**C9.ES**
Fuel	+/–	↓	Global consumption of fuelwood appears to have peaked in the 1990s and is now believed to be slowly declining.	**C9.ES**
Genetic resources, biochemicals, natural medicines, and	↑	↓	Demand for biochemicals and new pharmaceuticals is growing, but new synthetic technologies compete with natural products to meet the supply. Historically, use of natural	**C10**

[1] For provisioning services, human use increases if the human consumption of the service increases (e.g., greater food consumption); for regulating and cultural services, human use increases if the number of people affected by the service increases.

[2] For provisioning services, we define enhancement to mean increased production of the service through changes in area over which the service is provided (e.g., spread of agriculture) or increased production per unit area. For regulating and supporting services, enhancement refers to a change in the service that leads to greater benefits for people (e.g., the service of disease regulation could be improved by eradication of a vector known to transmit a disease to people). Degradation of a regulating and supporting services means a reduction in the benefits obtained from the service, either through a change in the service (e.g., mangrove loss reducing the storm protection benefits of an ecosystem), or human pressures on the service exceed its limits (e.g., excessive pollution exceeding the capability of ecosystems to maintain water quality). For cultural services, enhancement refers to a change in the ecosystem features that increase the cultural (recreational, aesthetic, spiritual, etc.) benefits provided by the ecosystem.

Service	Human Use[1]	Enhanced or Degraded[2]	Notes	MA Chapter source
pharmaceuticals			products has been cyclical. Genetic engineering in principle increases the demand for genetic material, but in practice most genetic material is currently obtained from the relatively small number of species and varieties already in collections. For many other natural products (cosmetics, personal care, bioremediation, biomonitoring, ecological restoration), use is growing.	
Ornamental resources	**Not assessed**	**Not assessed**		
Freshwater	↑	↓	Human modification to ecosystems (e.g., reservoir creation) have made more freshwater available to people but have not changed the actual quantity. The timing of availability of water has been altered by the use of infrastructure, such as dams, although vegetation changes have also had an impact on the seasonal flow of water in river systems. From 5 to possibly 25 percent of global fresh water use exceeds long-term accessible supplies and requires supplies either through engineered water transfers and/or overdraft of groundwater supplies.	**C7.2.2.1**

Service	Human Use	Enhanced or Degraded	Notes	MA Chapter source
Regulating Services				
Air quality regulation	↑	↓	The ability of the atmosphere to cleanse itself of pollutants has declined slightly since pre-industrial times but likely not by more than 10 percent. Ecosystems are also a sink for tropospheric ozone, ammonia, NO_x, SO_2, particulates, and CH_4 but changes in these sinks (apart from that for CO_2) were not assessed.	**C13ES**
Climate regulation – global	↑	↑	Ecosystems were on average a net source of CO2 during the 19th and early 20th century, and became a net sink sometime around the middle of the last century. The biophysical effect of historical land cover changes (1750 to present) is net cooling on a global scale due to increased albedo, partially offsetting the warming effect of associated CO2 emissions from land cover change over much of that period.	**C13.ES**
Climate regulation – regional and local	↑	↓	Changes in land cover have affected regional and local climates both positively and negatively, but there is a preponderance of negative impacts. For example tropical deforestation and desertification have tended to reduce local rainfall.	**C13.3, C11**
Water regulation	↑	+/-	The effect of ecosystem change on the timing and magnitude of runoff, flooding and aquifer recharge depends on the specific change and the specific ecosystem.	**C7**
Erosion regulation	↑	↓	Land use and crop/soil management practices have exacerbated soil degradation and erosion, although appropriate soil conservation practices are increasingly being adopted.	**C26**
Water purification and waste treatment	↑	↓	Globally, water quality is declining, although in developed countries pathogen and organic pollution of surface waters has decreased over the last 20 years. Both pesticide contamination and nitrate concentration have grown rapidly in	**C7.2.5.1**

Service	Human Use[1]	Enhanced or Degraded[2]	Notes	MA Chapter source
			the last 30 years.	
Disease regulation	↑	+/-	Ecosystem modifications associated with development have often increased the local incidence of infections diseases, although major changes in habitats can both increase or decrease the risk of particular infections diseases.	**C14**
Pollination	↑	↓*	There is established but incomplete evidence of a global decline in the abundance of pollinators. Pollinator declines have been reported in at least one region/country on every continent (except for Antarctica, which has no pollinators). Declines in abundance of pollinators have rarely resulted in complete failure to produce seed or fruit, but more frequently resulted in less seeds, or fruit of reduced viability or quantity. Losses in populations of specialized pollinators have directly affected the reproductive ability of some rare plants.	**C11 Box 11.2**
Pest regulation	↑	↓	In many agricultural areas pest control provided by natural enemies has been replaced by the use of pesticides. Such pesticide use has itself degraded the capacity of agro-ecosystems to provide pest control. In other systems, pest control provided by natural enemies is being used and enhanced through integrated pest management.	**C11**
Natural hazard regulation	↑	↓	People are increasingly occupying regions and localities that are exposed to extreme events, thereby exacerbating human vulnerability to natural hazards. This trend, along with the decline in the capacity of ecosystems to buffer from extreme events, has led to continuing high loss of life globally and rapidly rising economic losses from natural disasters.	**C16**

Cultural Services				
Cultural diversity	*	*		
Spiritual and religious values	↑	↓	There has been a recent rapid decline in the numbers of sacred groves and other such protected areas. The loss of particular ecosystem attributes (sacred species or sacred forests), combined with social and economic changes, can sometimes weaken the spiritual benefits people obtain from ecosystems in many parts of the world. On the other hand, under some circumstances (e.g., where ecosystem attributes are causing significant threats to people) the loss of some attributes may enhance spiritual appreciation for what remains.	**C17.2.3.2**
Knowledge systems	*	*		
Educational values	*	*		
Inspiration	*	*		
Aesthetic values	↑	↓	The demand for aesthetically-pleasing natural landscapes has increased in accordance with increased urbanization. There has been a decline in quantity and quality of areas to meet this demand. A reduction in the availability of and access to natural areas for urban residents may have important detrimental effects on	**C17.2.5.3**

Service	Human Use[1]	Enhanced or Degraded[2]	Notes	MA Chapter source
			public health and economies.	
Social relations	*	*		
Sense of place	*	*		
Cultural heritage values	*	*		
Recreation and ecotourism	↑	+/-	The demand for recreational use of landscapes is increasing, and areas are increasingly being managed to cater for this use, to reflect changing cultural values and perceptions. However, many naturally occurring features of the landscape (e.g. coral reefs) have been degraded as resources for recreation.	**C17.2.6**

Supporting Services				
Soil formation	NA[1]	Not assessed		
Photosynthesis	NA	Not assessed		
Primary Production	NA	Not assessed		
Nutrient cycling	NA	**+/-**	There have been large-scale changes in nutrient cycles in recent decades, mainly due to additional inputs from agriculture, and biomass burning. Inland water and coastal systems have increasingly affected by eutrophication due to transfer of nutrients from terrestrial to aquatic systems. Although we have increased the amount of nutrients being cycled through ecosystems it is unclear whether the service itself has been enhanced or degraded globally.	**C12, S7**
Water Cycling	NA	**+/-**	Humans have made major changes to water cycles through structural changes to rivers, extraction of water from rivers, and more recently by changing climate. As with nutrient cycling, it is unclear whether the service of water cycling itself has been enhanced or degraded globally.	**C7**

* = Insufficient global information to allow a global assessment.

[1] NA indicates that the category does not apply. By definition, humans don't directly use supporting services.

Figure 2.1 Efficiency frontier analysis of species persistence and economic returns. The production possibility shows feasible combinations of species persistence and economic returns for a sample landscape based on the Willamette Basin in Oregon, USA. The figures show results for 97 terrestrial vertebrates found in the Basin and economic returns from agriculture and forestry production. Each land parcel can be put into a biological reserve, agriculture or forestry. The land-use pattern determines the value of economic returns from agriculture and forestry production and the pattern of habitat. For each species, persistence depends upon the extent and pattern of suitable habitat.

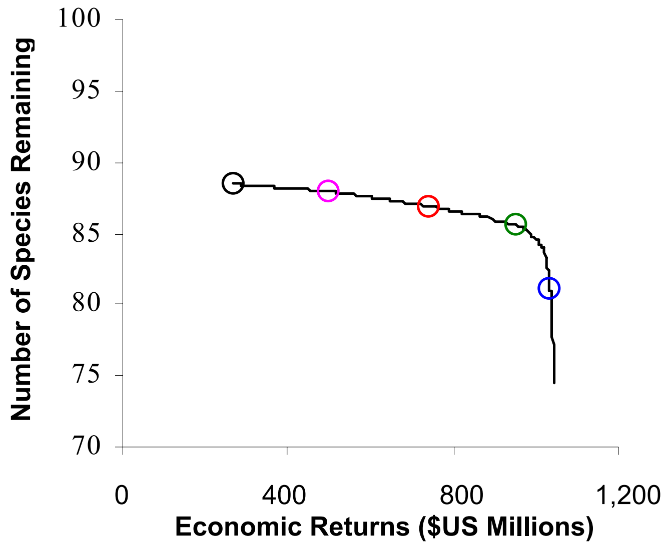


Figure 2.2. Where are the poor? Spatial distribution of the poor at various scales of aggregation in Ecuador. At the aggregate level, poverty shows up very clearly in eastern Ecuador while central Ecuador shows little evidence of poverty. However, if the data are disaggregated pockets of poverty appear even in Central Ecuador. Further disaggregation to the municipal level reveals high levels of poverty in particular municipalities.

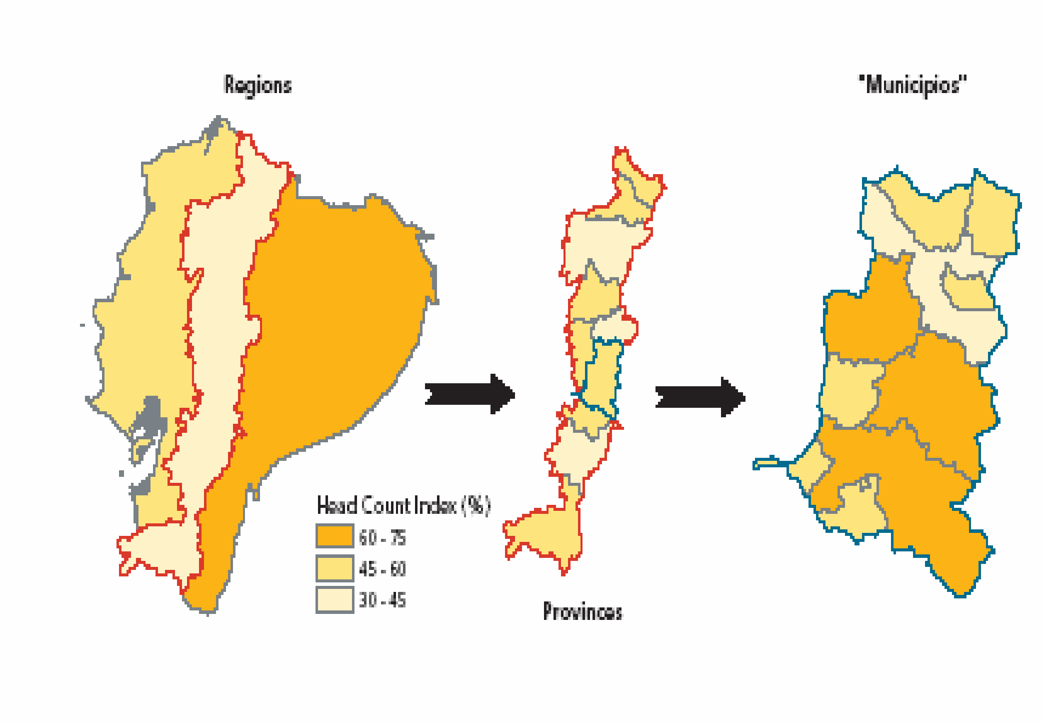


Table 2.1. Percentage of households that depended on the indigenous plant based coping mechanisms in the Kenya and Tanzania site. (C6 Table 6.4)

Activities that involve use of indigenous plants	Percentage of households, Kenya site	Percentage of households, Tanzania site
All use	94	94
Food use	69	54
Non-food use	40	42

3. What are the current trends and drivers of biodiversity loss?

Across the range of biodiversity measures, current rates of loss exceed those of the historical past by several orders of magnitude and show no indication of slowing.

Biodiversity is declining rapidly due to land use change, climate change, invasive species, over-exploitation, and pollution. These result from demographic, economic, sociopolitical, cultural, technological and other indirect drivers.

While these drivers vary in their importance among ecosystems and regions, current trends indicate a continuing loss of biodiversity.

3.1 Recent and Current Trends in Biodiversity

Across the range of biodiversity measures, current rates of change and loss exceed those of the historical past by several orders of magnitude and show no indication of slowing. At large scales, across biogeographic realms and ecosystems (biomes), declines in biodiversity are recorded in all parts of the habitable world. Among well-studied groups of species, extinction rates of organisms are high and increasing (medium certainty), and at local levels both populations and habitats are most commonly found to be in decline.

- **Virtually all of earth's ecosystems have now been dramatically transformed through human actions.** More land was converted to cropland since 1945 than in the 18th and 19th centuries combined. (C26.1.1). Between 1960 and 2000 reservoir storage capacity quadrupled (C7.2.4.1) and, as a result, the amount of water stored behind large dams is estimated to be 3 to 6 times the amount held by rivers (C7.3.2.1). Some 35 percent of mangroves have been lost in the last two decades in countries where adequate data are available (encompassing about half of the total mangrove area) (C19.2.1.2). Roughly one-quarter of the world's coral reefs were badly degraded or destroyed in the last several decades of the 20th century (C19.2.1.4). Although the most rapid changes in ecosystems are now taking place in developing countries, industrialized countries historically experienced comparable changes. Biomes with the highest rates of conversion in the last half of the 20th century were temperate, tropical and flooded grasslands and tropical dry forests (more than 14 percent lost between 1950 and 1990). Areas of particularly rapid change in terrestrial ecosystems over the past two decades include:

- the Amazon basin and Southeast Asia (deforestation and expansion of croplands)
- Asia (land degradation in drylands)
- Bangladesh, Indus Valley, parts of Middle East and Central Asia, the Great Lakes region of Eastern Africa, and the Great Plains region of the United States (expansion of croplands).

- **Habitat conversion to agricultural use has affected all biogeographical realms.** In all realms (except Oceania and Antarctica for which data shortages limit assessment), at least a quarter of the area had been converted to other land uses by 1950 (C4.5.4). By 1950 almost half of the natural habitat cover in the Indo-Malayan realm already been converted. In the 40 years from 1950 to 1990, habitat conversion has continued in nearly all biogeographic realms (Figure 3.1). The temperate northern realms of the Nearctic and Palearctic as well as the Neotropical realm have all had more than 10% of their land area converted to cultivation. They are currently extensively cultivated and urbanized; however, the amount of land under cultivation and pasture seems to have stabilized in the Nearctic with only small increases in the Palearctic in the last 40 years (Figure 3.1).The decrease in extensification of land under agricultural in these areas is counterbalanced by intensification of agricultural practices in order to ensure continued food production for expanding human populations. Within the tropics, rates of conversion to agriculture range from very high in the Indo Malayan realm to moderate in the Neotropics and the Afrotropics. Here, however, land cover change has not yet stabilized and shows large increases especially in cropland area since the 1950s. Australasia has relatively low levels of cultivation and urbanization but these have also increased in the last 40 years (Figure 3.1).

<<Figure 3.1>>

- **The majority of biomes have been greatly modified. Depending on the biome between 20% and 50% of nine of the fourteen global biomes have been transformed to croplands**. Tropical dry forests are the most impacted by cultivation, with almost half of the biome's native habitats replaced with cultivated lands. Three additional biomes (Temperate Grasslands, Temperate Broadleaf Forests, and Mediterranean Forests) have experienced 35% or more conversion. Biomes least impacted by cultivation, include deserts, boreal forests, and tundra. While cultivated lands provide many provisioning services (e.g., grains, fruits, meat), habitat conversion to agriculture typically leads to reductions in local native biodiversity even if global extinction has for most species has not yet occurred (C4.5.3).

- **Rates of human conversion among biomes have remained similar over at least the last century.** For example, Boreal Forests had lost very little native habitat cover up to 1950, and have lost only a small additional percentage since then. In contrast, the Temperate Grasslands biome had lost nearly 70% of its native cover by 1950 and has lost an additional 15.4% since then. Two biomes appear to be exceptions to this pattern: Mediterranean Forests and Temperate Broadleaf Forests (Figure 3.2). Both of these biomes had lost the majority of their native habitats by 1950, but since then have lost less than 2.5% additional habitat. These biomes contain many of the world's most established cities and most extensive surrounding agricultural development (e.g., Europe, the United States, the Mediterranean basin, China). It is possible that in these biomes the most suitable land for agriculture had already been converted by 1950.

<<Figure 3.2>>

- **Over the past few hundred years humans may have increased the species extinction rate by as much as three orders of magnitude.** This estimate is uncertain because: 1) The extent of extinctions of undescribed taxa is unknown; 2) The status of many described species is poorly known; 3) it is difficult to document the final disappearance of very rare species; and 4) there are extinction lags between the impact of a threatening process and the resulting extinction. However, the most definite information, based on recorded extinctions of known species over the past 100 years, indicates extinction rates are around 100 times greater than rates characteristic of species in the fossil record. Other less direct estimates, some of which refer extinctions hundreds of years into the future, estimate extinction rates 1000 to 10,000 times higher than rates recorded among fossil lineages (Figure 3.3).

<<Figure 3.3 Here>>

- **Between 12% and 52% of species within well-studied higher taxa are threatened with extinction according to the IUCN Red List.** Less than 10% of named species have been assessed in terms of their conservation status. Of those that have, birds have the lowest percentage of threatened species at 12% The patterns of threat are broadly similar for mammals and conifers, which have 23% and 25% of species threatened, respectively. The situation with amphibians looks similar, with 32% threatened, but information is more limited so this may be an under-estimate. Cycads have a much higher proportion of threatened species with 52% globally threatened. In regional assessments, taxonomic groups with the highest proportion of threatened species tended to be those that rely on freshwater habitats (C4.4). Threatened species show continuing declines in conservation status, and species threat rates tend to be highest in the realms with highest species richness (Figure 3.4) (C4.4).

<<Figure 3.4>>

- **Threatened vertebrates are most numerous in the biomes with intermediate levels of habitat conversion.** Low diversity biomes (such as Boreal Forest and Tundra) have low species richness and low threat rates, and have experienced little conversion. Very highly converted habitats in the temperate zone had lower richness than tropical biomes, and many species vulnerable to conversion may have gone extinct already. It is in the high diversity, moderately converted tropical biomes that the greatest number of threatened vertebrates are found (Figure 3.5) (C4.5)

<<Figure 3.5>>

- **Among a range of higher taxa, the majority of species are currently in decline**. Studies of amphibians globally, African mammals, birds in agricultural lands, British butterflies, Caribbean Corals, waterbirds, and fishery species show the majority of species to be declining in range or number. Increasing trends in species can almost always be attributed to management interventions such as protection in reserves, or elimination of threats such as over-exploitation, or are species that tend to thrive in human dominated landscapes. (C4.5.1 Biodiversity). An aggregate indicator of trends in species populations Living Planet Index (LPI) uses published data on trends in natural populations of a variety of wild species to identify overall trends in species abundance. Although more balanced sampling would enhance its reliability, the trends are all declining, at the highest rate in freshwater habitats (Figure 3.6)

<<Figure 3.6>>

- **Genetic diversity has declined globally, particularly among cultivated species**. In cultivated systems, since 1960 there has been a fundamental shift in the pattern of intra-species diversity in farmer's fields and farming systems as a result of the "Green Revolution." Intensification of agricultural systems coupled with specialization by plant breeders and the harmonizing effects of globalization, has led to a substantial reduction in the genetic diversity of domesticated plants and animals in agricultural systems. The on-farm losses of genetic diversity of crops have been partially offset by the maintenance of genetic diversity in seedbanks. In addition to cultivated systems, the extinction of species and loss of unique populations that has taken place has resulted in the loss of unique genetic diversity contained by those species and populations.

Globally, the net rate of conversion of some ecosystems has begun to slow, and in some regions ecosystems are returning to more natural states largely due to reductions in the rate of expansion of cultivated land, though in some instances such trends reflect the fact that little habitat remains for further conversion. Generally, opportunities for further expansion of cultivation are diminishing in many regions of the world as the finite proportion of land suitable for intensive agriculture continues to decline. (C26ES) Increased agricultural productivity is also diminishing pressures for agricultural expansion. Since 1950, cropland areas in North America, Europe and China have stabilized, and even decreased in Europe and China. (C26.1.1) Cropland areas in the Former Soviet Union have decreased since 1960. (C26.1.1). Within temperate and boreal zones, forest cover increased by approximately 3 million hectares per year in the 1990s, although approximately half of this increase consists of forest plantations (C21.2.5).

Translating biodiversity loss between different measures is not simple: rates of change in one biodiversity measure may underestimate or overestimate rates of change in another. The scaling of biodiversity between measures in not simple, and this is especially significant in the relationship between habitat area and species richness. Loss of habitat initially leads to less species loss than might be expected, but, depending on how much habitat remains, rates of loss of habitat can underestimate rates of loss of species.

Homogenization, defined as the process whereby species assemblages become increasingly dominated by a small number of widespread, human-adapted species, represents further losses in biodiversity that are often missed when only considering changes in absolute numbers of species. Human activities have both negative and positive impacts on animals and plants. The many species that are declining as a result of human activities tend to be replaced by a much smaller number of expanding species that thrive in human-altered environments. The outcome is a more homogenized biosphere with lower diversity at regional and global scales. One effect is that in some regions where diversity has been low because of isolation, the biotic diversity may actually increase – a result of invasions of non-native forms (this is true in continental areas such as the Netherlands as well as on oceanic islands). Recent data also indicate that the many losers and few winners tend to be non-randomly distributed among higher taxa and ecological groups, enhancing homogenization (C4.5).

While biodiversity loss has been a natural part of the history of the Earth's biota, it has always been countered by origination and, except for rare events, has occurred at extremely slow rates. Currently, however, loss far exceeds origination and rates are orders of magnitude higher than they have ever been in the past. Recall that biodiversity loss is not just global extinction, such as that faced by many threatened and endangered species, but declines in genetic, ecosystem, and landscape diversity are considered biodiversity loss as well. Even if every native species were retained in an ecological preserve, if the majority of the landscape has been converted to high intensity monoculture cropland systems, then biodiversity has declined significantly. Landscape homogenization is linked to biotic homogenization.

The patterns of threat and extinction are not evenly distributed amongst species but tend to be concentrated in particular ecological or taxonomic groups. Ecological traits shared by species facing high extinction risk include high trophic level, low population density, slow life history/low fecundity, and small geographical range size (C4.5). The degree of extinction risk also tends to be similar among related species, leading to the likelihood that entire evolutionary radiations can and have been lost. The majority of recorded species extinctions since 1500 AD have occurred on islands. However, predictions of increasing numbers of future extinctions suggest a significant shift from island to continental areas.

3.2 Drivers of Biodiversity Change and Their Trends

Biodiversity change is caused by a range of direct and indirect drivers. A driver is any natural or human-induced factor that *directly* or *indirectly* causes a change in an ecosystem. A *direct* driver unequivocally influences ecosystem processes. An *indirect* driver operates more diffusely, by altering one or more direct drivers. MA categories of indirect drivers of change are demographic, economic, socio-political, scientific and technological, and cultural and religious. Important direct drivers affecting biodiversity are habitat change, climate change, invasive species, overexploitation and pollution. (CF4)

No single measure or indicator represents the totality of the various drivers. Some direct drivers of change have relatively straightforward indicators, such as fertilizer usage, water consumption, irrigation, and harvests. Indicators for other drivers, including invasion by non-native species, climate change, land cover conversion, and landscape fragmentation are not as well-developed and data to measure them are not as readily available.

Changes in biodiversity and in ecosystems are almost always caused by multiple, interacting drivers. Changes are driven by combinations of drivers that work over time (e.g., population and income growth interacting with technological advances that lead to climate change), over level of organization (e.g., local zoning laws versus international environmental treaties) and that happen intermittently (e.g., droughts, wars, and economic crises). Changes in ecosystem services feed back to the drivers of changes. Reviews of case studies of deforestation and desertification reveal that the most common type of interaction is synergetic factor combinations - combined effects of multiple drivers that are amplified by reciprocal action and feedbacks. (S7.4)

Drivers interact across spatial, temporal, and organizational scales. Global trends like climate change or globalization can influence regional contexts. For example, a study in South Africa found that changes in export prices of cash crops can trigger land-use changes on the local level, and removal of national credits and subsidies can make some farmers more vulnerable to environmental changes while others profit from easier access to markets and are less vulnerable to climate change (S7.4).

Any specific ecosystem change is driven by a network of interactions among different drivers. Though some of the elements of these networks are global, the actual set of interactions that brings about an ecosystem change is more or less specific to a particular place. For example, a link between increasing producer prices and the extension of production can be found in many places throughout the world. The strength of this effect, however, is determined by a range of location-specific factors including production conditions, the availability of resources and knowledge and the economic situation of the farmer (Scenarios 7.4 Drivers). No single conceptual framework exists which captures the broad range of case study evidence about the interactions among drivers. Based on the findings of the sub-global assessments of the MA and recent literature, some examples of causal linkages for ecosystem change can be given (See Box 3.1, Box 3.2) (SG-Portugal, SG-SAfMA; C6.5).

3.2.1 *Indirect Drivers*

Biodiversity change is most clearly a consequence of the direct drivers. However, these reflect changes in indirect drivers. There are five categories of the root causes of changes in ecosystems: change in economic activity, population change, socio-political factors, cultural factors, and technological change.

- Global economic activity increased nearly 7-fold between 1950 and 2000 (S7, SG6 Table 6.1), and in the MA scenarios, is projected to grow by a factor of 1.9 to 4.4 by 2050. The many processes of globalization have amplified some driving forces of changes in ecosystem services and attenuated other forces by removing regional barriers, weakening national connections, and increasing the interdependency among people and between nations.
- Global population doubled in the past forty years, reaching 6 billion in 2000 (S7.2.1.2), and is projected to grow to between 8.1 and 9.6 billion by 2050 depending on the scenario. Urbanization influences consumption, generally increasing the demand for food and energy and thereby increasing pressures on ecosystems globally, but the same demographic and economic growth would have had an even bigger impact on biodiversity if the same people, with similar consumption and production patterns, were dispersed over the rural landscape.
- Over the past fifty years, there have been significant changes in sociopolitical drivers, including a declining trend in centralized authoritarian governments and a

rise in elected democracies which allows for new forms of management of environmental resources.

- Culture conditions individuals' perceptions of the world, and, by influencing what they consider important, has implications for conservation and consumer preferences, and suggests courses of action that are appropriate and inappropriate.
- The development and diffusion of scientific knowledge and technologies can, on the one hand allow for increased efficiency in resource use, and on the other hand it can provide the means to increase exploitation of resources.

3.2.2 *Direct Drivers*

Direct drivers vary in their importance within and among systems, and in the extent to which they are increasing in their impact. Historically, habitat and land use change have had the biggest impact on biodiversity across biomes. Now, climate change is projected to affect all aspects of biodiversity from individual organisms, through populations and species, to ecosystem composition and function with increasing impacts over the next century especially affecting some biomes. Pollution, especially the deposition of Nitrogen and Phosphorus, but also including the impact of other contaminants, is expected to have an increasing impact leading to declining biodiversity across biomes (Figure 3.7).

<<Insert Figure 3.7>>

For terrestrial ecosystems, the most important direct driver of change in the past fifty years has been land cover change (C7, SG7). Only biomes relatively unsuited to crop plants, such as deserts, boreal forests, and tundra are relatively intact. (C4) Deforestation and forest degradation affect 8.5% of the world's remaining forests, nearly half of which are in South America. Deforestation and forest degradation seem more extensive in the tropics than in the rest of the world but data on boreal forests are especially limited. Approximately 10 – 20% of drylands are considered degraded with the majority of these areas in Asia. Cropped areas cover 30% of the earth's surface. In the 20 year period after the early 1980s, 6.4% of these areas experienced major increase in cropping while 9.5% experienced major crop area decline. (S7) A study of the southern African biota shows how degradation of habitats led to loss of biodiversity across all taxa (Figure 3.8)

<<Insert Figure 3.8>>

Cropland covered 30 percent of the earth's surface in 1990. The exact proportion was between 12 and 14 percent depending on whether Antarctica and Greenland are included. Around 40 percent of the cropland was located in Asia; Europe accounts for 16 percent and Africa, North America and South America each accounted for 13 percent. The main areas of recent cropland increase are located in South and Southeast Asia, parts of the Middle East and Central Asia, in the region of the Great Lakes of eastern Africa, and along the southern border of the Amazon Basin in Latin America. North America accounts for most of the main areas of decrease in cropland (lowlands of south eastern United States), followed by Asia (eastern part of China) and South America (parts of Brazil and Argentina). (Figure 3.9; S7)

<<Insert Figure 3.9>>

For marine ecosystems, the most important direct drivers of change in the past fifty years, in the aggregate, has been fishing. Fishing is the major direct anthropogenic force impacting the structure, function and biodiversity of the oceans. (C18) Fishing pressure is so strong in some marine systems that the biomass of both targeted species, especially larger fishes, and those caught incidentally (the 'by-catch') has been reduced in much of the world by one or more orders of magnitudes relative to levels prior to the onset of industrial fishing, with a number of targeted stocks in all oceans collapsed, overfished or fished at their maximum sustainable levels. Recent studies have demonstrated that global fisheries landings peaked in the late 1980s and are now declining despite increasing effort and fishing power with little evidence of this trend reversing under current practices. In addition to the landings, the average trophic level of global landings is declining which implies that we are increasingly relying on fish that originate from the lower part of marine food webs. (Figure 3.10)

<<Insert Figure 3.10>>

For freshwater ecosystems, depending on the region, the most important direct drivers of change in the past fifty years include physical changes, modification water regimes, invasive species, and pollution. The loss of wetlands worldwide has been broadly estimated at 50% of those that existed in 1990, however, the accuracy of this figure has not been established due to an absence of reliable data. (C20.5.1) Massive changes have been made in water regimes: In Asia, 78% of the total reservoir volume was constructed in the last decade, and in South America almost 60% of all reservoirs have been built since the 1980s (C20.5.2). Water withdrawals from rivers and lakes for irrigation or urban or industrial use doubled between 1960 and 2000 (C7.3.3). Globally, humans now use roughly 10% of the available renewable freshwater supply, although in some regions such as the Middle East and North Africa, humans use 120% of renewable supplies (the excess is obtained through the mining of groundwater). (C7.3.2.1) The introduction of non-native invasive species is now considered to be a major cause of species extinction in freshwater systems. It is well established that the increased discharge of nutrients cause intensive eutrophication and potentially high levels of nitrate in drinking water and has long been recognized as a problem for water supply. It has also been well established for many years that pollution from point sources such as mining has had devastating impacts on the biota of inland waters.

Apparently stable areas of habitat may suffer from fragmentation leading to significant impacts on their biodiversity. Fragmentation is caused by natural disturbance (e.g., fires, wind) or by land use change and habitat loss, e.g. the clearing of natural vegetation for agriculture or road construction, which leads previously continuous habitats to become divided. Larger remnants, and remnants which are close to other remnants, are less affected by the fragmentation process. Small fragments of habitat can only support small species populations, which tend to be vulnerable to extinction. Moreover, small fragments of habitat may have altered interior habitat. Habitat along the edge of a fragment has a different climate and favors different species to the interior. Small fragments are therefore unfavorable for those species, which require interior habitat and may lead to the extinction of those species. Species, which are specialized to particular habitats, and species, whose dispersal ability is weak, suffer from fragmentation more than generalist species with good dispersal ability. Fragmentation affects all biomes, including in particular forests (Figure 3.11) and major freshwater systems (Figure 3.12).

<<Insert Figure 3.11>>

<<Insert Figure 3.12>>

Invasive alien species have been a major cause of extinction, especially on islands and in freshwater habitats, and continues to be a problem in many areas of the world. In fresh water habitats, the introduction of alien species is the second leading cause of species extinction, and on islands it is tied with habitat destruction as the lead cause of extinction over the past 20 years. Awareness about the importance of stemming the tide of invasive alien species is increasing, but effective implementation of preventative measures are lacking The rate of introductions continues to be extremely high, for example, in New Zealand plant introductions alone have occurred at a rate of 11 species per year since European settlement in 1840 (C4).

Over-exploitation remains a serious threat to many species and populations. Among the most commonly over-exploited species or groups of species, are marine fish (Figure 3.8) and invertebrates, trees, and animals hunted for meat. Most industrial fisheries are either fully or over-exploited. Many of the current concerns with over-exploitation of bushmeat, wild meat taken from the forests by local people for income or subsistence, are similar to those of fisheries, where sustainable levels of exploitation remain poorly understood, and where the offtake is difficult to manage effectively. Although the true extent of exploitations is poorly known, it is clear that rates of offtake are extremely high in the tropical forest throughout the world. The trade in wild plants and animals and their derivatives is poorly documented, but is estimated at nearly $US160 billion. It ranges from live animals for the food and pet trade to ornamental plants and timber. Because the trade in wild animals and plants crosses borders between countries, the effort to regulate it requires international cooperation to safeguard certain species from over-exploitation.

Over the past four decades, nutrient loading has emerged as one of the most important drivers of ecosystem change in terrestrial, freshwater, and marine ecosystems. While the introduction of nutrients into ecosystems can have both beneficial and adverse effects, as greater quantities of nutrients are introduced the adverse effects predominate. Synthetic production of nitrogen fertilizer has been the key driver for the remarkable increase in food production that has occurred during the past 50 years (Figure 3.13A) (S7.3). The total amount of reactive, or biologically available, nitrogen created by human activities increased 9-fold between 1890 and 1990, with most of that increase taking place in the second half of the century in association with increased use of fertilizers (C4.3.3.1). More than half of all the synthetic nitrogen fertilizer ever used on the planet has been used since 1985 (R9.2). Humans now produce more reactive nitrogen than is produced by all natural pathways combined (R9ES). Nitrogen application has increased five-fold since 1960, but 50% of the nitrogen fertilizer applied is often lost to the environment. Phosphorus application has increased three-fold since 1960, with steady increase until 1990, followed by leveling off at a level approximately equal to 1980's applications (Figure 3.13B). These changes are mirrored by P accumulation in soils, which can serve as an indicator of eutrophication potential for freshwater lakes and P-sensitive estuaries. Potential consequences include eutrophication of freshwater ecosystems, hypoxia in coastal marine ecosystems, nitrous oxide emissions contributing to global climate change, and air pollution by NO_x in urban areas. Occurrence of such problems varies widely in different world regions (Figure 3.14). (S7.3).

<<*Insert Figure 3.13*>>

<<*Insert Figure 3.14*>>

Climate change in the past century has already had a measurable impact on biodiversity. The Earth's climate system has changed since the pre-industrial era, in part due to human activities, and is projected to continue to change throughout the 21st century (Figure 3.15). During the last 100 years, the global mean surface temperature has increased by about 0.6C, faster than at any time in the past 10,000 years. Precipitation patterns have changed spatially and temporally, and global average sea level rose between 0.1 and 0.2 meters (S7-ES). Observed changes in climate, especially warmer regional temperatures, have already affected biological systems in many parts of the world. There have been changes in species distributions, population sizes, the timing of reproduction or migration events, and an increase in the frequency of pest and disease outbreaks, especially in forested systems. Many coral reefs have undergone major, although often partially reversible, bleaching episodes, when sea surface temperatures have increased by 1^{o}C during a single season, with extensive mortality occurring with observed increases in temperature of 3^{o}C. A recent paper, using the climate envelope/species-area technique, estimated that the projected changes in climate by 2050 could lead to an eventual extinction of 15-52% of the sub-set of 1103 endemic species (mammals, birds, frogs, reptiles, butterflies and plants) analyzed (R13.1.3). While the growing season in Europe has lengthened over the last 30 years, in some regions of Africa the combination of regional climate changes and anthropogenic stresses has led to decreased cereal crop production since 1970. Changes in fish populations have been linked to large scale climate oscillations, e.g., El-Niño events have impacted fisheries off the coasts of South America and Africa, and decadal oscillations in the Pacific have impacted fisheries off of the west coast of North America (R13.1.3).

<<*Insert Figure 3.15*>>

Present-day threats are often multiple and of greater intensity than historical threats which can have far more significant impacts on biodiversity than has occurred in the past. The susceptibility of an ecological community to a given threat will depend on the "extinction filters" that have occurred in the past, or what past drivers have shaped our current biota. If the present-day threats are novel, they will have dramatic effects on populations and species that lack adaptations to such novel threats. Even if some drivers are similar in nature to past drivers (e.g., climate has always varied), in many cases the intensity of current-day drivers are unprecedented (e.g., the rate of climate change far exceeds recorded rates of climate change). Further, current-day drivers of extinction are often multiple (e.g., land use change, emerging disease, invasive species, are all co-occurring). Because exposure to one threat type often makes a species more susceptible to a second, exposure to a second makes a species more susceptible to a third, and so on, consecutive, multiple threats to species may have quite dramatic impacts on biodiversity.

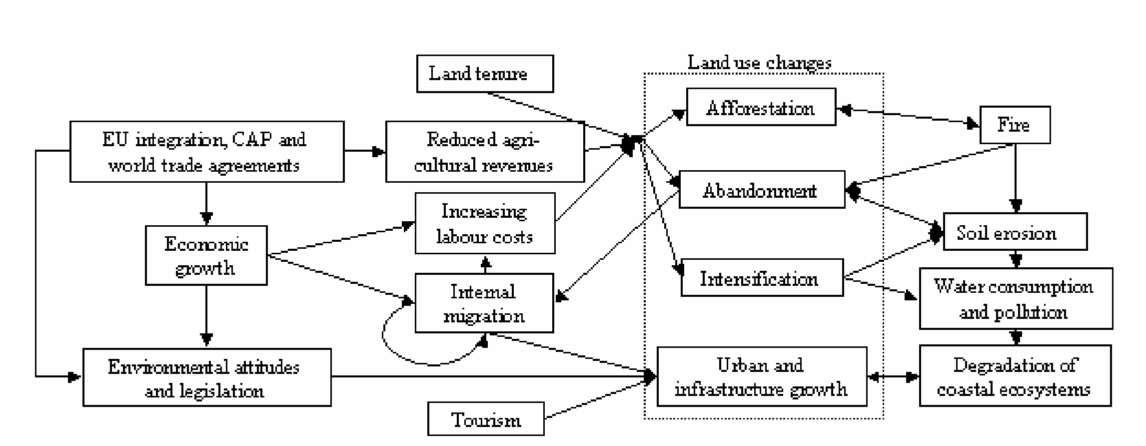
Each driver has a spatial and temporal scale over which it changes and over which it has an effect on ecosystem services and human well-being. Climate change may operate on a spatial scale of a large region; political change may operate at the scale of a nation or a municipal district. Social-cultural change typically occurs slowly, on a time scale of decades, while economic forces tend to occur more rapidly. Because of the variability in ecosystems, their services and human well-being in space and time, there may be mismatches or lags between the scale of the driver and the scale of its effects on ecosystem services (SG6.3.2, SG6.3.5).

For the species and habitats that show continuing decline rates of future decline depend upon sources of inertia, and the time lag between a management intervention and the response. Natural sources of inertia correspond to the timescales inherent to natural systems; for example, recovery of a population cannot proceed more quickly than the average turnover or generation time, and established recovery will often take several generations. On top of this is anthropogenic inertia, resulting from the time scales inherent in human institutions for decision-making and implementation. For most systems these two sources of inertia will lead to delays of years, and more often decades, in slowing and reversing a declining biodiversity trend. This analysis assumes that the drivers of change could indeed be halted or reversed in the near term, yet currently, there is little evidence that any of the direct or indirect drivers are slowing, or that any are well-controlled at large to global scale. Most significantly, other indications are that time lags may mean we have yet to see the consequences of some of the changes in the past.

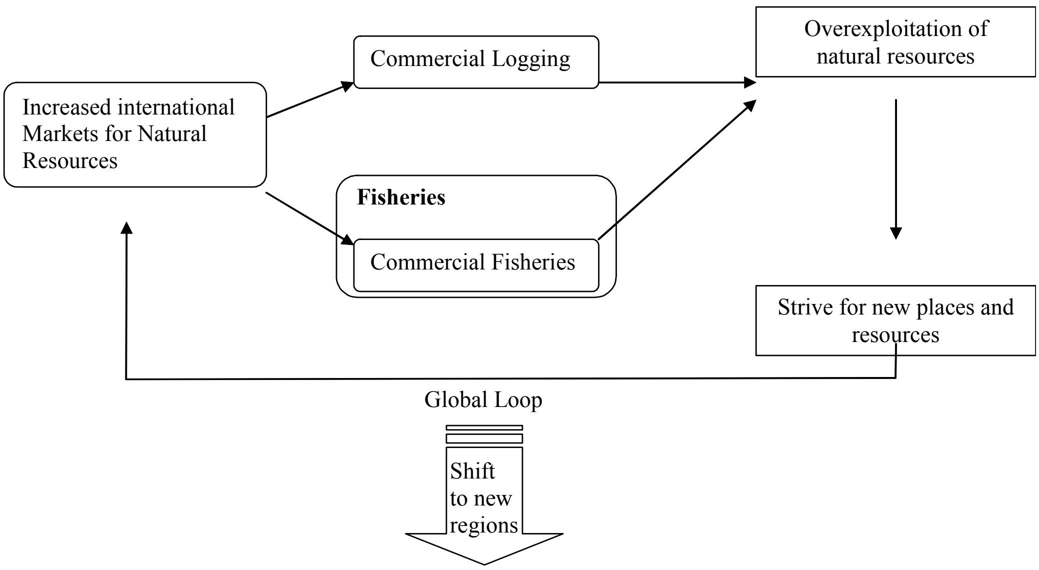
The delay between a driver impacting a system and its consequences for biodiversity change can be highly variable. In the case of species extinctions this process has been well studied, and habitat loss shown to be a driver where the lag times most often will be longest. In studies of tropical forest bird species the time from habitat fragmentation to species extinction has been estimated to have a half-life of approximately decades to hundreds of years. Overall, these results suggest that about half of the species losses may occur over a period of 100 to 1000 years. Therefore, humans have the opportunity to deploy active habitat restoration practices that may rescue some of the species that otherwise would have been in a trajectory towards extinction. Notwithstanding, habitat restoration measures will not be likely to save the most sensitive species that will go extinct soon after habitat loss (C4.5).

Box 3.1: Interactions between Indirect and Direct drivers revealed in sub-global assessments

a) Illustration of feedbacks and interaction between drives in Portugal Millennium Ecosystem Assessment (MA-Portugal).



b) Summary of interactions among drivers associated with the over-exploitation of natural resources (SG6.5.3.)



Box 3.2 Direct Drivers: Example from Sub-global Assessments

The direct drivers of biodiversity loss in southern Africa include the impacts of land use change, of alien invasives, overgrazing, and overharvesting, all of which have already had a large impact on the region's biodiversity, its ecosystem services, and human well-being, and these are likely to spread in the absence of interventions.

The dominant direct driver of ecosystem change in southern Africa is considered to be widespread land use change that, in some cases, has led to degradation. Forests and woodlands are being converted to croplands and pastures at a rate somewhat slower than those in south-east Asia and the Amazon during the 1990s, but nevertheless sufficient to endanger ecosystem services at a local scale. Half of the region consists of drylands, where overgrazing is the main cause of desertification. In the timeframe of the first half of the 21st century, climate change is a real threat to water supplies, human health, and biodiversity in southern Africa. These threats, however, also arise partly because the projected warming may, over large areas, be accompanied by a drying trend, and partly because of the low state of human welfare and weak governance that increases vulnerability of humans to climate change. Although some of these threats have slowed in some regions (e.g., afforestation in South Africa has decreased), same have accelerated elsewhere (e.g., afforestation in Mozambique has increased). Thus, the region's biodiversity remains vulnerable to land use change. In addition, the more subtle threat of land degradation is considered a bigger threat in the region.

In addition to these direct drivers that have already had known impacts, climate change poses additional serious threats to the regions biodiversity and human well-being. Several studies indicated that the biodiversity of southern Africa is at risk. There is now evidence, for example, that *Aloe dichotoma* is declining in the northern part of its range, but stable in the southern part, as predicted by the global change models. In addition there is experimental evidence that the recorded expansion of woody invasions into grasslands and savannas may be driven by rising global CO2 concentrations. The ability of species to disperse and survive these pressures will be hampered by a fragmented landscape made inhospitable by human activities. The AIACC project is currently analyzing response options that may conserve biodiversity under future climate and land cover scenarios in southern Africa. (SG-SAfMA)

Figure 3.1: Percentage change (1950-1990) in land area of biogeographic realms remaining in natural condition or under cultivation and pasture. Two biogeographic realms are omitted due to lack of data: Oceania and Antarctic**.**

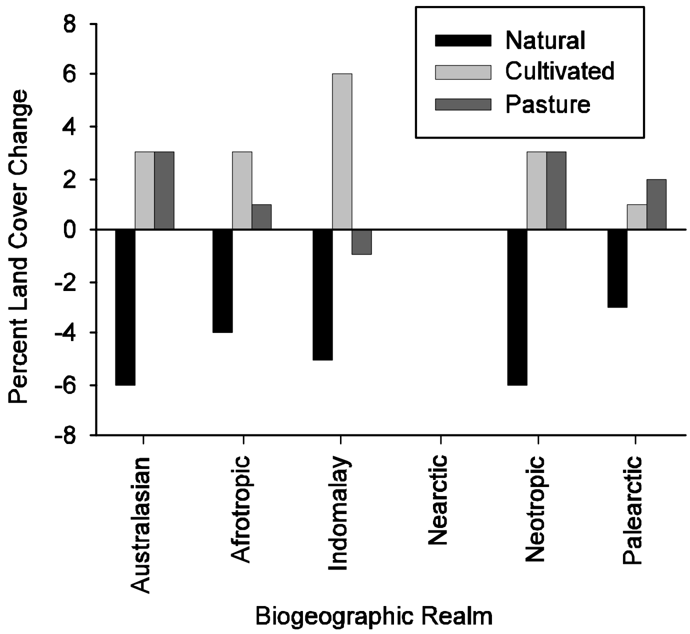


Figure 3.2: Relationship between native habitat loss by 1950 and additional losses between 1950 and 1990. Biome codes as in Figure 1.3.

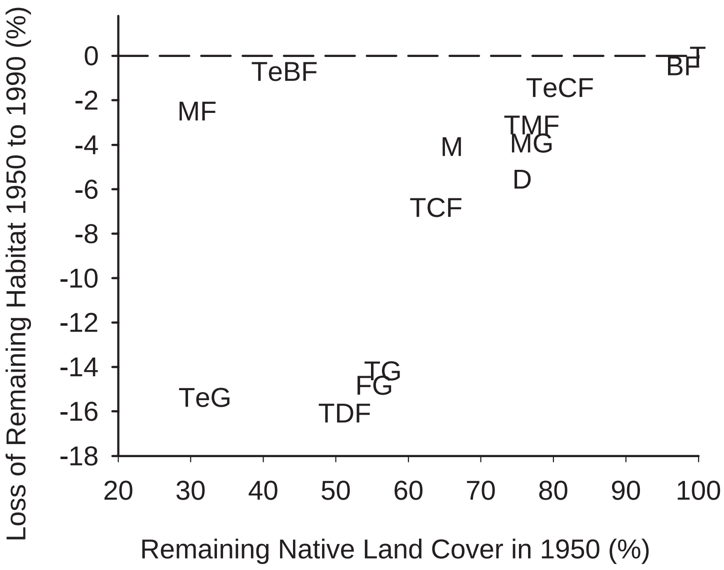
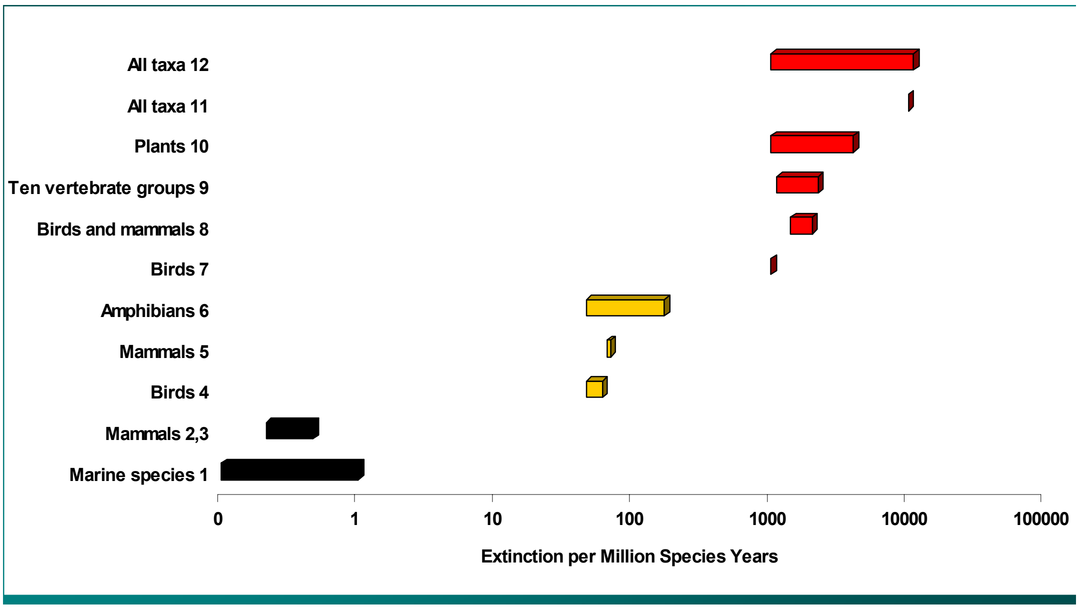


Figure 3.3. Background and contemporary extinction rates. Background extinction rates are in black, extinction rates based on observed extinctions are in yellow and estimated contemporary extinctions using a number of different approaches are in red.



Based on: Background extinction rates from the fossil record; May (1995)1, Alroy (1998)2 (lower estimate of 0.21), Foote (1997)3 (higher estimate of 0.46). Observed extinctions; Baillie et al. (2004)4,5,6. Projections based on threatened species; Pimm & Brooks (1997)7, Smith et al. (1993)8 (also uses recently extinct species), Mace (1994)9. Plant extinctions using species-area curve with assumptions about habitat loss from agricultural/urban expansion and from climate change; Scenarios Chapter X10. Increased energy consumption; Ehrlich (1994)11. Species-area relationship from deforestation rates; four studies in Reid (1992)12.

Figure 3.4 (a) Red List Indices for birds for 1988–2004 in different biogeographic realms. (Not currently in MA) (Butchart et al 2005). (b) Density Distribution Map of Globally Threatened Bird (n=1,213) Species Mapped at a Resolution of ¼ Degree Grid Cell. Dark orange colours correspond to higher richness, dark blue to lowest.

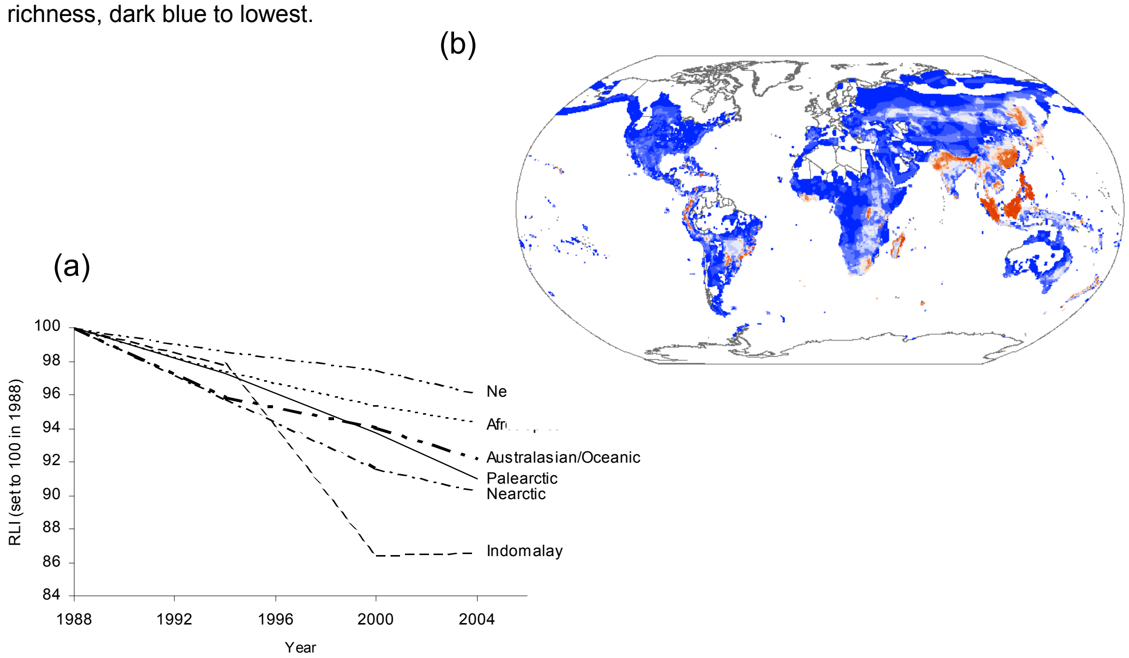


Figure 3.5 The number of threatened vertebrates in the 14 biomes, shown ranked by the amount of their habitat converted by 1950.

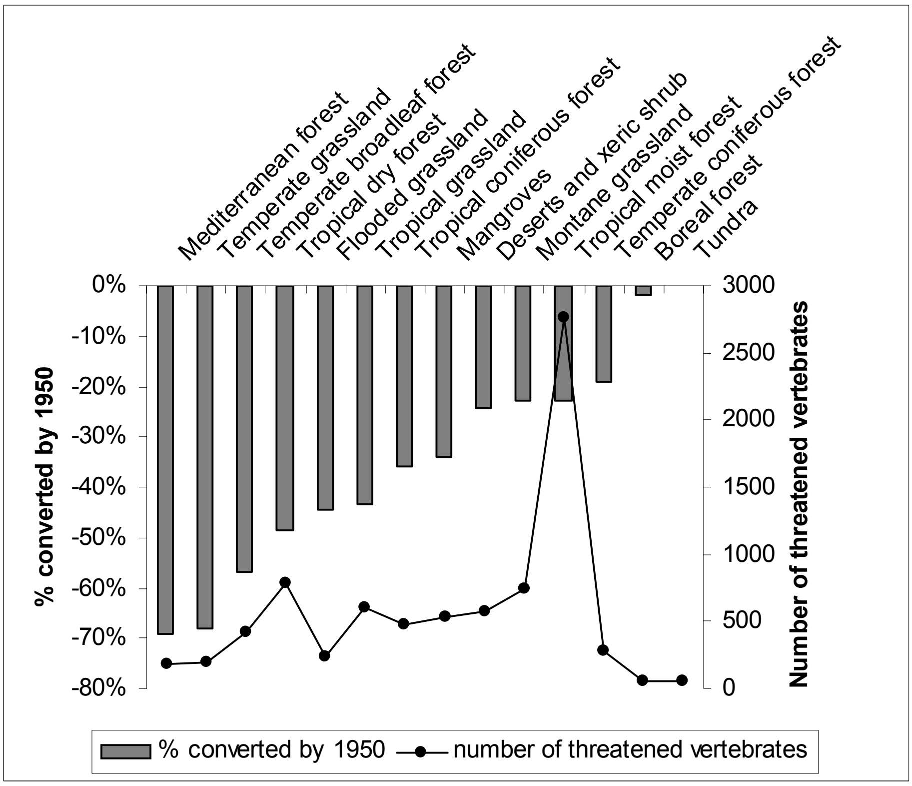


Figure 3.5 The Living Planet Index 2004 shows that the index fell by about 40% between 1970 and 2000. The LPI currently incorporates data on the abundance of 555 terrestrial species, 323 freshwater species, and 267 marine species around the world. While the LPI fell by some 40% between 1970 and 2000, the terrestrial index fell by about 30%, the freshwater index by about 50%, and the marine index by around 30% over the same period.

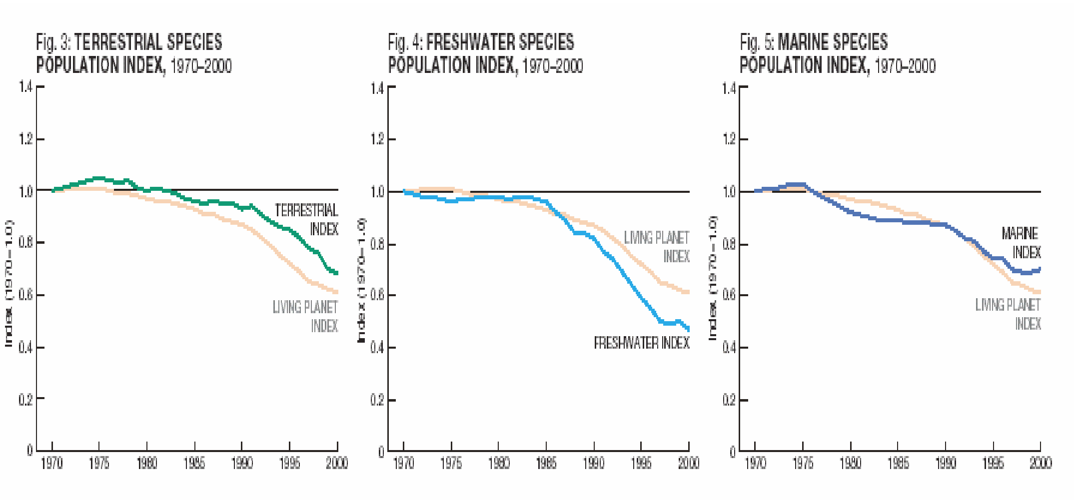


Figure 3.7 Main direct drivers for biomes /MA systems. The cell colour indicates the current and to date impact of each driver on biodiversity in each biome, over the past 50 to 100 years. The arrows indicate the trend in the impact of the driver on biodiversity. Horizontal arrows indicate stabilisation of the impact, diagonal and vertical arrows indicate progressively stronger increasing trends in impact.

BIOME		MAIN DRIVERS OF BIODIVERSITY CHANGE				
		Habitat change	**Climate Change**	**Invasive species**	**Over-exploitation**	**Pollution (N, P especially)**
Forest	Boreal	↗	↑	↗	→	↑
	Temperate	↘	↑	↑	→	↑
	Tropical	↑	↑	↑	↗	↑
Dryland	Temperate grassland	↗	↑	→	→	↑
	Mediterranean	↗	↑	↑	→	↑
	Tropical grassland & savannah	↗	↑	↑	→	↑
	Desert	→	↑	→	→	↑
Inland Water		↑	↑	↑	→	↑
Coastal		↗	↑	↗	↗	↑
Marine		↑	↑	→	↗	↑
Island		→	↑	→	→	↑
Mountain		→	↑	→	→	↑
Polar		↗	↑	→	↗	↑

Low impact of driver
Moderate impact of driver
High impact of driver
Very high impact of driver

Figure 3.8 The effect of increasing land use intensity on the fraction of the inferred original population (300 years ago: pre-colonial) of different taxa that remains. The x-axis percentages refer to the percentage of southern Africa under the respective land uses (see SAfMA). Human landscape modifications can also lead to increases of populations under conditions of light use (see amphibians).

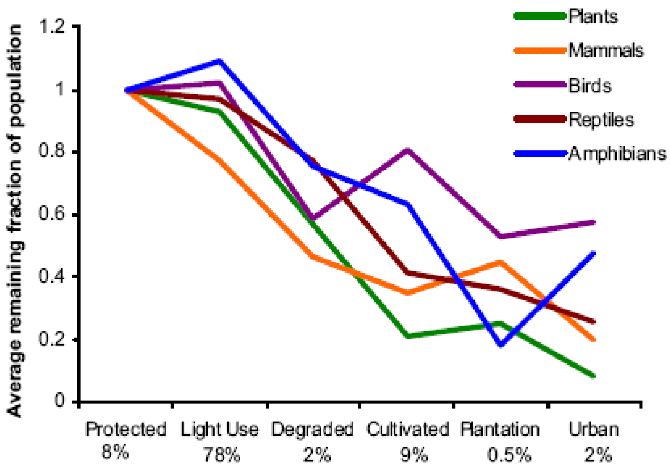


Figure 3.9. Main areas of change in cropland extent for the period 1980 to 1990. (C28 Fig3)

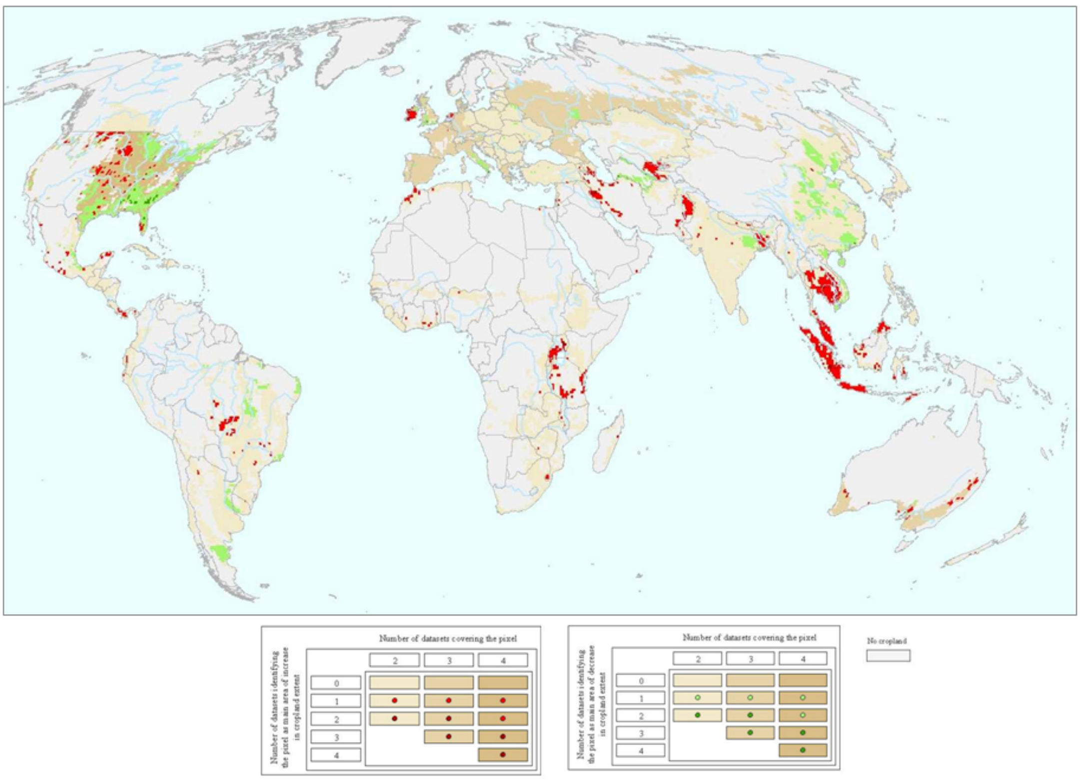


Figure 3.10 Impact of fisheries. (a) Tropic Level Change (1950–2000)reflecting the impact of fisheries on marine species assemblages.) (b) Estimated Global Fish Catches (1950–2001) by Target Group (Upper) and by Biome (Lower) with adjustment for over-reporting. Note a third graph of the total landings. adjusted and not adjusted for China (C18 Marine)

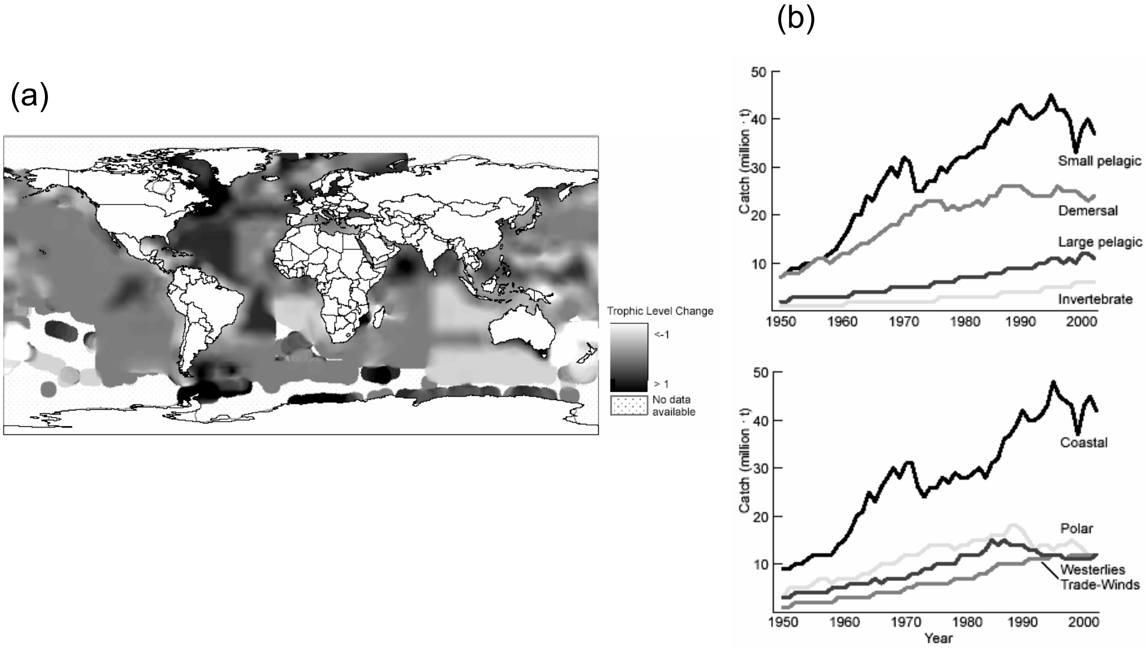


Figure 3.11. Estimates of forest fragmentation due to anthropogenic causes.

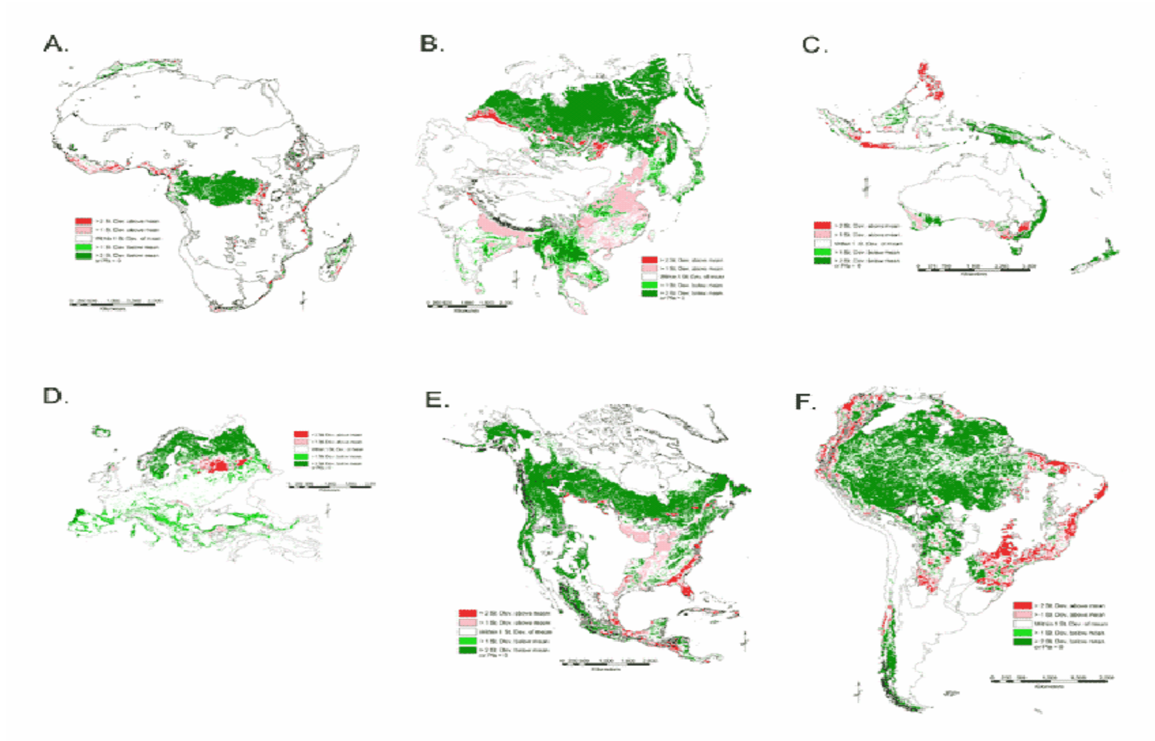


Figure 3.12 Fragmentation and flow in major rivers. From C20 Inland waters

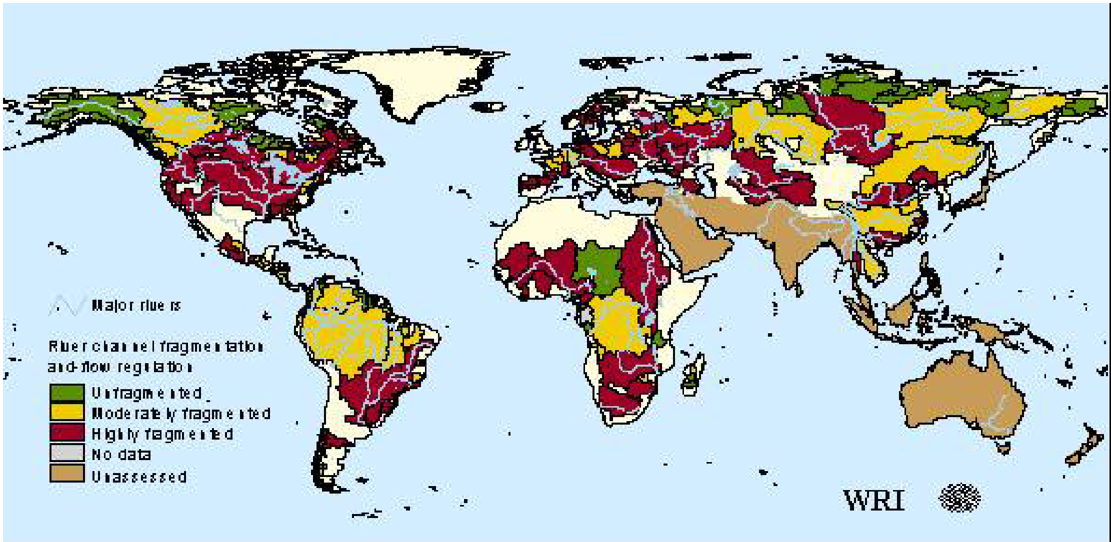


Figure 3.13 (a) Trends in global consumption of N fertilizer, Mt N, 1961-2001
(b) World phosphate fertilizer consumption, Mt P2O5, 1961-2000. (S7 Drivers)

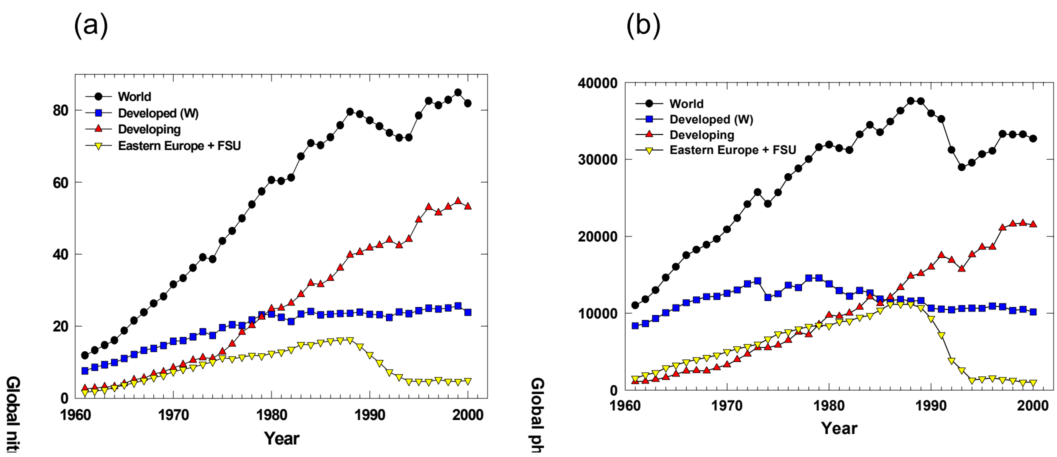


Figure 3.14 Global Nitrogen deposition based on biogeochemical modeling. Spatial patterns of total inorganic nitrogen deposition in (a) 1860, (b) early-1990s and c) 2050, mg N m-2 yr-1.

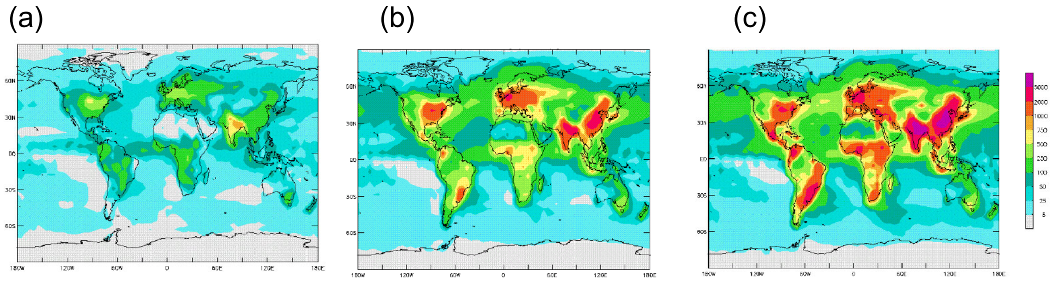
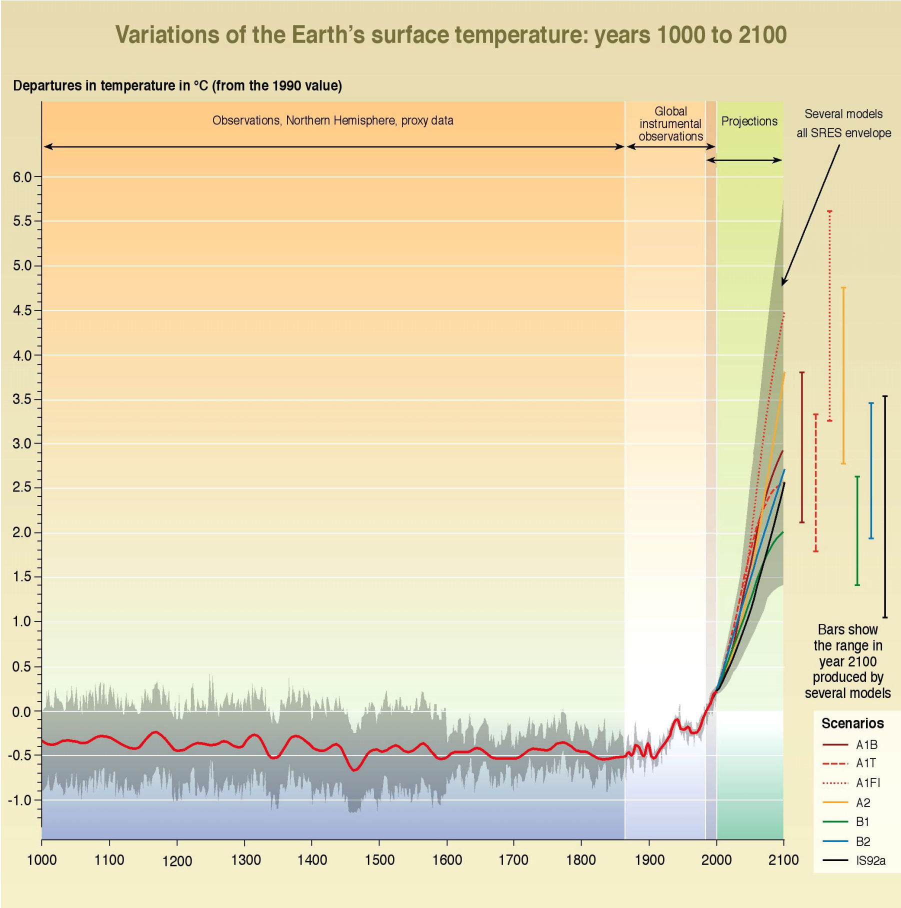


Figure 3.15 Variations of the Earth's surface temperature years 1000 to 2100
Note: The temperature scale is departure from the 1990. (See S7 Drivers)



4. What is the future for biodiversity and ecosystem services under plausible scenarios?

In the range of plausible scenarios explored by the MA, biodiversity will continue to be lost at extremely high rates over the next fifty years. Given the inertia in the indirect drivers and in ecosystems it will be unlikely that this loss can be halted. Nonetheless, opportunities exist to minimize the loss of biodiversity and associated ecosystem services if society places an emphasis on ecosystem protection, restoration and management.

Statements of certainty in the following conclusions are conditional statements, in that they refer to level of certainty or uncertainty in the particular projection should that scenario and its associated changes in drivers unfold.

4.1 Global scenarios and ecosystem change

Future scenarios studies by the MA all project continued loss of biodiversity, with attendant changes in ecosystems services and declines in human well-being in some regions and populations. The MA scenarios address the consequences of different plausible futures for ecosystem services and human well-being (S5). These futures were selected to explore a wide range of contexts under which sustainable development will be pursued, as well as a wide range of approaches to sustainable development. Two basic contexts are explored, one in which the world becomes increasingly globalized and one in which the world becomes increasingly regionalized. In terms of approaches, scenarios focus either on futures that emphasize economic growth and promotion of public goods, or futures that emphasize proactive management of ecosystems and their services. The four extremes across these futures and approaches result in four scenarios (Box 4.1). Many of the MA Sub-global Assessments also developed scenarios; two examples are provided in Box 4.2

<<Insert Box 4.1 and Box 4.2>>

Habitat loss will lead, *with high certainty,* to continuing decline in the local and global diversity of some taxa, especially vascular plants, in all four scenarios (S10.2). Habitat decline between 1970 and 2050 ranges from 15% to 30% (Figure 4.1), leading to global extinctions as populations approach equilibrium with the remnant habitat. The number of species lost at equilibrium is likely to be between 12% and 16% of the species present in 1970 (*low certainty*). The two scenarios which take a more proactive approach to the environment (TG and AM) have more success in reducing both habitat and terrestrial biodiversity loss in the near future than the two scenarios which take a reactive approach to environmental issues. The scenario that where the world becomes increasingly regionalized due to concerns with security and where society takes a reactive approach towards the environment (OS) has the highest rates of biodiversity loss.

<<Insert Figure 4.1>>

Habitat and vascular plant populations are projected to be lost in the MA scenarios at the fastest rate in warm mixed forests, savannahs, scrub, tropical forests, and tropical woodlands (*high certainty*). Regions that will lose species at the lowest rate include those with low human impact as well as those where major land-use changes and human intervention have already occurred, such as the Palearctic (S10.2, Figure 4.2). Tropical Africa is the region that will lose most vascular plant species, mostly as a result of rapid population growth and strong increases in per capita food production in the region. The Indo-Malayan region loses the second-most biodiversity.

<<Insert Figure 4.2>>

Land-use changes are associated primarily with further expansion of agriculture and secondarily, with the expansion of cities and infrastructure (S9). This expansion is caused by increases in population, economic growth and changing consumption patterns**.** By 2050 global population increases (medium to high certainty) to between 8.1 and 9.6 billion, depending on the scenario. At the same time, the global economy (as measured by GDP) expands by a factor of 1.9 - 4.4, depending on the scenario (low to medium certainty). Demand is dampened by increasing efficiency in the use of resources. The expansion of agricultural land occurs mainly in the low-income and arid regions, while in the high income regions, agricultural area declines (Figure 4.3). The reverse pattern occurs in terms of forest cover, with some forest being regained in the developed countries but with 30% of the forest in the developing world being lost from 1970 to 2050, resulting in a global net loss of forest. The two scenarios with a proactive approach to the environment (TG and AM) are the most land-conserving scenarios because of increasingly efficient agricultural production, lower meat consumption, and lower population increases. Existing wetlands and the services they provide (e.g. water purification) are faced with increasing risk in some areas due to reduced runoff and/or intensified land use. Considering past and projected future trends in habitat change indicates that those biomes that have already suffered the greatest change (Mediterranean Forests and Temperate Grasslands) show the highest recoveries over the next 50 years, while the biomes that suffered intermediate changes in the past have the highest rates of change in the near future. Finally, biomes at higher latitudes which had not been converted to agriculture in the past will continue to be relatively unchanged. In a few biomes expected changes post 1990 are greater that those seen in the past half century.

<<Insert Figure 4.3>>

In terrestrial systems, for the three drivers that were tested globally across scenarios, land-use change was the dominant driver of biodiversity loss followed by changes in climate and nitrogen deposition (*medium certainty*, S10.2). Some individual biomes showed different patterns. For example, climate change was the dominant driver of biodiversity change in tundra, boreal forest, cool conifer forest, savanna and deserts. Nitrogen deposition was found to be a particularly important driver in warm mixed forests and temperate deciduous forest. These two ecosystems are sensitive to deposition and relatively close to densely populated areas. In addition, the impact of other drivers, e.g., invasive species and overexploitation, could not be assessed as fully and may therefore be underestimated.

Vast changes are expected in world freshwater resources and hence in their provisioning of ecosystem services. (S9.4.6,

Figure *4*.4) Under the two scenarios with a reactive approach to the environment (OS and GO), massive increases in water withdrawals in developing countries are expected to lead to an increase in untreated wastewater discharges, causing a deterioration of freshwater quality. Climate change leads to both increasing and declining river runoff, depending on the region. The combination of huge increases in water withdrawals, decreasing water quality, and decreasing runoff in some areas, leads to an intensification of water stress over wide areas. In sum, a deterioration of the services provided by freshwater resources (aquatic habitat; fish production; water supply for households, industry and agriculture) is expected under the two scenarios with a reactive approach to the environment and a less severe decline under the two scenarios with a proactive approach (*medium certainty*).

<<Insert

Figure 4.4>>

Fish populations are lost from river basins under all scenarios due to the combined effects of climate change and water withdrawals, with impacts concentrated in poor tropical and subtropical countries. Under all scenarios, 30% of the modeled river basins decrease in water availability from the combined effects of climate change and water withdrawal, resulting in eventual losses of up to 65% (by 2100) of fish species from these basins (*low certainty*). Climate change rather than water withdrawal is the major driver for the species losses from most basins, with projected losses from climate change alone of up to 65% by 2100. Rivers that are forecast to lose most fish species are concentrated in poor tropical and subtropical countries, where the needs for human adaptation are most likely to exceed governmental and societal capacity to cope (S10.3).

Demand for fish as food expands under all the scenarios, and the result will be an increasing risk of a major long-lasting collapse of regional marine fisheries (*low to medium certainty*). The demand for fish from both freshwater and marine sources, as well as from aquaculture, increases across all scenarios because of increasing human population, income growth and increasing preferences for fish (S9.4.3). Increasing demand raises the pressure on marine fisheries, which may already be near their maximum sustainable yield and could cause a long-term collapse in their productivity. The production of fish via aquaculture adds to the risk of collapse of marine fisheries as aquaculture continues to depend on marine fish as a feed source. However, the diversity of marine biomass is sensitive to changes in regional policy. Scenarios with policies that focus on maintaining or increasing the value of fisheries result in declining biomass diversity, while those scenarios with policies that focus on maintaining the ecosystem responded with increasing biomass diversity. Rebuilding selected stocks does not necessarily increase biomass diversity as effectively as an ecosystem-focused policy (S10.5).

4.2 Ecological Degradation and Human Well-Being

Major adverse ecological surprises include runaway climate change, desertification, fisheries collapse, eutrophication and disease. Major adverse social surprises include severe conflict, governance failure, and increasing fundamentalism and nationalism (S11). Likelihood of surprises, society preparedness and ecosystem resilience interact to determine the vulnerability of human well-being to ecological and other forms of surprise in any given scenario. The vulnerability of human well-being to adverse ecological, social and other forms of surprise varies among the scenarios, but it is greatest in the scenario with a focus on security through boundaries and where the society is not proactive to the environment (OS).

Scenarios which limit deforestation show relatively better preservation of regulating services. Tropical deforestation could be reduced by a combination of reduced tropical hardwood consumption in the North, technological developments leading to substitution, and slower population growth in the South (TG), or through greater protection of local ecosystems (AM). In contrast, in the scenarios that are not proactive to the environment, a combination of market forces, undervaluation, and feedbacks lead to substantial deforestation, not only in the tropics but also in large swathes of Siberia (OS and GO). Deforestation increasingly interacts with climate change in all scenarios, not only to cause more flooding during storms, but also more fires and famine during droughts, greatly increasing the risk of runaway climate change (S11).

Terrestrial ecosystems currently absorb CO2 at a rate of about 1 to 2 Gt C/yr (with medium certainty) and thereby contribute to the regulation of climate, but the future of this service is uncertain (S9). Deforestation is expected to reduce the carbon sink, most strongly in a global world with focus on security through boundaries (OS, medium certainty). Carbon release or uptake by ecosystems affects the CO2 and CH4 content of the atmosphere at the global scale and thereby global climate. Currently, the biosphere is a net sink of carbon, absorbing approx. 20% of fossil fuel emissions (medium certainty). It is very likely that the future of this service will be greatly affected by expected land use change. Enhanced net productivity of ecosystems is expected as a consequence of higher atmospheric CO2, but this does not indicate (with low to medium certainty) additional global carbon sink potential (some regions are expected to store more carbon, however, e.g., many boreal forests). The limited understanding of soil respiration processes, and their response to changed agricultural practices, generates uncertainty about the future of this sink. There is a medium likelihood that additional sources of CO2 or CH4 will be caused by climate change in some regions (e.g., in Arctic tundras).

The increase in global temperature between 2000 and 2050 is about 1.0 to 1.5^{o}C, and between 2000 and 2100 about 2.0 to 3.5^{o} C, depending on the scenario (*low to medium certainty*). There is an increase in global average precipitation (*medium certainty).* Furthermore, according to the climate scenarios of the MA, there is an increase in precipitation over most of the land area of the earth (low to medium certainty). However, some arid regions (e.g. North Africa, Middle East) could become even more arid (low certainty). Climate change will directly alter ecosystem services, for example, by causing changes in the productivity and growing zones of cultivated and non-cultivated vegetation. It will also indirectly affect ecosystem services in many ways, such as by causing sea level to rise which threatens mangroves and other vegetation that now protect shorelines.

The scenarios indicate (*medium certainty*) certain "hot spot regions" of particularly rapid changes in ecosystem services, including Sub-Saharan Africa, Middle East and Northern Africa, and South Asia (S9). To meet its needs for development, Sub-Saharan Africa is likely to rapidly expand its withdrawal of water, and this will require an unprecedented investment in new water infrastructure. Under some scenarios (medium certainty) this rapid increase in withdrawals will cause a similarly rapid increase in untreated return flows to the freshwater systems which could endanger public health and aquatic ecosystems. This region could experience not only accelerating intensification of agriculture but also further expansion of agricultural land onto natural land. Further intensification could lead to a higher level of contamination of surface and groundwaters. Expansion of agriculture will come at the expense of the disappearance of a large fraction of Sub-Saharan Africa's natural forest and grasslands (medium certainty) as well as the ecosystem services they provide. Rising income in the Middle East and Northern African countries leads to greater meat demand which could lead to a still higher level of dependency on food imports (low to medium certainty). There is a medium likelihood that rising incomes put further pressures on limited water resources which will either stimulate innovative approaches to water conservation or could limit development. In South Asia, deforestation continues, despite increasingly intensive industrial-type agriculture. Here rapidly increasing water withdrawals and return flows further intensify water stress.

While the GDP per person improves on average in all the scenarios, this can mask increased inequity and declines in some ecosystem services. Food security improves in the South in all scenarios except in a world with a focus on security trough boundaries and reactive to the environment (OS, Figure 4.5). However, food security remains out of reach for many people and child malnutrition cannot be eradicated even by 2050, with number of malnourished children still at 151 million in one scenario (OS). In a regionalized world which is proactive to the environment there is an improvement of provisioning services in the South through investment in social, natural and, to a lesser extent, human capital, at local and regional levels (AM). Global health improves in a globalize world that places an emphasis on economic development (GO) but worsens in a regionalized world with a focus on security, with new diseases affecting poor populations, and anxiety, depression, obesity and diabetes affecting richer populations (OS). New health technologies and better nutrition could help to unleash major social and economic improvements, especially among poor tropical populations, where it is increasingly well-recognized that development is being undermined by numerous infectious diseases, widespread under-nutrition, and high birth. Good population health depends crucially upon institutions. In a regionalized world with a focus on the environment, the greatest improvements in social relations occur, as civil society movements strengthen (AM). Curiously, security is least in a world with focus on security through boundaries (OS). This scenario also sees freedom and choices reduced both in the North and the South, while other scenarios see an improvement, particularly in the South.

<<Insert Figure 4.5>>

4.3 Implication and opportunities for trend reversion

The MA scenarios demonstrate the fundamental interdependence between energy, climate change, biodiversity, wetlands, desertification, food, health, trade, and economy, since ecological change affects the scenario outcomes. This interdependence between environmental and development goals stresses the importance of partnerships and the potential for synergies among multilateral environmental agreements (S14). As the bases for international co-operation, all global environmental agreements operate under profoundly different circumstances in the four scenarios and their current instruments (exchange of scientific information and knowledge, technology transfer, benefit sharing, financial support) might need to be revised and complemented by new ones according to the changing socio-political conditions.

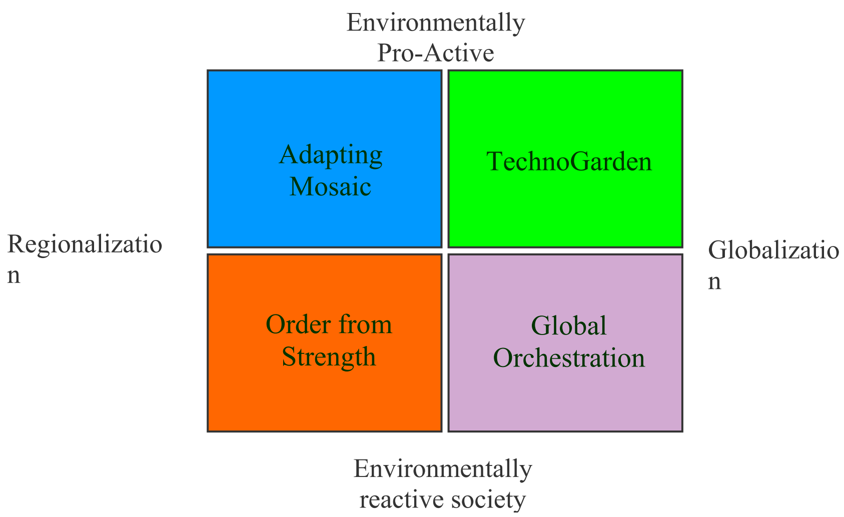
Tradeoffs between ecosystem services continue and perhaps intensify. The gains in provisioning services such as food supply and water use will come partly at the expense of losses of other provisioning services. Providing food to an increasing population will lead (with low to medium certainty) to the expansion of agricultural land and this will lead to the loss of natural forest and grassland, as well as the loss of other services associated with this land (genetic resources, wood production, habitat for fauna and flora). While water use will increase in developing countries (with high certainty), this is likely to be accompanied by a rapid and perhaps extreme deterioration of water quality, with losses of the services provided by clean freshwaters (genetic resources, fish production, habitat for aquatic and riparian flora and fauna). Hence, policies regarding world ecosystems should take into account these tradeoffs, and should try and minimize the losses of services that result from the gains.

The prospect of large unexpected shifts in ecosystem services can be addressed by policies that hedge (e.g. by diversifying the ecosystem services used in a particular region), choose reversible actions, monitor to detect impending changes in ecosystems, and adjust flexibly as new knowledge of ecosystem change becomes available. Adapting approaches are inherently experimental. Although some experiments fail, others succeed and form the basis of more robust management systems (AM). A path where technological innovation is used as a means of increasing production and engineering responses to unexpected change, has higher economic growth but greater risk of very large breakdowns of ecosystem services (TG). The scenarios with a reactive attitude to environmental issues show the effects of policies that do not account for the possibility of large-scale ecological change. However, in on case, greater economic growth provides greater capacity to react to large ecological changes after they have occurred (GO).

More attention to indicators and monitoring for large changes in ecosystem services would increase society's capacity to avert large disturbances of ecosystem services, or adapt to them more rapidly if they occur. Without monitoring and policies that anticipate the possibility of large ecosystem changes, society will face increased risk of large impacts from unexpected disruptions of ecosystem services. In the scenarios, the greatest risks of large, unfavorable ecological changes arise in dryland agriculture, marine fisheries, degradation of quality of freshwaters and coastal marine waters, emergence of disease, and regional climate change. These are also some of the ecosystem attributes most poorly monitored at present.

Box 4.1. An Outline of the Four MA Scenarios.

It is important to remember that no scenario will match the future as it actually occurs. None of the scenarios represents a "best" path or a "worst" path. There could be combinations of policies and practices that produce significantly better, or worse, outcomes than any of the scenarios. The future will represent a mix of approaches and consequences described in the scenarios, as well as events and innovations that have not been imagined at the time of writing. The focus on alternative approaches to sustaining ecosystem services distinguishes the MA scenarios from previous global scenario exercises. The four approaches were developed based on interviews with leaders in non-governmental organizations, governments and business from five continents, the literature, and policy documents addressing linkages between ecosystem change and human well-being



- **The Global Orchestration scenario explores the possibilities of a world in which global economic and social policies are the primary approach to sustainability.** The recognition that many of the most pressing global problems seem to have roots in poverty and inequality evokes fair policies to improve well-being of those in poorer countries by removing trade barriers and subsidies. Environmental problems are dealt with in an ad-hoc reactive manner as it is assumed that improved economic well-being will eventually create demand for and the means to achieve environmental protection. Nations also make progress on global environmental problems, such as greenhouse gas emissions and depletion of pelagic marine fisheries. However, some local and regional environmental problems are exacerbated. The results for ecosystem services are mixed. While human well-being is improved in many of the poorest countries (and in some rich countries), a number of ecosystem services deteriorate by 2050.

- **The Order from Strength scenario examines the outcomes of a world in which protection through boundaries becomes paramount.** The policies enacted in this scenario lead to a world in which the rich protect their borders, attempting to confine poverty, conflict, environmental degradation, and deterioration of ecosystem services to areas outside the borders. However, poverty, conflict, and environmental problems often cross the borders, impinging upon the well-being of those within.

- **The Adapting Mosaic scenario explores the benefits and risks of local and regional management as the primary approach to sustainability.** In this scenario, lack of faith in global institutions, combined with increased understanding of the importance of resilience and local flexibility lead to approaches that favor experimentation and local control of ecosystem management. The results are mixed, as some regions do a good job managing ecosystems and others do not. High levels of communication and interest in learning leads regions to compare experiences and learn from one another. Gradually the number of successful experiments begins to grow. While global problems are ignored initially, later in the scenario they are approached with flexible strategies based on successful experiences with locally adaptive management. However, some systems suffer long-lasting degradation.

- **The TechnoGarden scenario explores the potential role of technology in providing or improving the provision of ecosystem services.** The use of technology and the focus on ecosystem services is driven by a system of property rights and valuation of ecosystem services. In this scenario, people push ecosystems to their limits of producing the optimum amount of ecosystem services for humans through the use of technology. Often, the technologies they use are more flexible than today's environmental engineering and they allow multiple needs to be met from the same ecosystem. Provision of ecosystem services in this scenario is high world-wide, but flexibility is low due to high dependence on a narrow set of optimal approaches. In some cases, unexpected problems created by technology and erosion of ecological resilience lead to vulnerable ecosystem services, which are subject to interruption or breakdown. Additionally, the success in increasing the production of ecosystem services often undercuts the ability of ecosystems to support themselves, leading to surprising interruptions of service provision and collapse of some ecosystem services. These interruptions and collapses sometimes have serious consequences for human well-being.

Box 4.2. Results of to MA Sub-global Assessment scenarios (SG9.8.1)

Southern Africa

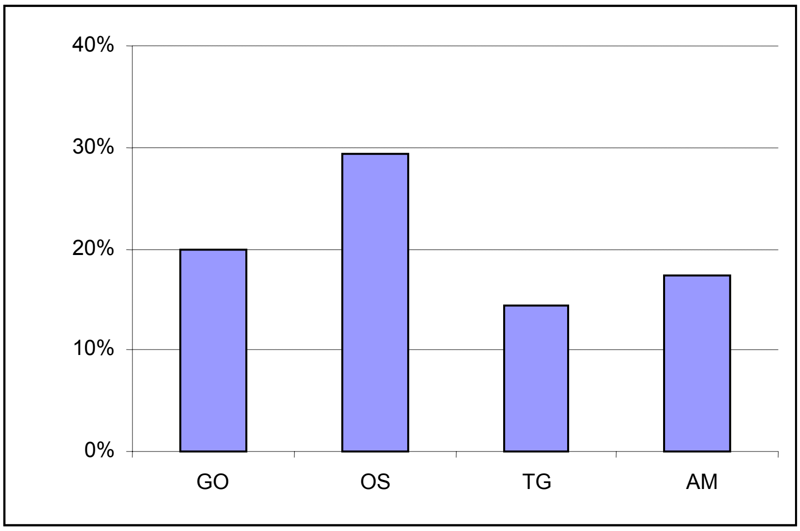
Most Southern Africa scenarios indicate that the conditions remain stable or worsen over the next three decades; only under a limited set of circumstances is it anticipated that a significant improvement will occur. It is anticipated that biodiversity, freshwater quality and quantity, biomass fuel and air quality will decline under both scenarios of strong and poor central governance, although the degree of decline as well as the underlying processes will differ. Food production is expected to remain stable or decline slightly under conditions of poor governance, whereas improved governance is expected to result in a strong improvement in food security. The Southern Africa regional and local-scale scenarios highlight that general trends in ecosystem services at the regional and basin-scale may be reversed in particular local situations. The multi-scale structure of the Southern Africa assessment also showed that certain responses or developments at larger scales are experienced as surprises or shocks at local scales e.g. mega parks and large irrigation schemes implemented without adequate local stakeholder participation and consideration of impacts.

Caribbean Sea

The Caribbean region is considered particularly vulnerable to externalities because of its current and historically high reliance on international markets and expertise, and the effects of economies of scale on small islands and developing states. Under three of the four scenarios developed for the Caribbean Sea, ecosystem services will decline. Only in the *Quality over Quantity* scenario, which describes the creation of a set of specific environmental policies to address ecosystem degradation, is this trend of ecosystem service degradation reversed.

Figure 4.1.Losses of habitat and vascular plant diversity as a result of habitat loss between 1970 and 2050 for the four MA scenarios (S10.2), Global Orchestration (GO), Order from Strength (OS), TechnoGarden (TG), and Adapting Mosaic (LL).

(a) Percent loss of habitat between 1970 and 2050



(b) Reduction in the equilibrium number of species resulting from habitat loss between 1970 and 2050 in the four MA Scenarios

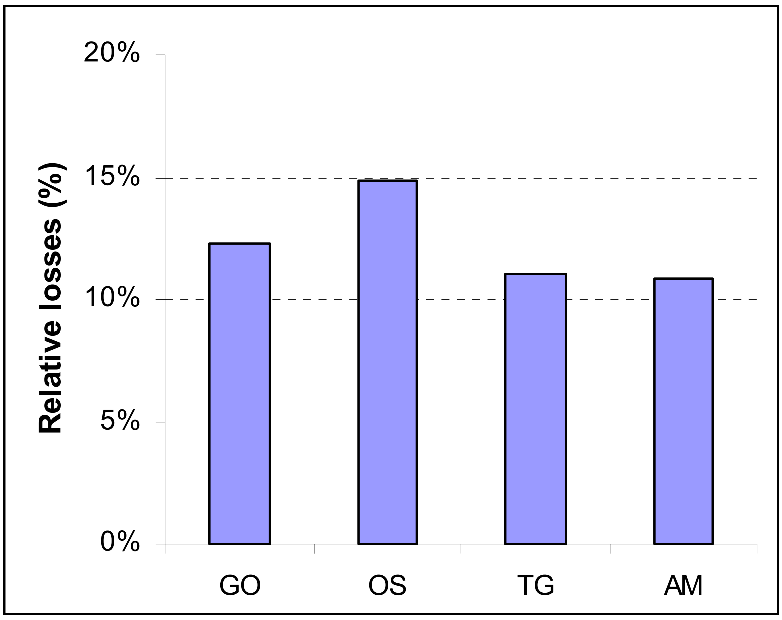
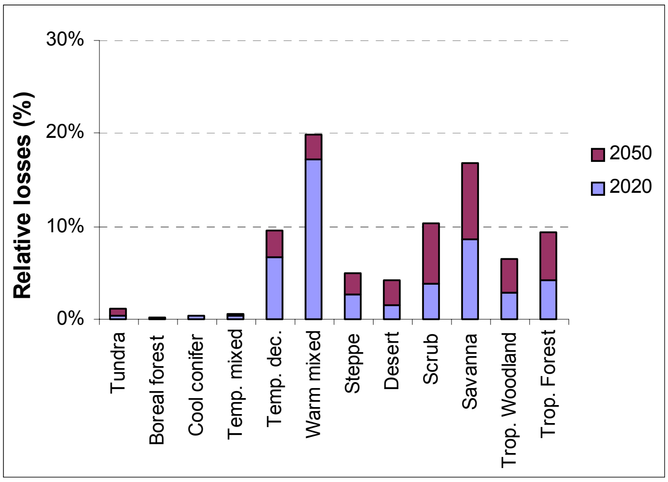


Figure 4.2. Relative loss of biodiversity of vascular plants through habitat loss for different biomes and realms for the Order from Strength scenario (S10.2). Losses would occur when populations reach equilibrium with habitat available in year 2050 and are relative to 2000 values.



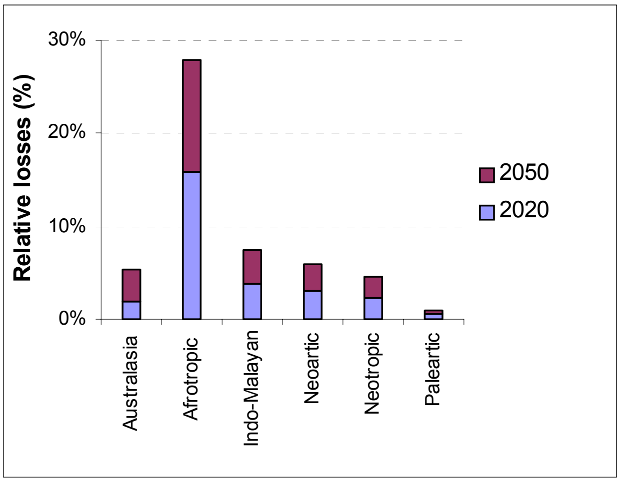


Figure 4.3. Evolution of forest (left) and cropland/pasture (right) from 1970 to 2050 in the MA scenarios, for developed and developing regions.

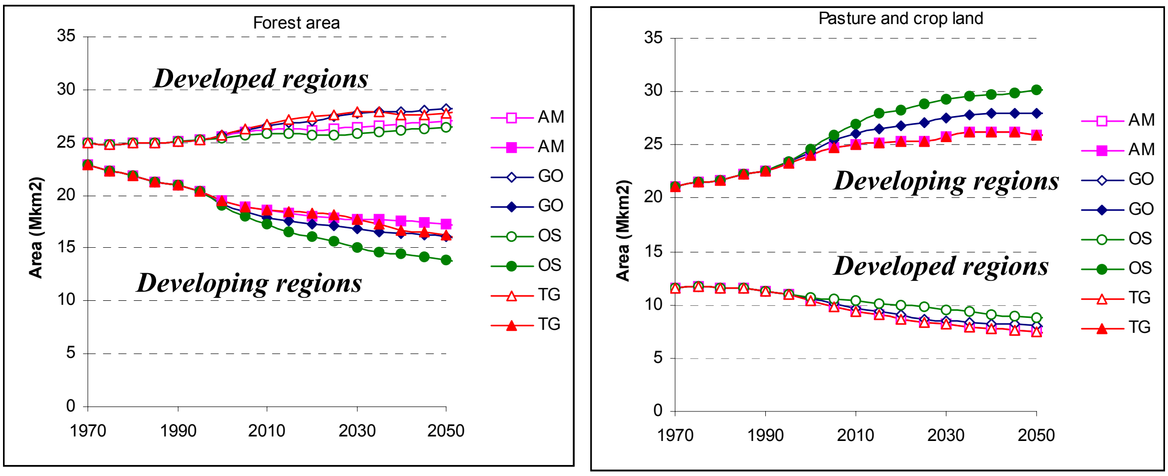


Figure 4.4. Changes in annual water availability in Global Orchestration by 2100. Shades from gray through red indicate regions that are drying.

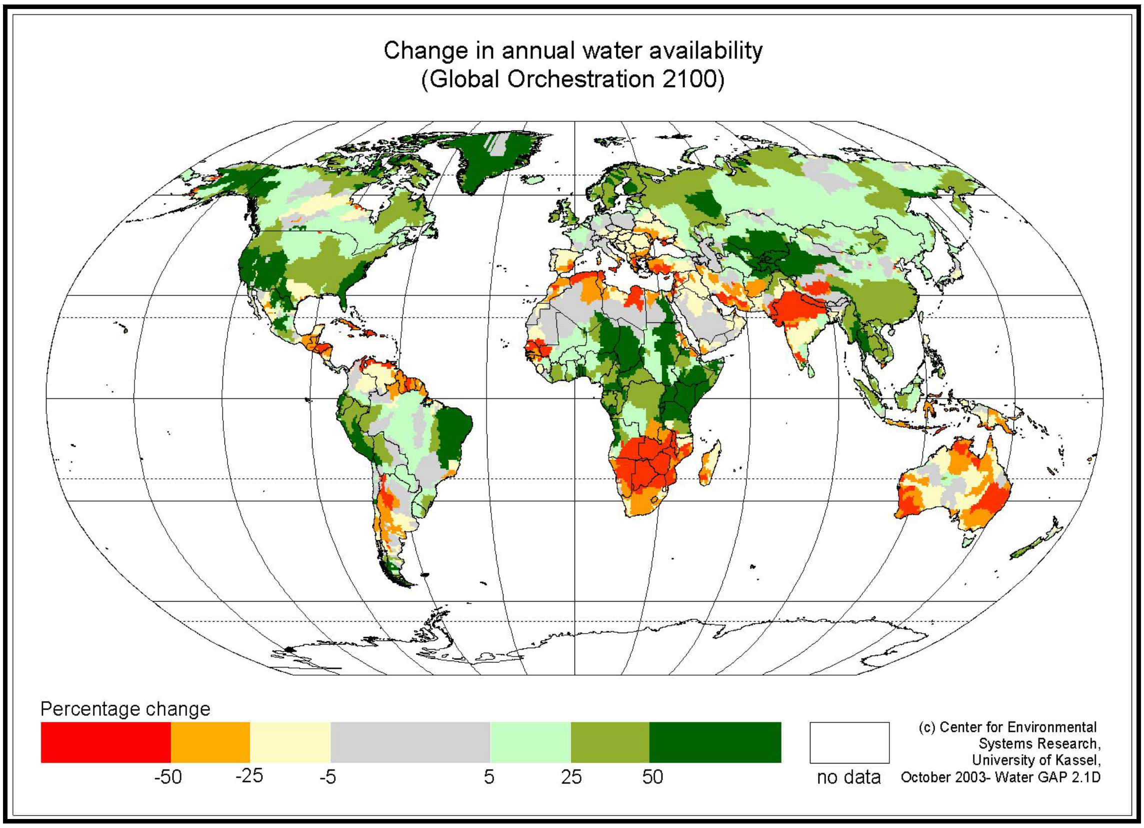
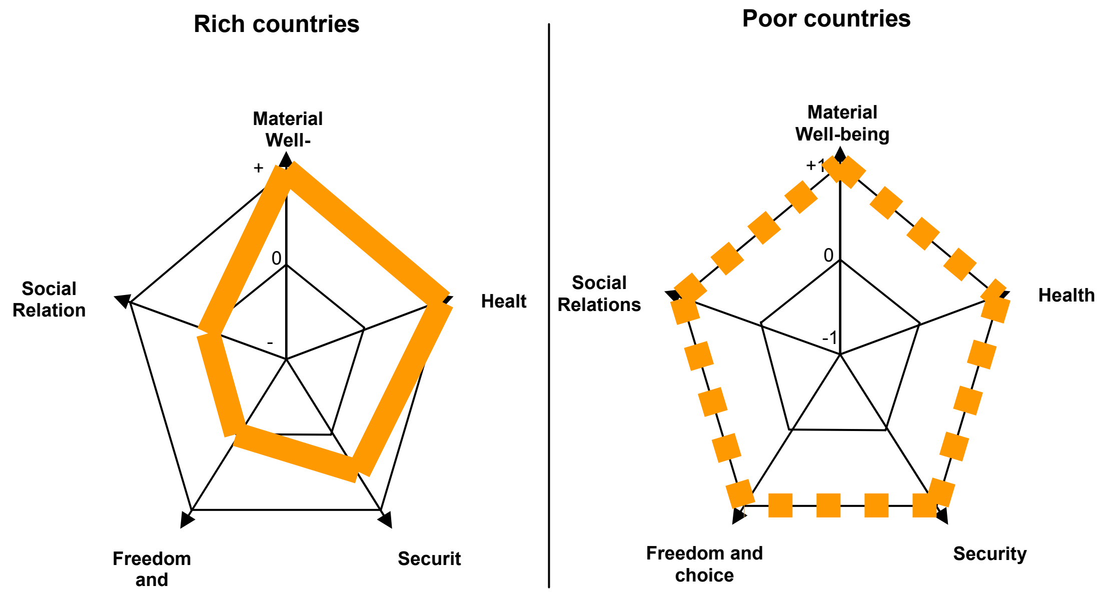
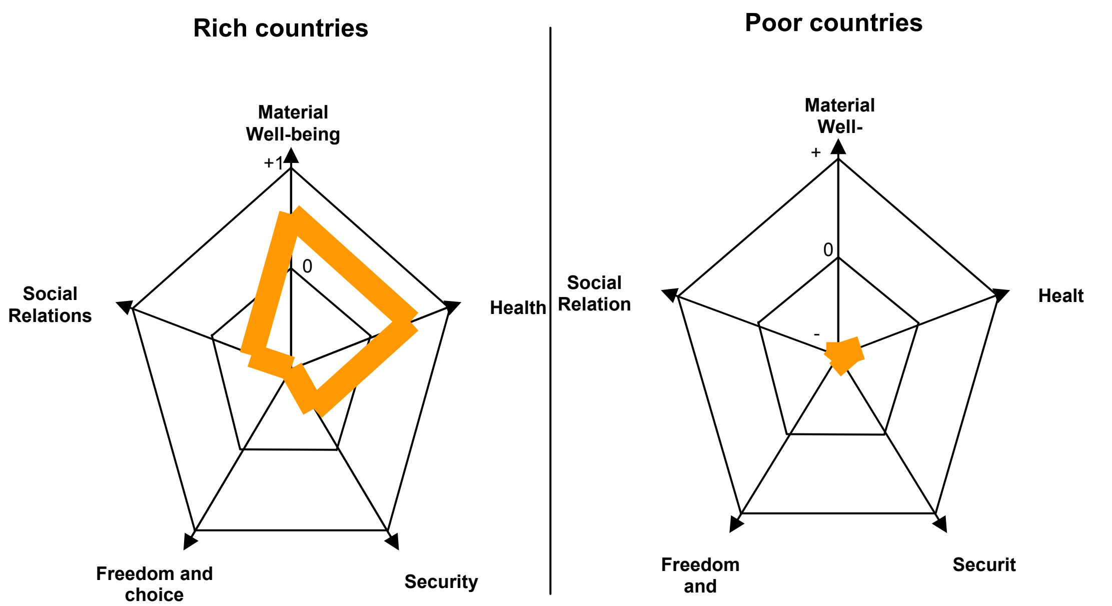


Figure 4.5. Changes in human well-being and socio-ecological indicators between today (indicated by ‘0’) and 2050 for all four MA scenarios (S11). Each arrow in the star diagrams on the left represents one human well-being (HWB) component. The area marked by the lines between the arrows represents HWB as a whole. The ‘0’ line represents the status of each of these components today. If the line moves more towards the center of the pentagon this HWB component deteriorates in relative terms between today and 2050, if it moves more towards outer edges of the pentagon it improves.

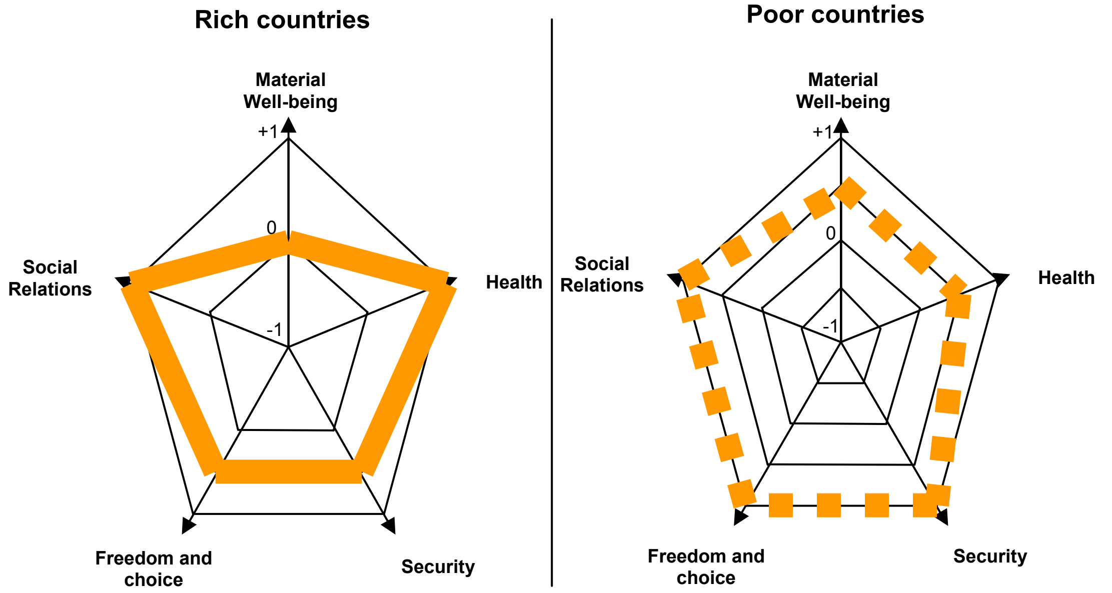
Global Orchestration



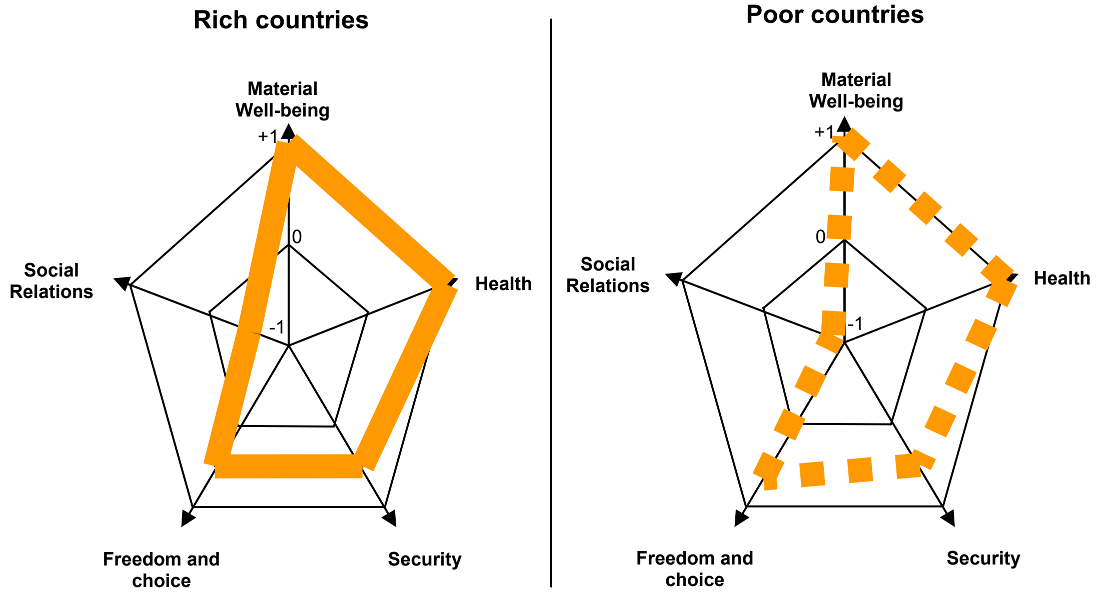
Order from Strength



Adapting Mosaic



TechnoGarden



5. What response options can conserve biodiversity and promote human well-being?

Biodiversity loss is driven by local, regional and global factors, so responses are also needed at all scales.

Responses need to acknowledge multiple stakeholders with different needs.

Given certain conditions, many effective responses are available for addressing the issues identified.

Responses designed to address biodiversity loss will not be sustainable or sufficient unless relevant direct and indirect drivers of change are addressed.

Further progress in reducing biodiversity loss will come through greater coherence and synergies among responses, and more systematic consideration of trade-offs among ecosystem services or between biodiversity conservation and other needs of society.

5.1 Local and global scales for drivers of biodiversity loss and responses to the drivers

Some drivers of biodiversity loss are localized, for example, over-exploitation. Others are global, for example, climate change, while many operate at a variety of scales, such as the local impacts of invasive species through global trade. Most of the responses addressed here were designed to address the direct drivers of biodiversity loss. However, these are better seen as symptoms of the indirect drivers such as consumption, demographic change, and globalization that were not assessed, yet may ultimately be more important for the loss of biodiversity.

At the local/regional scale, responses to the drivers may promote both local biodiversity values and human well-being by better quantifying and acting on the synergies between maintenance of local biodiversity and provision of key ecosystem services. Responses promoting local management for global biodiversity values depend on local "capture" of the global values in a way that provides both ongoing incentives for management and support for local well-being.

At the global scale, effective responses set priorities for conservation and development efforts in different regions, and create shared goals or programs, such as the biodiversity-related conventions and the Millennium Development Goals. Effective trade-offs and synergies will be promoted when different strategies or instruments are used in an integrated, coordinated way.

The MA assessment of biodiversity responses places human well-being at the central focus for assessment, recognizing that people make decisions concerning ecosystems based on a range of values relating to well-being, including the intrinsic and option values of biodiversity and ecosystems. The assessment therefore has viewed biodiversity responses as addressing values at different scales, with strong links to ecosystem service values and well-being arising at each of these scales. The well-being of local people dominates the assessment of many responses, including those relating to protected areas, governance, wild species management, and various responses related to local capture of benefits.

Focusing exclusively on values at only one level often hinders responses that could promote values at all levels, or reconcile conflicts between the levels. Effective responses function across scales, addressing global values of biodiversity while identifying opportunity costs and /or synergies with local values. Local consideration of global biodiversity recognizes the value of what is unique at a place (or what is not yet protected elsewhere). The values of ecosystem services, on the other hand, do not always depend on these unique elements, but on what makes that place similar to many others. Effective biodiversity responses recognize both kinds of values.

These considerations guide the assessment (summarized below) of a range of response strategies that to varying degrees integrate global and local values, and seek effective trade-offs and synergies for biodiversity, ecosystem services, and human well-being.

Difficulties in measuring biodiversity have complicated assessments of the impact of all response strategies. Further, existing measures often focus on local biodiversity and do not estimate the marginal gains in regional/global biodiversity values. For example, biodiversity gains from organic farming are typically expressed only as localized species richness, with no consideration of degree of contribution to regional/global biodiversity or trade-offs with high-productivity industrial agriculture.

Even while the bulk of biodiversity remains unknown, better ways are required to estimate the biodiversity importance of different places. Developing a better calculus of biodiversity would enhance integration among strategies /instruments. For example, the use of payments for biodiversity conservation can be targeted to complement the contributions already made, not just by other private land participants but also by the formal protected areas system.

5.2 How effective are protected areas for conservation of biodiversity and for contributing to human well-being? (R5)

Protected areas are an extremely important part of programs to conserve biodiversity and ecosystems, especially for sensitive environments that require active measures to ensure the survival of certain components of biodiversity. Since 1950, both the number and area of protected areas increased at rates greater than either the rate of population or economic growth. Protected areas also play an important role in ensuring the respect, recognition and maintenance of important traditions, cultures and sacred sites. Increasingly, protected areas are being used as a mechanism to promote peace-keeping efforts among nations, notably through Transboundary Protected Areas and “Peace Parks.”

The establishment of the Kgalagadi Transfrontier Park bordering South Africa and Botswana is a clear illustration of an attempt to capture transboundary issues relevant for its success.

Recent assessments have shown that, at the global and regional scales, the existence of current protected areas, while essential, is not sufficient for conservation of the full range of biodiversity. Protected areas need to be better located, designed, and managed to deal with problems like lack of representativeness, impacts of human settlement within protected areas, illegal harvesting of plants and animals, unsustainable tourism, impacts of invasive alien species, and vulnerability to global change. Marine and freshwater ecosystems are even less well protected than terrestrial systems, leading to increasing efforts to expand protected areas in these biomes.

Based on a survey of management effectiveness of a sample of nearly 200 protected areas in 34 countries, only 12% were found to have implemented an approved management plan. The assessment concluded that PA design, legal establishment, boundary demarcation, resource inventory and setting objectives were relatively well addressed. But management planning, monitoring and evaluation, budget security and law enforcement were generally weak among the surveyed protected areas.

Success of protected areas systems as responses to biodiversity loss requires better site selection, incorporating regional trade-offs, in order to avoid the ad hoc establishment that can leave some ecosystems poorly represented while over-representing others. Success also requires adequate legislation and management, sufficient resources, better integration with the wider region surrounding protected areas, and expanded stakeholder engagement. Many of these measures are included in the CBD program of work on protected areas.

Assessments indicate that protected areas may contribute to poverty where rural people are excluded from resources that have traditionally supported their well-being, but can contribute to improved livelihoods through providing ecosystem services when they are managed to benefit local people.

Relations with local people could be more effectively addressed through adequate consultation and planning. One useful strategy is to promote the broader use of all IUCN protected areas management categories. Success depends on a collaborative management approach between government and stakeholders, an adaptive approach that tests options in the field, comprehensive monitoring that provides information on management success or failure, and empowerment of local communities in a participatory system that clarifies access and ownership of resources.

An important consideration for PA design is the future impact of climate change. The impacts of climate change will increase the risk of extinctions of certain species and change the distribution of ecosystems. Shifts in species distribution as a result of climate change are well documented. Today's species conservation plans may incorporate adaptation and mitigation aspects for this threat, drawing on existing tools to help assess species' vulnerability to climate change. Corridors and other habitat design aspects to give flexibility to protected areas are good precautionary strategies. Improved management of habitat corridors and production ecosystems between protected areas will help biodiversity adapt to changing conditions.

The multiple benefits provided by protected areas can help provide the basis for various innovative mechanisms for financing them. This highlights the need for effective valuation of the goods and services that can stimulate funding of protected areas

The "paper parks" problem remains: geographic areas may be labeled as some category of protected area but not achieve the promised form of management. Representation and management targets and performance indicators work best when they go beyond measuring total area apparently protected. Percent-area coverage for protected areas associated with the Millennium Development Goals provide a broad indicator, but regional/national-level planning requires targets that take into account trade-offs and synergies with other ecosystem services.

The effectiveness of protected areas can be improved through 1) strategies for effective PA design and management that are appropriate to their ecological, social, historical, and political setting; 2) regional planning strategies that place protected areas within the context of the lands and waters surrounding them, and seeking trade-offs and synergies with ecosystem services; and 3) a better appreciation of the multiple economic and social values of protected areas, for local people, the nation in which they are located, and the world at large.

5.3 How effective is local capture of biodiversity benefits, including payments and markets for biodiversity and ecosystem services, as a response to biodiversity loss? (R5)

Economic incentives that encourage the conservation and sustainable use of biodiversity show considerable promise. However, economic incentives cannot be all things to all people. Trade-offs between biodiversity, economic gains and social needs have to be more realistically acknowledged. The promotion of 'win-win' outcomes has been politically correct at best and naïve at worst**.** Despite the importance of compensating people for any costs they experience as a result of restricting their impacts on biodiversity, responses that only compensate people and do not create conservation incentives seldom lead to biodiversity conservation.

The impact of market instruments, such as trading rights for development (Transferable Development Rights; TDRs) and tax credits, in encouraging and achieving conservation of biodiversity is unclear. Such instruments have been the subject of some criticisms, notably for being relatively complex. Possible modifications may imply high transaction costs and the establishment of new supporting institutions. Market instruments require appropriate and well defined property rights, but to date have been unable to target specific habitat types and properties. Whether they promote either human well-being or protect priority elements of biodiversity remains highly uncertain.

Transferring rights to own and manage services to private individuals gives them a stake in conserving those services, but these measures can backfire without adequate levels of institutional support. For example, in South Africa, changes in wildlife protection legislation allowed a shift in land ownership and a conversion from cattle and sheep farming to profitable game farming, enabling conservation of indigenous wildlife. On the other hand, the CAMPFIRE program in Zimbabwe, based on sustainable community-managed use of wildlife, has now become an example of how success can turn into failure, with the state repossessing the areas given to individuals and breaking the level of trust and transparency which are critically needed for these economic responses to work efficiently and equitably.

Commercialization of non-timber forest products has achieved modest successes for local livelihoods but has not always created incentives for conservation. Increased value does not automatically translate into effective incentives for conservation and can have the opposite effect. Policy frameworks must create incentives for sustainable management of non-timber forest products, including exploration of joint production of timber and non-timber products

Payments to local landowners for ecosystem services show promise of improving allocation of ecosystem services and are applicable to biodiversity conservation. However, compensating mechanisms addressing the distributive and equitable aspects of these economic instruments may need to be designed in support of such efforts. By 2001, over 280,000 ha of forests had been incorporated in Costa Rica within reserves at a cost of about US$30 million per year, with typical annual payments ranging from $35 to $45/ha for forest conservation. However, the existence of direct payment initiatives does not guarantee success in achieving conservation and development objectives, or benefits for human well-being. Empirical analyses about actual impacts are rare.

Direct payments have been criticized for requiring on-going financial commitments to maintain the link between investment and conservation objectives. Furthermore they have led in some instances to inter- and intra-community conflict. However, many success stories show the effectiveness of direct payments and the transfer of property rights in providing incentives for local communities to conserve biodiversity. Effectiveness of payments in conserving regional biodiversity may be enhanced by new approaches that target payments based upon estimated marginal gains ("complementarity" values; (R5 Box 5.3)).

Direct payments are often more effective than indirect incentives, as seen in the widespread inability of Integrated Conservation-Development Projects (ICDPs) to achieve their ambitious objectives. ICDPs are designed to allow local populations to improve their well-being by capturing international willingness to pay for biodiversity conservation, but in practice ICDPs rarely turn that "capture" into on-going incentives for conservation. Overall, long-term success for these response strategies depends on meeting the economic and social needs of communities whose basic welfare already depends to varying degrees on biodiversity products and the ecosystem services biodiversity supports. Links to markets, national policies, and law enforcement are also required. (R5)

Significant improvements can be made to mitigate biodiversity loss and ecosystem changes by removing or redirecting economic subsidies which cause more harm than good. Agricultural subsidies in developed countries reduce world prices for many commodities developing countries produce. Lower prices provide the wrong incentives, encouraging these countries to adopt unsustainable agricultural activities which destroy ecosystems as well as push many poor farmers into poverty. Therefore, the removal or redirection of agricultural subsidies is highly likely by itself to produce major improvements in ecosystem services and check the rate of biodiversity loss.

5.4 The management of individual species is a common response strategy, both for harvestable species and problem species.

The major species-specific threat is from non-native species that cause damage to biodiversity (commonly called invasive alien species). Direct management of invasive species will become an even more important biodiversity conservation response. Invasive alien species are a growing threat to biodiversity and the 2003 IUCN Red List of Threatened Species documented several specific cases. Control or eradication of an invasive species once it is established has appeared extremely difficult and costly, while prevention and early intervention have been shown to be more successful and cost-effective. Successful eradication cases have three key factors in common: particular biological features of the target species (for example, poor dispersal ability); sufficient economic resources devoted for a sufficient duration; and widespread support from the relevant agencies and the public (R5.2). Successful prevention requires increased efforts in the context of international trade, and in raising awareness (R 5.2).

Chemical control of invasive plant species, sometimes combined with mechanical removal like cutting or pruning, has been useful for controlling at least some invasive plants, but has not proven particularly successful in eradication. In addition to its low efficiency, chemical control can be expensive. Biological control of invasive species has also been attempted but results are mixed. For example, the introduction of a non-native predatory snail to control the giant African snail in Hawaii led to extinction of many native snails. The prickly pear moth, used to fight invading cactus species in Australia, has recently invaded the United States, posing a serious threat to native cactus species. Some 160 species of biological agents, mainly insects and fungi, are registered for controlling invasive species in North America and many of them appear highly effective. However, at least some of the biological agents used are themselves potential invaders.

Although biological invasions are complex ecological, evolutionary and socio-economic problems, a better understanding is being achieved, especially in ecology both of invasiveness and habitat vulnerability to invasion. This knowledge is essential to determine how much effort to invest in controlling an invasive species that has already become established or to clarify the trade-offs managers and land planners will have to consider. Social and economic aspects have received less attention, perhaps because of difficulties in estimating these trade-offs. The Global Invasive Species Program (GISP) is an international response to address the problem, supported by the CBD COP. The CBD has adopted Guiding Principles on Invasive Alien Species (Decision VI/23) as a basic policy response, but it is too early to assess the effectiveness of implementation.

Sustainable use of natural resources is an integral part of any sustainable development program yet its contribution to conservation remains a highly controversial subject within the conservation community. Conserving exploited species when the management objective is ensuring resource availability to support human livelihoods is frequently unsuccessful. This is because optimal management for resources frequently requires overexploitation of particular wild species and an overall loss in biodiversity. Attention to social, cultural, and economic factors, beyond the biological and ecological characteristics of the resource involved, is a key to success. In particular, care in establishing positive incentives for conservation and sustainable use is critical to success.

Where the goal is species conservation, and where a specific population has a distinct identity and can be managed directly, species management approaches can be effective. However, managing for a single species is rarely a good substitute when the goal is ecosystem health, which is tied to the entire suite of species present in the area. Where human livelihoods depend on single species resources, species management can be effective, but where, as is frequently the case, people depend on a range of different wild resources, multiple species management is the appropriate approach.

5.5 How effective are strategies for integrating biodiversity issues in production sectors such as agriculture, fishery, and forestry?

Biodiversity will only be conserved and sustainably used when it becomes a mainstream concern of production sectors. Food production is by far the largest user of ecosystems and their provisioning services, and it has the largest impact on ecosystems and biodiversity. Intensive exploitation of ecosystems to satisfy needs for food might erode the productive capacity of these ecosystems through, for example, soil degradation, water depletion or contamination, collapse of fisheries, and biodiversity loss. A fundamental trade-off therefore exists between the need to increase food production and the need to sustain, in the long run, the capacity of the ecosystems to support food production.

The analysis of drivers associated with food production indicates that, while some recent trends in the slowdown of demographic growth and potential advances in agricultural technology are encouraging, increasing pressures on the resource base (land, water, fisheries, biodiversity) and potentially serious long-term effects from the regional impacts of climate change are causes for concern (C08; R6.3.4). In addition, increased fertilizer use will likely increase pressure on non-production ecosystems through nutrient loading (R9).

At the national level, integrating biodiversity issues into agriculture, fishery, and forestry management encourages sustainable harvesting and minimizes negative impacts on biodiversity. Agriculture is directly dependent on biodiversity, but agricultural practices in recent decades have focused on maximizing yields by focusing research and development on relatively few species, thus downplaying the importance of biodiversity; a large amount of genetic diversity has been lost *in situ.* Effective response strategies include sustainable intensification which minimizes the need for expanding total area for production, so allowing more area for biodiversity conservation. Practices such as integrated pest management, some forms of organic farming, and protection of field margins, riparian zones, and other non-cultivated habitats within farms, can promote synergistic relationships between agriculture, domestic biodiversity, and wild biodiversity. However, assessments of biodiversity contributions from such management reveal little data about contributions to regional biodiversity conservation (C 26; R5).

A review of 36 initiatives to conserve wild biodiversity while enhancing agricultural production, demonstrated benefits to landscape and ecosystem diversity, while impacts on species diversity were very situation specific. Assessing the impact of these approaches suffers from a lack of consistent, comprehensively documented research on the systems, particularly regarding interactions between agricultural production and ecosystem health.

Tropical deforestation at a local level can be controlled most effectively when the livelihood needs of local inhabitants are addressed within the context of sustainable forestry. The early drivers of forest certification hoped it would be an effective response to tropical deforestation, but most certified forests are in the North, managed by large companies and exporting to Northern retailers. The proliferation of certification programs to meet the needs of different stakeholders has meant that no single program has emerged as the only credible or dominant approach internationally (R 8.3.9). Forest management policies should center on existing land and water ownership at the community level. Relevant legal tools include redesigning ownership to small scale private ownership of forests, public-private partnerships, direct management of forests by indigenous people, and company-community partnerships. New land tenure systems must be context relevant and accompanied by enforcement if they are to be effective. They need to include elements of education, training, health and safety to function effectively.

5.6 How can biodiversity conservation efforts be incorporated in regional planning for land/water use in order to address trade-offs and synergies with other needs of society? (R5)

Incorporating biodiversity into integrated regional planning promotes effective measures to manage trade-offs/synergies among biodiversity, ecosystem services and other needs of society. The "ecosystem approach" adopted by the CBD Conference of Parties has prompted successful mainstreaming and bioregional planning that achieve trade-offs/synergies, even without exact quantification of biodiversity gains. However, the potential benefits from developing a quantitative regional "calculus" of biodiversity are substantial: marginal gains/losses in biodiversity from different places, and from different response strategies, can be estimated as a basis for planning the use of land and water. Using such estimates, integrated regional land-use planning based on multi-criteria analyses can provide a balance among biodiversity conservation and various land and water uses.

Even in regions with very high potential conflict between biodiversity conservation and provision of other ecosystem services, trade-offs based planning reveals potential to achieve high conservation at remarkably small cost. For example, in a Papua New Guinea planning study, high value biodiversity areas often overlapped with high opportunity cost areas, but the use of complementarity-based selection allowed a system with low cost to be designed. The use of multi-criteria analyses show potential as the basis for strategies to minimize conflict and also to find synergies with other values in the location of priority protected areas. For most effective trade-offs and synergies, the biodiversity value for a place depends upon what else is "protected" both inside and outside protected areas.

Because conventional percent-area targets may not guarantee priority for conservation of such priority areas, they should be combined with broader decision frameworks that use complementarity and cost measures to achieve high levels of biodiversity conservation.

5.7 What can the private sector contribute to biodiversity objectives? (R5)

The private sector can make significant contributions to biodiversity conservation, but limitations include insufficient synthesis of lessons to date concerning best pathways to "encouragement" and ongoing distrust between conservationists and

business. Some parts of the private sector are showing greater willingness to contribute to biodiversity conservation and sustainable use, due to the influence of shareholders, customers, and government regulation. Many companies are now preparing their own biodiversity action plans, managing their own landholdings in ways that are more compatible with biodiversity conservation, supporting certification schemes that promote more sustainable use, and accepting their responsibility for addressing biodiversity issues in their operations. Influence of shareholders or customers is limited in cases where the company is not publicly listed or is government-owned. Further developments are likely to focus on two main areas. First, the debate will move away from simply assessing the impact of companies on biodiversity, important though this is; instead, increasing emphasis will be given to ecosystem services, and how companies rely on them. This will require development of mechanisms for companies to understand their risk exposure and to manage those risks. Second, the biodiversity conservation community is likely to accept that business has a role to play in the discussions about biodiversity trade-offs and synergies.

5.8 What institutions, forms of governance, and multilateral processes can promote effective conservation of biodiversity? (R5)

Governance approaches to support biodiversity conservation and sustainable use are required at all levels. The principle that biodiversity should be managed at the lowest appropriate level has led to decentralization in many parts of the world, with variable results. The key to success is strong institutions at all levels, with security of tenure and authority at the lower levels essential to providing incentives for sustainable management.

At the same time that management of some ecosystem services is being devolved to lower levels, management approaches are also evolving to deal with large-scale processes with many stakeholders. Problems such as regional water scarcity and conservation of large ecosystems require large-scale management structures. For example, most of the major rivers in Southern Africa flow across international borders, so international water co-management organizations are being designed to share the management of riparian resources and ensure water security for all members. However, political instability in one state may negatively affect others, and power among stakeholders is likely to be uneven.

Devolution and evolution of authority to different scales does not always result in better management. For example, the power of Catchment Management Agencies (CMAs) in South Africa is constrained to their catchment, but impacts may be from outside or upstream. Further, such agencies may have too many members for any one to assume accountability. The best strategy may be one with multi-subsidiarity; that is, functions which subordinate organizations perform effectively belong more properly to them (because they have the best information) than to a dominant central organization, and the central organization functions as a center of support, coordination, and communication.

Legal systems in countries are multi-layered; and local practices may be much stronger than the law on paper. Important customs relate to the local norms and traditions of managing property rights and managing the ecosystems around them. Since these are embedded in the local societies, changing these customs and customary rights through external incentive and disincentive schemes are very difficult, unless the incentives are very carefully designed. Local knowledge becomes absolutely critical for addressing ways of managing local ecosystems.

More effort is needed in integrating biodiversity conservation and sustainable use activities within larger macroeconomic decision making frameworks. New poverty reduction strategies have been developed in recent years, covering a wide range of policies, different scales and actors. However, the integration or mainstreaming of ecosystems and ecosystem services is largely ignored. Their focus seems to be on institutional and macroeconomic stability, generation of sectoral growth and reduction of the number of people living with less than US$1 per day in poor countries. It is well documented that many of the World Bank/IMF Structural Adjustment Programs (SAPs) of the mid to late 1980's caused deterioration in ecosystem services and a deepening of poverty in many developing countries (R17).

International cooperation through multilateral environmental agreements (MEAs) requires increased commitment to implementation of activities that effectively conserve biodiversity and promote sustainable use of biological resources. Numerous multilateral environmental agreements have now been established that contribute to conserving biodiversity. The Convention on Biological Diversity is the most comprehensive, but numerous others are also relevant, including World Heritage, Convention on International Trade in Endangered Species (CITES), Ramsar Convention on Wetlands, UN Convention to Combat Desertification, UN Framework Convention on Climate Change, and numerous regional agreements. Their impacts at policy and practice levels depend on the will of the contracting parties. Effective responses may build on recent attempts (e.g. through joint work plans) to create synergies between conventions. The lack of compulsory jurisdiction for dispute resolution is a major weakness in international environmental law, but requirements to report puts pressure on countries to undertake measures and exposes them in the event they have not been able to implement their goals. An effective instrument should include sanctions for violations and/ or non-compliance procedures to help countries come into compliance. Links between biodiversity conventions and other international legal institutions that have significant impacts on biodiversity (such as the World Trade Organization) remain weak.

A strong consensus agrees that the international agreements with the greatest impact on biodiversity are not in the environmental field but rather deal with economic and political issues. These typically ignore their impact on biodiversity. The literature indicates that it is vital that these agreements are closely linked with other agreements and that solutions designed for one regime do not necessarily lead to problems in other regimes. For example, efforts to sequester carbon under the Kyoto Protocol should be designed to enhance biodiversity, not harm it (e.g. by planting multiple species of native trees rather than monospecific plantations of exotics). (R5)

Although biodiversity loss is a recognized global problem, most direct actions to halt or reduce loss need to be taken locally or nationally. Indirect drivers like globalization and international decisions on trade and economics often have a negative effect on biodiversity and should be addressed at a higher level, but the proximate responsibility to detect and act directly on biodiversity loss is at the local and national level. For threatened endemic species or ecosystems limited to an area within a single country or local administrative unit, the relevant agencies should give high priority to these species or ecosystems. If the agencies need assistance for acting, a global regional or national support system should be in place. On the other side, uniqueness could also be an asset to be exploited locally, for example through tourism development. Not all biodiversity can be conserved at every local level, but when considering trade-offs between investing in biodiversity or land use change for development in a given area, the question of endemism or alternative areas for biodiversity also at intra specific level must be addressed.

5.9 How can the identification, design and implementation of responses be improved?

Numerous response options exist to improve the benefit streams from ecosystem services to human societies without undermining biodiversity. The political and social changes now occurring in many parts of the world will have far-reaching consequences for the way ecosystem services and human well-being are managed in the future; it is thus imperative to develop an increased understanding of the opportunities and constraints that are faced in choosing and implementing responses. (See Box 5.1)

Responses do not work in a vacuum. A variety of enabling conditions, a combination of instrumental freedoms and institutional frameworks as described in the MA conceptual framework, "Ecosystems and Human Well-being", play critical roles in determining the success or failure of a response strategy. The assessments repeatedly highlighted that the success or failure of many responses were largely influenced by the various institutional frameworks that were in place in the country (CF3; R17).

Education and communication programs have both informed and changed preferences for biodiversity conservation and have improved implementation of biodiversity responses. (R5) While the importance of communication and education is well recognized, providing the human and financial resources to undertake effective work is a continuing barrier.

Ecosystem restoration activities are now common in many countries and include actions to restore almost all types of ecosystems including wetlands, forests, grasslands, estuaries, coral reefs, and mangroves. Restoration will become an increasingly important response as more ecosystems become degraded and demands for their services continue to grow. Ecosystem restoration, however, is generally far costlier than protecting the original ecosystem and it is rare that all of the biodiversity and services of a system can be restored.

Rather than the 'win-win' outcomes promoted (or assumed) by many practitioners, conflict is more often the norm, and trade-offs between conservation and development need to be acknowledged. Identifying and then negotiating trade-offs is complex, involving different policy options, different priorities for conservation and development, and different stakeholders. In the case of biodiversity conservation, the challenge is in negotiating these trade-offs, determining levels of acceptable biodiversity loss, and stakeholder participation. Where trade-offs must be made, decision-makers must consider and make explicit the consequences of all options. Better trade-offs from policies that remove perverse incentives and /or create markets for biodiversity protection can achieve a given level of biodiversity protection (regionally) at lower cost.

The "ecosystem approach", described in detail in documents of the CBD, provides principles for integration across scales and across different responses. Central to its rationale is that "the full range of measures is applied in a continuum from strictly protected to human-made ecosystems" and that integration can be achieved through both spatial and temporal separation across the landscape, as well as through integration within a site. The MA sub-global assessments highlight useful synergies and trade-offs where different responses are integrated into a coherent regional framework. While some effective approaches will not require quantification of biodiversity gains, quantifying marginal gains/losses from different sources can strengthen such integration and enable one strategy to be used to complement another in a targeted, strategic, way.

There is a tremendous scope for minimizing the actual biodiversity loss associated with a given habitat change through systematic conservation planning. In any region facing habitat loss, some portions of that habitat will be of greater value for conserving various components of biodiversity than other regions. And, some regions will also provide synergistic benefits of biodiversity conservation and the protection of important ecosystem services. Systematic conservation planning methods that weigh trade-offs and synergies (R5.2) can be used to identify sites for conservation and sites for conversion that can minimize overall biodiversity loss in the face of habitat loss. In particular, regionally designed response strategy that make use of systematic planning and multiple policy instruments (such as protected areas plus targeted conservation payments) have proved to be effective in several cases in significantly reducing that amount of biodiversity that would otherwise have been lost to development in the region.

Society may receive greater net benefits when opportunity costs of conservation in a place are adjusted to reflect positive gains from ecosystem services provided; and when setting of biodiversity targets takes all land/water use contributions into account. Debates about the relative value of formal protected areas versus lands that are more intensely used by people but that conserve (at least some) components of biodiversity are more constructive when conservation is seen as a continuum of possibilities. Weaknesses of both ends of the spectrum can be overcome by linking them in integrated regional strategies. For example, an area converted to agriculture can lead to loss of biodiversity, but can still contribute to regional biodiversity if it contributes certain complementary elements of biodiversity to overall regional biodiversity conservation. Formal protected areas are criticized for foreclosing other opportunities for society, but an integrated regional approach can build on the biodiversity protection gains from the surrounding lands, thereby reducing some of the pressure for biodiversity protection in the face of other anticipated uses over the region. Many contributions to overall biodiversity protection are made from production or other off-reserve lands, and integration allows these contributions to be credited at the regional planning scale and increase regional net benefits. But this ideal of measurable gains from production lands should not reduce the more general efforts to mainstream biodiversity into other sectors; even without formal estimates of complementarity values, mainstreaming policies can be seen as important aspects of integration.

Many of the responses designed with the conservation of biodiversity or ecosystem service as the primary goal will not be sustainable or sufficient unless other indirect and direct drivers of change are addressed. For example, the sustainability of protected areas will be severely threatened by human caused climate change. Similarly, the management of ecosystem services cannot be sustainable globally if the growth in consumption of services continues unabated. From the standpoint of decision-makers focused on the goal of the conservation and sustainable use of biodiversity, it is likely to be most cost effective to encourage the establishment of responses to drivers that have the most direct impact on biodiversity rather than on the entire array of indirect and direct drivers of change. Responses addressing other direct and indirect drivers that would be particularly important for biodiversity and ecosystem services are needed that address the following issues:

- *Elimination of subsidies that promote excessive use of specific ecosystem services*. Subsidies paid to the agricultural sectors of OECD countries between 2001 and 2003 averaged over US$324 billion annually, or one third the global value of agricultural products in 2000. (S7ES) These subsidies lead to over-production, reduce the profitability of agriculture in developing countries, and promote overuse of fertilizers and pesticides. Similar problems are created by fishery subsidies which amounted to approximately $6.2 billion in OECD countries in 2002, or about 20 percent of the gross value of production. (S7ES) Removal of perverse subsidies will not be without costs. Reduced subsidies within OECD countries will lessen pressure on some ecosystems in these countries, but could lead to more rapid conversion of land to agriculture in developing countries. And compensation mechanisms will be required for the poor who may be adversely affected by the immediate removal of subsidies.
- *Promotion of sustainable intensification of agriculture*. Agricultural expansion will continue to be one of the major drivers of biodiversity loss well into the 21st century. Development, assessment and diffusion of technologies that could sustainably increase the production of food per unit area would significantly lessen pressure on biodiversity.
- *Slowing climate change*. Based on the current understanding of the climate system, and the response of different ecological and socio-economic systems, if significant global adverse changes to ecosystems are to be avoided, the best guidance that can currently be given suggests that efforts be made to limit the increase in global mean surface temperature to 2oC above pre-industrial levels and limit the rate of change to less than 0.2oC per decade. This will require that the atmospheric concentration of carbon dioxide be limited to about 450 ppm and the emissions of other greenhouse gases stabilized or reduced. (R13.ES)
- *Slowing the global growth in nutrient loading (even while increasing nutrient application in relatively poor regions such as Sub-Saharan Africa).* Technologies already exist for reduction of nutrient pollution at reasonable costs but new policies are needed for these tools to be applied on a sufficient scale to slow and ultimately reverse the increase in nutrient loading. (R9)
- *Correction of market failures and internalization of environmental externalities that lead to the degradation of ecosystem services*. (R17, R10, R13) Because many ecosystem services are not traded in markets, markets fail to provide appropriate signals that might otherwise contribute to the efficient allocation and sustainable use of the services. In addition, many of the harmful trade-offs and costs associated with the management of one ecosystem service are borne by others and so too do not weigh into decisions regarding the management of that service. In countries with supportive institutions in place, market based tools can be used to correct some market failures and internalize externalities, particularly with respect to provisioning ecosystem services.
- *Integration of biodiversity conservation strategies and responses within broader development planning frameworks*. For example, protected areas, restoration ecology and markets for ecosystem services will have higher chances of success if these responses are reflected in the national development strategies or in poverty reduction strategies in the case of many developing countries. In this manner, the costs and benefits of these conservation strategies and their contribution to human development are explicitly recognized in the Public Expenditure Review and

resources for the implementation of the responses can be set aside in the Mid-Term Budgetary Framework.

Box 5.1. Key factors of successful responses to biodiversity loss

- ***Mobilize Knowledge.*** Ensure that the available knowledge is presented in ways that can be used by decision-makers.
- ***Recognize complexity.*** Responses must serve multiple objectives and /or sectors; they must be integrated.
- ***Acknowledge uncertainty.*** In choosing responses, understand the limits to current knowledge, and expect the unexpected.
- ***Enable natural feedbacks.*** Avoid creating artificial feedbacks that are detrimental to system resilience.
- ***Be made through an inclusive process.*** Make information available and understandable to a wide range of affected stakeholders.
- ***Enhance adaptive capacity.*** Resilience is increased if institutional frameworks are put in place which allow and promote the capacity to learn from past responses and adapt accordingly.
- ***Establish supporting instrumental freedoms.*** Responses do not work in a vacuum and it is therefore critical to identify the necessary supporting instrumental freedoms needed in order for the response to work efficiently and equitably.
- ***Establish legal frameworks***: A legally binding agreement is generally likely to have a much stronger effect than a soft law agreement.
- ***Clear definitions***: Agreements with clear definitions and unambiguous language will be easier to implement.
- ***Principles:*** Clear principles can help guide the parties to reach future agreement and guide the implementation of an agreement.
- ***An elaboration of obligations and appropriate rights***: An agreement with a clear elaboration of obligations and rights is more likely to be implemented.
- ***Financial resources***: Availability of financial resources increases the opportunities for implementation.
- ***Mechanisms for implementation***: Where financial resources are not sufficient, market mechanisms may increase the potential for implementation.
- ***Establishment of implementing and monitoring agencies***. The establishment of subsidiary bodies with authority and resources to undertake specific activities to enhance the implementation of the agreements is vital to ensure continuity and preparation and follow-up to complex issues.
- ***Good links with scientific bodies***: As ecological issues become more complex, it becomes increasingly important to establish good institutional links between the legal process and the scientific community.
- ***Integrate traditional and scientific knowledge.*** Identify opportunities for incorporating traditional and local knowledge in designing responses.

6. What are the prospects for reducing the rate of loss of biodiversity by 2010 or beyond, and other implications for the Convention on Biological Diversity?

Biodiversity will continue to decline during this century. While biodiversity makes important contributions to human well-being, many of the actions needed to promote economic development and reduce the number of people living on less than a dollar a day are likely to reduce biodiversity. These make policy changes necessary to reverse these trends unlikely in the short term. However since biodiversity is essential to human well being and survival, biodiversity loss has to be controlled in the long term. A reduction in the rate of loss of biodiversity is a necessary first step. Progress in this regard can be achieved by 2010 for some components, but it is unlikely that it can be achieved for biodiversity overall at the global level by 2010.

Many of the necessary actions to reduce the rate of biodiversity loss are already incorporated into the programs of work of the Convention on Biological Diversity and if fully implemented they would make a substantial difference. Even if existing measures are implemented, this would be insufficient to address all of the drivers of biodiversity loss.

In April 2002, the Conference of the Parties of the Convention on Biological Diversity adopted the target, subsequently endorsed in the Johannesburg Plan of Implementation adopted at the World Summit on Sustainable Development, to "*achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional, and national level as a contribution to poverty alleviation and to the benefit of all life on earth*" (CBD Decision VI/26). In 2004, the Conference of the Parties adopted a framework for evaluation including a small number of global 2010 sub-targets and a set of indicators which will be used in assessing progress. For the purposes of assessing progress towards the target, the Conference of the Parties defines biodiversity loss as the long-term or permanent qualitative or quantitative reduction in components of biodiversity and their potential to provide goods and services, to be measured at global, regional and national levels (CBD Decision VII/30). The objectives of the Convention and the 2010 target are translated into policies and concrete action through the agreement of international guidelines and the implementation of work programs of the Convention and National Biodiversity Strategies and Action Plans.

An unprecedented effort would be necessary to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional, and national levels. The 2010 target implies that, to be achieved, the rate of loss of biodiversity – as indicated by measures of a range of components or attributes – would need to be significantly less in 2010 than the current or recent trends described in Chapter 3 of this report (Figure 6.1). This is unlikely to be achieved globally for various reasons: current trends show few indications of slowing rate of loss; most of the direct drivers of biodiversity loss are projected to increase; and inertia in natural and human institutional systems implies lags – of years, decades or even centuries – between actions taken and their impact on biodiversity and ecosystems.

<< Insert Figure 6.1 >>

With appropriate responses at global, regional, and especially national level, it is possible to achieve, by 2010, a reduction in rate of biodiversity loss for certain components of biodiversity (or for certain indicators), and in certain regions, and several of the 2010 sub-targets adopted by the CBD could be met. Overall the rate of habitat loss – the main driver of biodiversity loss in terrestrial ecosystems -- is slowing in certain regions and could slow globally if proactive approaches are taken (S10). This may not necessarily translate into lower rates of species loss however, because (i) the nature of the relationship between numbers of species and area of habitat (ii) decades or centuries may pass before species extinctions reach equilibrium with habitat loss; and (iii) other drivers of loss, such as climate change, nutrient loading and invasive species, are projected to increase. While rates of habitat loss are decreasing in temperate areas, they are projected to continue to increase in tropical areas. (C4; S11; R). At the same time, if areas of particular importance for biodiversity and functioning ecological networks are maintained within protected areas or by other conservation mechanisms, and if proactive measures are taken to protect endangered species, then the rate of biodiversity loss of the targeted habitats and species could be reduced. Further, it would be possible to achieve many of the sub-targets aimed at protecting the components of biodiversity if the response options that are already incorporated into the programs of work of the CBD are implemented. However, it appears highly unlikely that the sub-targets aimed at addressing threats to biodiversity (land use change; climate change, pollution and invasive alien species) could be achieved by 2010. It will also be a major challenge to maintain goods and services from biodiversity to support human well-being. (see Table 6.1.) (R)

<< Insert Table 6.1 >>

There is substantial scope for greater protection of biodiversity through actions justified on their economic merits for material or other benefits to human well-being. Conservation of biodiversity is essential as a source of particular biological resources, to maintain different ecosystem services, to maintain the resilience of ecosystems, and to provide options for the future. These benefits that biodiversity provides to people have not been well reflected in decision-making and resource management and thus the current rate of loss of biodiversity is higher than what it would be had these benefits been taken into account. (See Figure 6.2.)

<< Insert figure 6.2 >>

However, the total amount of biodiversity that would be conserved based strictly on utilitarian considerations is likely to be less than the amount present today (*medium certainty*). Even if utilitarian benefits were fully taken into account, the planet would still be losing biodiversity. Other utilitarian benefits often 'compete' with the benefits of maintaining greater diversity and on balance the level of diversity that would exist would be less than that present today. Many of the steps taken to increase the production of ecosystem services require the simplification of natural systems (e.g., agriculture). And, protecting some other ecosystem services may not necessarily require the conservation of biodiversity. (For example, a forested watershed could provide clean water whether it was covered in a diverse native forest or in a single-species plantation.) Ultimately, the level of biodiversity that survives on Earth will be determined to a significant extent by ethical concerns including considerations of intrinsic values of species.

Trade-offs between achieving the 2015 targets of the Millennium Development Goals (MDGs) and reducing the rate of biodiversity loss are likely. **For a reduction in the rate of biodiversity loss to contribute to poverty alleviation, priority would need to be given to protecting the biological diversity of particular importance to the well-being of poor and vulnerable people.** Long term sustainable achievement of the Millennium Development Goals requires that biodiversity loss is controlled as part of MDG7 – ensure environmental sustainability, even though it is not possible at present to define "how much biodiversity" is necessary or desirable. However, there are both potential synergies and trade-offs between the shorter-term targets of achieving the 2015 targets of the MDGs and reducing the rate of loss of biodiversity by 2010. For example, one of the MA scenarios that showed relatively good progress toward a number of the MDG targets such as eradicating extreme poverty and health gains (*Global Orchestration)* also showed relatively high rates of habitat loss and the second highest rate of biodiversity loss. (Figure 6.3) However, some short-term improvements in material welfare and livelihoods that are derived from actions that lead to the loss of biodiversity that is of particular importance to the poor and vulnerable may actually make these gains temporary and in fact exacerbate all constituents of poverty in the long term. To avoid this, efforts for the conservation and sustainable use of biodiversity need to be integrated into countries' strategies for poverty reduction.

<< Insert Figure 6.3 >>

Given the characteristic response times for human (politico-socio-economic) systems and ecological systems longer term goals and targets (e.g., for 2050) are needed to guide policy and actions in addition to short term targets. Biodiversity loss is projected to continue for the foreseeable future (S10). The ultimate drivers of biodiversity loss are related to economic, demographic, socio-political, cultural and technological factors. Consumption of ecosystems services, and of energy and no-renewable resources, impacts, directly and indirectly, on biodiversity and ecosystems. Total consumption is a factor of per capita consumption, population and efficiency of natural resource use. Halting biodiversity loss (or reducing it to a minimal level) requires that the combined effect of these factors in driving biodiversity loss be reduced. Differences in the inertia of different drivers of biodiversity change and different attributes of biodiversity itself make it difficult to set targets or goals over a single time frame. For some drivers, such as the over-harvest of particular species, lag times are rather short, for others such as nutrient loading and, especially, climate change, lag times are much longer. Addressing the indirect drivers of change may also require somewhat longer time horizons given the politic-socio-economic and demographic inertias. Population is projected to stabilize around the middle of the century and then decrease. Attention also needs to be given to addressing unsustainable consumption patterns

A very wide array of possible futures for biodiversity remains within the choices of people and decision-makers today and these different futures have very different implications for human well-being and for future generations. The world in 2100 could have substantial remaining biodiversity or could be relatively homogenized and contain relatively low levels of diversity. Sites that are globally important for biodiversity sites could be protected while locally or nationally important biodiversity lost. Biodiversity important for utilitarian concerns and ecosystem services could be protected, while biodiversity of intrinsic value lost. Multiple objectives for biodiversity will thus be necessary to produce the pattern and distribution of biodiversity that would be most desirable. Science can help to inform the costs and benefits of these different futures and identify paths to achieve those futures (plus risks and thresholds), but ultimately the choice of biodiversity futures must be determined by society.

Figure 6.1. Hypothetical approach to measuring achievement of the 2010 target. For indicators of the status of components of biodiversity, a trend line could be fitted to existing data (filled circles), and projected to 2010 giving a "business as usual" projection (BAU: open circle on the trend line). In 2010, any point that is significantly above this BAU projection would signal achievement of the target for that component of biodiversity. In practice, the lack availability of sufficient time series data and the difficulty of aggregating different measures of biodiversity condition, make such calculations difficult.

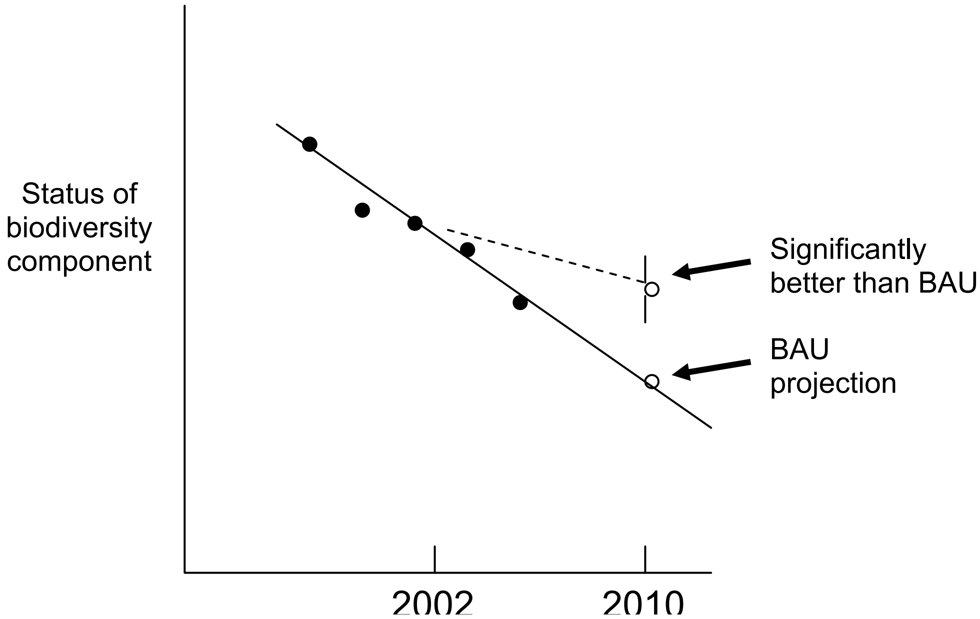


Figure 6.2. How much biodiversity will remain? The level of biodiversity present on the planet today will decline significantly by the end of the century under the policies and practices in place today. The height of the bar in the figure below represents the level or amount of biodiversity. The solid arrow shows the likely loss of biodiversity between today and 2100 under current policies and practices. Given the technologies available today, some loss of biodiversity is an inevitable result of trade-offs with other important human needs. Land converted to agriculture over the last several decades and likely to be converted over the next several decades, for example, will result in both local and global species extinctions during the century. However, the full costs and risks associated with biodiversity loss are not currently considered in management and resource use decisions and as a result relatively more biodiversity is lost than actually would be justified on utilitarian grounds. If instead, the importance of biodiversity for ecosystem services was factored into decisions, then more biodiversity would persist through the end of the century. And if the full benefits of the added capability that biodiversity will provide in adapting to change, avoiding unwanted threshold changes, and serving as a source of future options were also added, still more biodiversity would be conserved on utilitarian grounds. Even so, strictly utilitarian considerations are not likely to be sufficient to justify the protection of all current biodiversity in the face of other utilitarian needs that are sometimes in conflict with biodiversity conservation. For some elements of biodiversity such as species diversity, however, some people feel that even beyond the utilitarian role of biodiversity, even more conservation is justified because of the intrinsic value of species – that other species have as much 'right' to exist on the planet as humans.

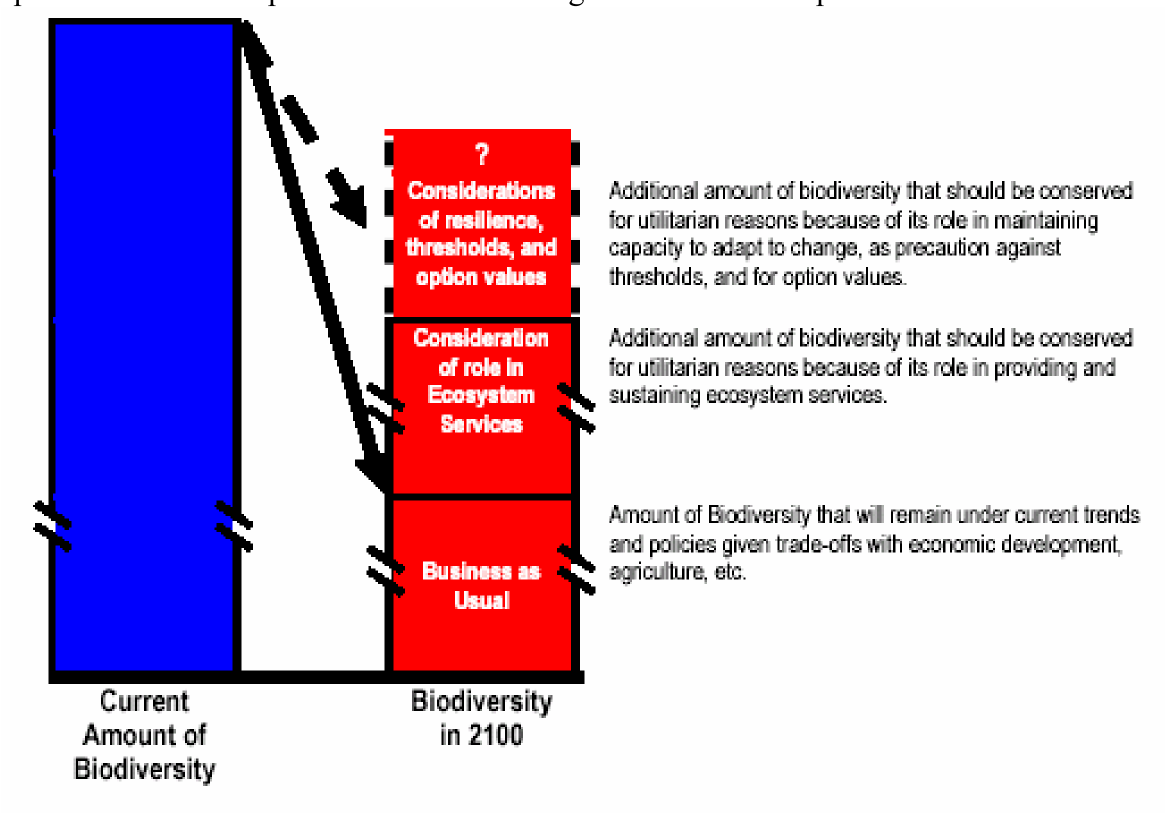


Figure 6.3. Tradeoffs between promoting human well-being and limiting biodiversity loss under the MA scenarios to 2050. Loss of biodiversity is least in the two scenarios that feature a proactive approach to environmental management (*Technogarden* (TG) and *Adaptive Mosaic* (AM)) while the *Global Orchestration* (GO) scenario does most to promote human well-being and achieves the fastest progress towards the Millennium Development Goals of eradicating hunger and extreme poverty. The *Order from Strength* (OS) scenario performs badly by both sets of objectives.

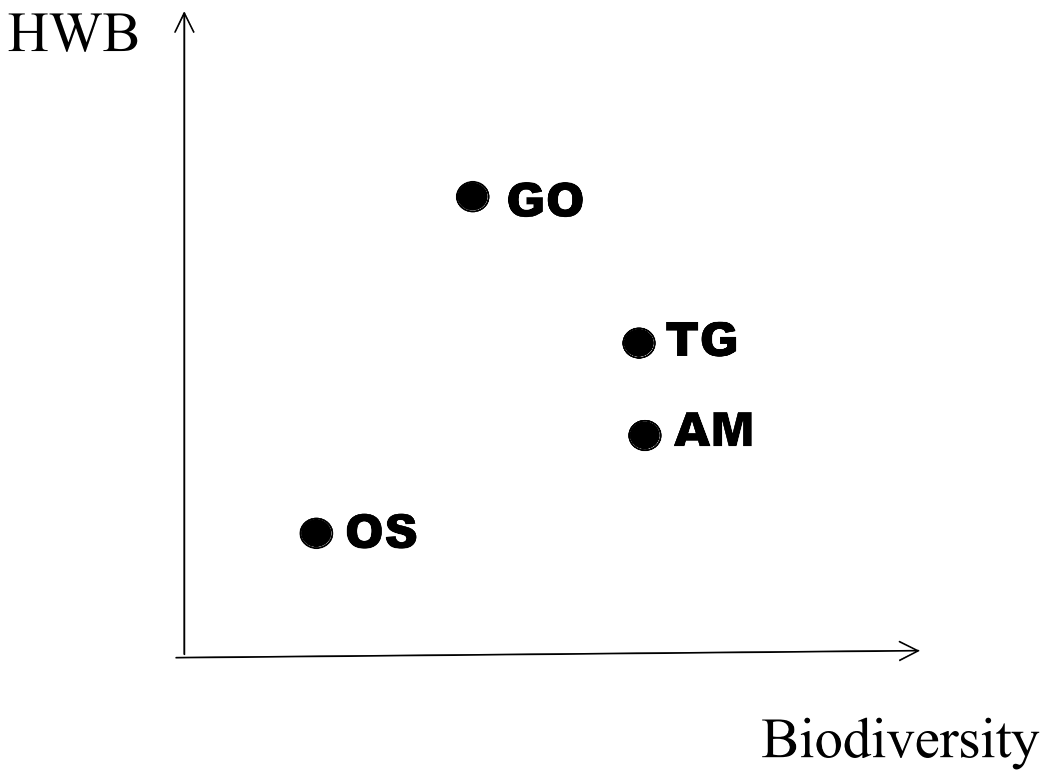


Table 6.1 Prospects for attaining the 2010 sub-targets agreed to under the Convention on Biological Diversity

Goals and Targets	Prospects for progress by 2010
Protect the components of biodiversity	
Goal 1. Promote the conservation of the biological diversity of ecosystems, habitats and biomes Target 1.1: At least 10% of each of the world's ecological regions effectively conserved. Target 1.2: Areas of particular importance to biodiversity protected	*Good prospects for most terrestrial regions. Major challenge to achieve for marine regions. Difficult to provide adequate protection of inland water systems.*
Goal 2. Promote the conservation of species diversity Target 2.1: Restore, maintain, or reduce the decline of populations of species of selected taxonomic groups Target 2.2: Status of threatened species improved.	*Many species will continue to decline in abundance and distribution, but restoration and maintenance of priority species possible.* *More species will become threatened, but species-based actions will improve status of some.*
Goal 3. Promote the conservation of genetic diversity Target 3.1: Genetic diversity of crops, livestock, and of harvested species of trees, fish and wildlife and other valuable species conserved, and associated indigenous and local knowledge maintained.	*Good prospects for ex situ conservation. Overall, agricultural systems likely to continue to be simplified. Significant losses of fish genetic diversity likely. Genetic resources* in situ *and traditional knowledge will be protected through some projects, but likely to decline overall*
Promote sustainable use	
***Goal 4. Promote sustainable use and consumption*.**	
Target 4.1: Biodiversity-based products derived from sources that are sustainably managed, and Production areas managed consistent with the conservation of biodiversity.	*Progress expected for some components of biodiversity. Sustainable use is unlikely to be a large share of total products and production areas*
Target 4.2 Unsustainable consumption, of biological resources, or that impacts upon biodiversity, reduced	*Unsustainable consumption likely to increase*
Target 4.3:No species of wild flora or fauna endangered by international trade	*Progress possible, for example through implementation of the Convention on International Trade in Endangered Species (CITES).*
Address threats to biodiversity	
Goal 5. Pressures from habitat loss, land use change and degradation, and unsustainable water use, reduced. Target 5.1: Rate of loss and degradation of natural habitats decreased	*Unlikely to reduce overall pressures in the most biodiversity-sensitive regions. However, pro-active protection of some of the most important sites is possible*

Goal 6. Control threats from invasive alien species Target 6.1: Pathways for major potential alien invasive species controlled. Target 6. 2: Management plans in place for major alien species that threaten ecosystems, habitats or species.	*Pressure is likely to increase (from greater transport, trade and tourism, especially in GO scenario). Measures to address major pathways could be put in place (especially in GO and TG scenarios).* *Management plans could be developed.*
Goal 7. Address challenges to biodiversity from climate change, and pollution Target 7.1: Maintain and enhance resilience of the components of biodiversity to adapt to climate change Target 7.2: Reduce pollution and its impacts on biodiversity	*Pressures from both climate change and Pollution, especially N deposition will increase. These increases can be mitigated, under UNFCCC for climate change, and through agricultural and trade policy, as well as energy policy for N pollution. Mitigation measures include C sequestration through LULUCF and use of wetlands to sequester or denitrify reactive N.* *Proactive measures to reduce impacts on biodiversity possible, but challenging given other pressures.*
6.1.1.1 Maintain goods and services from biodiversity to support human well-being	
Goal 8. Maintain capacity of ecosystems to deliver goods and services and support livelihoods Target 8.1: Capacity of ecosystems to deliver goods and services maintained. Target 8.2: biological resources that support sustainable livelihoods, local food security and health care, especially of poor people maintained	*Given expected increases in drivers can probably be achieved only on a selective basis by 2010. Attainment of target 8.2 would contribute to the achievement of the MDG 2015 targets, especially targets 1, 2 and 9*
Protect traditional knowledge, innovations and practices	
Goal 9 Maintain socio-cultural diversity of indigenous and local communities Target 9.1 Protect traditional knowledge, innovations and practices Target 9.2: Protect the rights of indigenous and local communities over their traditional knowledge, innovations and practices, including their rights to benefit sharing	*Possible to take measures to protect traditional knowledge and rights, but continued long term decline in traditional knowledge likely*
Ensure the fair and equitable sharing of benefits arising out of the use of genetic resources	
Goal 10. Ensure the fair and equitable sharing of benefits arising out of the use of genetic resources Target 10.1: All transfers of genetic resources are in line with the Convention on Biological Diversity, the International Treaty on Plant Genetic Resources for Food and Agriculture and other applicable agreements.	*Progress is possible. In the MA scenarios, more equitable outcomes were obtained under the Global Orchestration and Technogarden Scenarios, but were not achieved under the Order from Strength Scenario.*

Target 10.2: Benefits arising from the commercial and other utilization of genetic resources shared with the countries providing such resources	
Ensure provision of adequate resources	
Goal 11: Parties have improved financial, human, scientific, technical and technological capacity to implement the Convention Target 11.1: New and additional financial resources are transferred to developing country Parties, to allow for the effective implementation of their commitments under the Convention, in accordance with Article 20. *Target 11.2: Technology is transferred to developing country Parties, to allow for the effective implementation of their commitments under the Convention, in accordance with its Article 20, paragraph*	*Progress is possible. In the MA scenarios, this outcome would be more likely under the Global Orchestration and Technogarden Scenarios, but would not be achieved under the Order from Strength Scenario.*

Annex I: Table of Contents of Assessment Reports

Conceptual Framework – *Ecosystems and Human Well-being: A Framework for Assessment* [1]

Condition and Trends Report

[1] Text references to CF, CWG, SWG, RWG, or SGWG refer to the entire working group reports.

Scenarios Report

Responses Report

Combined index of soil and vegetation degradation per

Sub-Global Report

SG.01	Introduction
SG.02	Ecosystem Services and Human Well-being
SG.03	Multi-Scale Approach
SG.04	Knowledge Systems
SG.05	Assessment Process
SG.06	Drivers of Ecosystem Change
SG.07	Condition and Trends
SG.08	Responses
SG.09	Scenarios
SG.10	Community Assessments
SG.11	Synthesis

Sub-Global Assessments

SG-SAfMA	Southern Africa Millennium Ecosystem Assessment
SG-Portugal	Portugal Millennium Ecosystem Assessment