Chapter **5**

Biodiversity

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Main messages

Biodiversity provides the basis for ecosystems and the services they provide, upon which all people fundamentally depend. The following are the main messages of this chapter:

People rely on biodiversity in their daily lives, often without realizing it. Biodiversity contributes to many aspects of people's livelihoods and well-being, providing products, such as food and fibres, whose values are widely recognized. However, biodiversity underpins a much wider range of services, many of which are currently undervalued. The bacteria and microbes that transform waste into usable products, insects that pollinate crops and flowers, coral reefs and mangroves that protect coastlines, and the biologically-rich landscapes and seascapes that provide enjoyment are only a few. Although much more remains to be understood about the relationships between biodiversity and ecosystem services, it is well established that if the products and services that are provided by biodiversity are not managed effectively, future options will become ever more restricted, for rich and poor people alike. However, poor people tend to be the most directly affected by the deterioration or loss of ecosystem services, as they are the most dependent on local ecosystems, and often live in places most vulnerable to ecosystem change.

Current losses of biodiversity are restricting future development options. Ecosystems are being transformed, and, in some cases, irreversibly degraded, a large number of species have gone extinct in recent history or are threatened with extinction, reductions in populations are widespread and genetic diversity is widely considered to be in decline. It is well established that changes to biodiversity currently underway on land and in the world's fresh and marine waters are more rapid than at any time in human history, and have led to a degradation in many of the world's ecosystem services.

Reducing the rate of loss of biodiversity, and ensuring that decisions made incorporate the full values of goods-and-services provided by biodiversity will contribute substantially towards achieving sustainable development as described in the report of the World Commission on Environment and Development (Brundtland Commission report).

- **Biodiversity plays a critical role in providing livelihood security for people.** It is particularly important for the livelihoods of the rural poor, and for regulating local environmental conditions. Functioning ecosystems are crucial as buffers against extreme climate events, as carbon sinks, and as filters for water-borne and airborne pollutants.
- **From the use of genetic resources to harnessing other ecosystem services, agriculture throughout the world is dependent on biodiversity.** Agriculture is also the largest driver of genetic erosion, species loss and conversion of natural habitats. Meeting increasing global food needs will require one or both of two approaches: intensification and extensification. Intensification is based on higher or more efficient use of inputs, such as more efficient breeds and crops, agrochemicals, energy and water. Extensification requires converting increasing additional areas of land to cultivation. Both approaches have the potential to dramatically and negatively affect biodiversity. In addition, the loss of diversity in agricultural ecosystems may undermine the ecosystem services necessary to sustain agriculture, such as pollination and soil nutrient cycling.
- **Many of the factors leading to the accelerating loss of biodiversity are linked to the increasing use of energy**

by society. Dependence on and growing requirements for energy are resulting in significant changes in species and ecosystems, as a result of the search for energy sources and of current energy use patterns. The consequences can be seen at all levels: locally, where the availability of traditional biomass energy is under threat, nationally, where energy prices affect government policies, and globally, where climate change driven by fossil-fuel use is changing species ranges and behaviour. The latter is likely to have very significant consequences for livelihoods, including changing patterns of human infectious disease distribution, and increased opportunities for invasive alien species.

- **Human health is affected by changes in biodiversity and ecosystem services.** Changes to the environment have altered disease patterns and human exposure to disease outbreaks. In addition, current patterns of farming, based on high resource inputs (such as water and fertilizers) and agricultural intensification, are putting great strains on ecosystems, contributing to nutritional imbalances and reduced access to wild foods.
- **Human societies everywhere have depended on biodiversity for cultural identity, spirituality, inspiration, aesthetic enjoyment and recreation.** Culture can also play a key role in the conservation and sustainable use of biodiversity. Loss of biodiversity affects both material and non-material human well-being. Both the continued loss of biodiversity and the disruption of cultural integrity represent obstacles towards the attainment of the Millennium Development Goals (MDGs).

Biodiversity loss continues because current policies and economic systems do not incorporate the values of biodiversity effectively in either the political or the market systems, and many current policies are not fully implemented. Although many losses of biodiversity, including the degradation of ecosystems, are slow or gradual, they can lead to sudden and dramatic declines in the capacity of biodiversity to contribute to human well-being. Modern societies can continue to develop without further loss of biodiversity only if market and policy failures are rectified. These failures include perverse production subsidies, undervaluation of biological resources, failure to internalize environmental costs into prices and failure to appreciate global values at the local level. Reducing the rate of biodiversity loss by 2010 or beyond will require multiple and mutually supportive policies of conservation, sustainable use and the effective recognition of value for the benefits derived from the wide variety of life on Earth. Some such policies are already in place at local, national and international scales, but their full implementation remains elusive.

INTRODUCTION

The understanding of the importance of biodiversity has developed in the 20 years since the report of the World Commission on Environment and Development (Brundtland Commission). There is increased recognition that people are part of, not separate from, the ecosystems in which they live, and are affected by changes in ecosystems, populations of species and genetic changes. Along with human health and wealth, human security and culture are strongly affected by changes in biodiversity, and associated impacts on ecosystem services.

As the basis for all ecosystem services, and the foundation for truly sustainable development, biodiversity plays fundamental roles in maintaining and enhancing the well-being of the world's more than 6.7 billion people, rich and poor, rural and urban alike. Biodiversity comprises much of the renewable natural capital on which livelihoods and development are grounded. However, ongoing, and in many cases, accelerating declines and losses in biodiversity over the past 20 years have decreased the capacity of many ecosystems to provide services, and have had profound negative impacts on opportunities for sustainable development around the planet. These impacts are particularly pronounced in the developing world, in large part due to the patterns of consumption and trade in the industrial world, which themselves are not sustainable.

If future concerns are not taken into account, and the products and services provided by biodiversity are not managed effectively, future options become limited or are eliminated, for rich and poor people alike. While technological alternatives to some of the services provided by biodiversity are available, they are typically more costly, compared to the benefits derived from well-managed ecosystems. Biodiversity loss particularly affects the poor, who are most directly dependent on ecosystem services at the local scale, and are unable to pay for alternatives. Although the private, more restricted, financial benefits of activities that result in the loss of biodiversity, such as the conversion of mangroves to aquaculture enterprises, are usually high, they often externalize many of the social and environmental costs. The overall benefits are frequently considerably less than the societal, more distributed, benefits that are lost along with the biodiversity, but for which the monetary value is often not known. For example, the loss of mangrove ecosystems contributes to declining fisheries, timber and fuel, the reduction of storm protection, and increased vulnerability to the impacts of extreme events.

In addition to the values of biodiversity for the supply of particular ecosystem services, biodiversity also has intrinsic value, independent from its functions and other benefits to people (see Box 5.1). The challenge is to balance the cultural, economic, social and environmental values so that the biodiversity of today is conserved and used in a manner that will allow it to be available for and to sustain the generations of the future. Biodiversity management and policies have an impact upon all sectors of society, and have strong cross-cultural and cross-boundary implications. Policies relating to issues such as trade, transport, development, security, health care and education all have impacts on biodiversity. Discussions on access and benefit sharing relating to genetic resources, one of the provisions of the UN Convention on Biological Diversity (CBD), show that understanding the full value of biodiversity is not simple. In addition to the gaps remaining in the understanding of biodiversity and ecosystem functioning, each individual stakeholder may hold different values for the same attribute of biodiversity. Building a fuller understanding of these values will require considerable additional research, and increasingly comprehensive, interdisciplinary and quantified assessments of the benefits that biodiversity provides to people's health, wealth and security.

Box 5.1 Life on Earth

Biodiversity is the variety of life on Earth. It includes diversity at the genetic level, such as that between individuals in a population or between plant varieties, the diversity of species, and the diversity of ecosystems and habitats. Biodiversity encompasses more than just variation in appearance and composition. It includes diversity in abundance (such as the number of genes, individuals, populations or habitats in a particular location), distribution (across locations and through time) and in behaviour, including interactions among the components of biodiversity, such as between pollinator species and plants, or between predators and prey. Biodiversity also incorporates human cultural diversity, which can be affected by the same drivers as biodiversity, and which has impacts on the diversity of genes, other species and ecosystems.

Biodiversity has evolved over the last 3.8 billion years or so of the planet's approximately 5 billion-year history. Although five major extinction events have been recorded over this period, the large number and variety of genes, species and ecosystems in existence today are the ones with which human societies have developed, and on which people depend.

The relationships among biodiversity and the five main themes assessed in this chapter – livelihood security, agriculture, energy, health and culture – clearly demonstrate the importance of biodiversity to these aspects of human well-being. Biodiversity forms the basis of agriculture, and enables the production of foods, both wild and cultivated, contributing to the health and nutrition of all people. Genetic resources have enabled past and current crop and livestock improvements, and will enable future ones, and allow for flexibility according to market demand and adaptation according to changing environmental conditions. Wild biodiversity is perhaps of greatest direct importance to the one billion people around the world who live a subsistence lifestyle. The decline of this diversity has considerable implications for their health, culture and livelihoods. Supporting services, such as nutrient cycling and soil formation, and regulating services, such as pest and disease control, flood regulation and pollination, underpin successful agricultural systems, and contribute to livelihood security.

Cultural ecosystem services are being increasingly recognized as key determinants of human well-being, including through the maintenance of cultural traditions, cultural identity and spirituality. Among the wide range of other benefits from biodiversity, it has enabled the production of energy from biomass and fossil fuels. Such use of biodiversity has brought tremendous benefit to many people (see Box 5.2), but has had

Box 5.2 Value of biodiversity and ecosystem services

The supply of ecosystem services depends on many attributes of biodiversity. The variety, quantity, quality, dynamics and distribution of biodiversity that is required to enable ecosystems to function, and the supplying benefits to people, vary between services. The roles of biodiversity in the supply of ecosystem services can be categorized as provisioning, regulating, cultural and supporting (see Chapter 1), and biodiversity may play multiple roles in the supply of these types of services. For example, in agriculture, biodiversity is the basis for a provisioning service (food, fuel or fibre is the end product), a supporting service (such as micro-organisms cycling nutrients and soil formation), a regulatory service (such as through pollination), and potentially, a cultural service in terms of spiritual or aesthetic benefits, or cultural identity.

The contributions of biodiversity-dependent ecosystem services to national economies are substantial. The science of valuation of ecosystem services is new, and still developing basic conceptual and methodological rigour and agreement, but it has already been very instructive, since the value of such services is generally ignored or underestimated at decision and policy making levels. Identifying economic values of ecosystem services, together with the notions of intrinsic value and other factors, will assist significantly in future decisions relating to trade-offs in ecosystem management.

Value of:

- Annual world fish catch – US$58 billion (provisioning service).
- Anti-cancer agents from marine organisms – up to US$1 billion/year (provisioning service).
- Global herbal medicine market – roughly US$43 billion in 2001 (provisioning service).
- Honeybees as pollinators for agriculture crops – US$2–8 billion/year (regulating service).
- Coral reefs for fisheries and tourism – US$30 billion/year (see Box 5.5) (cultural service).

Honey bees (*Apis mellifera, Apis mellifica*) provide regulatory services through pollination.

Credit: J. Kottmann/WILDLIFE/Still Pictures

Cost of:

- Mangrove degradation in Pakistan – US$20 million in fishing losses, US$500 000 in timber losses, US$1.5 million in feed and pasture losses (regulating provisioning services).
- Newfoundland cod fishery collapse – US$2 billion and tens of thousands of jobs (provisioning service).

Of those ecosystem services that have been assessed, about 60 per cent are degraded or used unsustainably, including fisheries, waste treatment and detoxification, water purification, natural hazard protection, regulation of air quality, regulation of regional and local climate, and erosion control (see Chapters 2, 3, 4 and 6). Most have been directly affected by an increase in demand for specific provisioning services, such as fisheries, wild meat, water, timber, fibre and fuel.

Sources: Emerton and Bos 2004, FAO 2004, MA 2005, Nabhan and Buchmann 1997, UNEP 2006a, WHO 2001 some significant negative knock-on effects in the form of human-induced climate change, and habitat conversion. These trade-offs, inherent in so much of biodiversity use, are becoming increasingly apparent, as there are greater demands for ecosystem services.

People directly use only a very small percentage of biodiversity. Agriculture reduces diversity to increase productivity for a component of biodiversity of particular interest. However, people rely indirectly on a much larger amount of biodiversity without realizing it. There are bacteria and microbes that transform waste into usable products, insects that pollinate crops and flowers, and biologically diverse landscapes that provide inspiration and enjoyment around the world. Such ecosystem services, or the benefits derived from biodiversity, are ultimately dependent on functioning ecosystems. However, the amount of biodiversity required to enable ecosystems to function effectively varies enormously, and how much biodiversity is needed for the sustainable supply of ecosystem services in the present, and into the future, remains largely unknown.

Despite the critical need for more effective conservation and sustainable use, the loss of biodiversity continues, and in many areas is currently increasing in magnitude. Rates of species extinction are 100 times higher than the baseline rate shown by the fossil record (see Box 5.3). The losses are due to a range of pressures, including land-use change and habitat degradation, overexploitation of resources, pollution and the spread of invasive alien species. These pressures are themselves driven by a range of socio-economic drivers, chiefly the growing human population and associated increases in global consumption of resources and energy, and the inequity associated with high levels of per capita consumption in developed countries.

Box 5.3 The sixth extinction

All available evidence points to a sixth major extinction event currently underway. Unlike the previous five events, which were due to natural disasters and planetary change (see Box 5.1), the current loss of biodiversity is mainly due to human activities. The current rapid rates of habitat and landscape changes and modifications, increased rates of species extinction, and the reduction in genetic variability due to population declines, are having impacts on natural processes and on the needs of people. The details of many of these impacts remain uncertain, but their major negative influences can be foreseen and avoided or mitigated.

Responses to the continuing loss of biodiversity are varied, and include further designation of protected areas, and, increasingly, the improved management for biodiversity in production landscapes and seascapes. There are recent signs of an emerging consensus that biodiversity conservation and sustainable development are inextricably linked, as for example illustrated by the endorsement by the 2002 Johannesburg World Summit on Sustainable Development (WSSD) of the CBD's 2010 target, and its subsequent incorporation into the Millennium Development Goals.

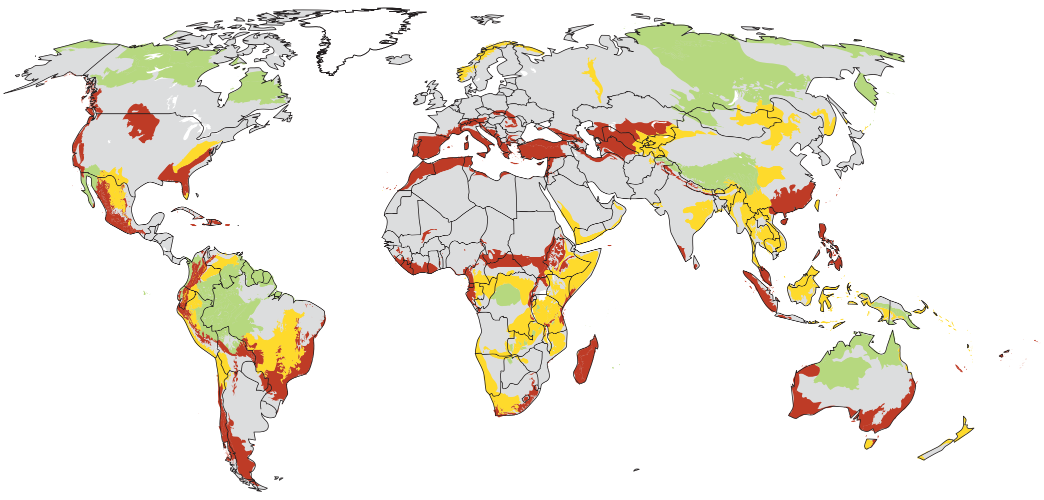
GLOBAL OVERVIEW OF THE STATUS OF BIODIVERSITY

Ecosystems

Ecosystems vary greatly in size and composition, ranging from a small community of microbes in a drop of water, to the entire Amazon rain forest. The very existence of people, and that of the millions of species with which the planet is shared, is dependent on the health of our ecosystems. People are putting increasing strain on the world's terrestrial and aquatic ecosystems (see Chapters 3 and 4). Despite the importance of ecosystems, they are being modified in extent and composition by people at an unprecedented rate, with little understanding of the implications this will have in terms of their ability to function and provide services in the future (MA 2005). Figure 5.1 depicts an analysis of the status of terrestrial ecosystems.

For more than half of the world's 14 biomes, 20–50 per cent of their surface areas have already been converted to croplands (Olson and others 2001). Tropical dry broadleaf forests have undergone the most rapid conversion since 1950, followed by temperate grasslands, flooded grasslands and savannahs. Approximately 50 per cent of inland water habitats are speculated to have been transformed for human use during the twentieth century (Finlayson and D'Cruz 2005) (see Chapter 4). Some 60 per cent of the world's major rivers have been fragmented by dams and diversions (Revenga and others 2000), reducing biodiversity as a result of flooding of habitats, disruption of flow patterns, isolation of animal populations and blocking of migration routes. River systems are also being significantly affected by water withdrawals, leaving some major rivers nearly or completely dry. In the marine realm, particularly threatened ecosystems include coral reefs and seamounts (see Box 5.4).

Figure 5.1 Status of terrestrial ecoregions



Note: An ecoregion is a large unit of land containing a geographically distinct assemblage of species, natural communities, and environmental conditions.

Source: WWF 2006

Box 5.4 Deep-sea biodiversity

The deep sea is increasingly recognized as a major reservoir of biodiversity, comparable to the biodiversity associated with tropical rain forests and shallow-water coral reefs. The wealth of diverse deep-sea habitats – hydrothermal vents, cold seeps, seamounts, submarine canyons, abyssal plains, oceanic trenches and recently-discovered asphalt volcanoes – contain a vast array of unique ecosystems and endemic species. Although the magnitude of deep-sea diversity is not yet understood (only 0.0001 per cent of the deep seabed has been subject to biological investigations), it has been estimated that the number of species inhabiting the deep sea may be as high as 10 million. It is believed that the deep seabed supports more species than all other marine environments. Marine biodiversity and ecosystems are threatened by pollution, shipping, military activities and climate change, but today fishing presents the greatest threat. The emergence of new fishing technologies and markets for deep-sea fish products has enabled fishing vessels to begin exploiting these diverse, but poorly understood deep-sea ecosystems.

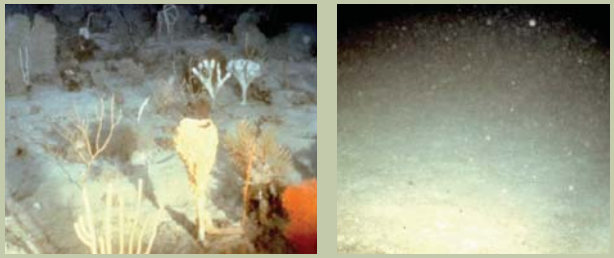
The greatest threat to biodiversity in the deep sea is bottom trawling. This type of high seas fishing is most damaging to seamounts and the coldwater corals they sustain. These habitats are home for several commercial bottom-dwelling fish species. Seamounts are also important spawning and feeding grounds for species, such as marine mammals, sharks and tuna, which make them very attractive fishing grounds. The long life cycles and slow sexual maturation of deep-sea fish make them particularly vulnerable to large-scale fishing activities. The lack of data on deep-sea ecosystems and associated biodiversity makes it difficult to predict and control the impacts of human activities, but current levels of bottom trawling on the high seas is unlikely to be sustainable, and may even be unsustainable at greatly reduced levels.

Effective management measures for deep-sea fisheries and biodiversity need to be established. Conservation of marine ecosystems has recently extended to the deep sea with the designation in 2003 of the Juan de Fuca Ridge system and associated Endeavour Hydrothermal Vents (2 250 metres deep and 250 kilometres south of Vancouver Island, Canada) as a marine protected area. There are several mechanisms to conserve deep seas, such as the 1982 UN Convention of the Law of the Sea (UNCLOS), 1995 UN Fish Stocks Agreement (UNFSA), International Seabed Authority (ISA), 1992 Convention on Biological Diversity (CBD) and the 1973 Convention on Trade in Endangered Species (CITES). However, these mechanisms need more effective implementation if deep-sea ecosystems are to be conserved and sustainably used.

Sources: Gianni 2004, UNEP 2006b, WWF and IUCN 2001

Examples of species inhabiting the deep sea. False boarfish, *Neocytlus helgae* (left) and cold water coral, *Lophelia* (right).

Credit: Deep Atlantic Stepping Stones Science Party, IFE, URI-IAO and NOAA (left), UNEP 2006b (right)



The seafloor off Northwest Australia showing dense populations of corals and sponges before trawling (left) and after trawling (right).

Credit: Keith Sainsbury, CSIRO

The fragmentation of ecosystems is increasingly affecting species, particularly migratory species that need a contiguous network of sites for their migratory journeys, species that rely on particular microhabitats and those that require multiple types of habitats during different life cycle stages.

Species

Although about 2 million species have been described, the total number of species range between 5 and 30 million (IUCN 2006, May 1992). Much of this uncertainty relates to the most species-rich groups such as invertebrates.

Current documented rates of extinction are estimated to be roughly 100 times higher than typical rates in the fossil record (MA 2005). Although conservation success in the recovery of several threatened species has been noted (IUCN 2006), and a few species that were presumed extinct have been rediscovered (Baillie and others 2004), it is feasible that extinction rates will increase to the order of 1 000–10 000 times background rates over the coming decades (MA 2005).

Fewer than 10 per cent of the world's described species have thus far been assessed to determine their conservation status. Of these, over 16 000 species have been identified as threatened with extinction. Of the major vertebrate groups that have been comprehensively assessed, over 30 per cent of amphibians, 23 per cent of mammals and 12 per cent of birds are threatened (IUCN 2006).

To understand trends in extinction risk, the conservation status of an entire species group must be assessed at regular intervals. Currently, this information is only available for birds and amphibians, both of which indicate a continuing increase in the risk of extinction from the 1980s to 2004 (Baillie and others 2004, Butchart and others 2005, IUCN 2006).

The threat status of species is not evenly distributed. Tropical moist forests contain by far the highest number of threatened species, followed by tropical dry forests, montane grasslands and dry shrublands. The distribution of threatened species in freshwater habitats is poorly known, but regional assessments from the United States, the Mediterranean Basin and elsewhere indicate that freshwater species are, in general, at much greater risk of extinction than terrestrial taxa (Smith and Darwall 2006, Stein and others 2000). Fisheries have also been greatly depleted, with 75 per cent of the world's fish stocks fully or overexploited (see Chapter 4).

The Living Planet Index measures trends in the abundance of species for which data is available around the world (Loh and Wackernagel 2004). Despite the fact that invertebrates comprise the vast majority of species, trend indices for invertebrate groups only exist for a very small number of species groups, such as butterflies in Europe (Van Swaay 1990, Thomas and others 2004a). The existing limited information suggests that invertebrate and vertebrate population declines may be similar, but further studies are required (Thomas and others 2004b).

Invertebrates, including butterflies, comprise the vast majority of species.

Credit: Ngoma Photos

Genes

Genetic diversity provides the basis for adaptation, allowing living organisms to respond to natural selection, and adapt to their environment. Genes therefore play a strong role in the resilience of biodiversity to global changes, such as climate change or novel diseases. Genes also provide direct benefits to people, such as the genetic material needed for improving yield and disease resistance of crops (see the Agriculture section) or for developing medicines and other products (see the Health and Energy sections).

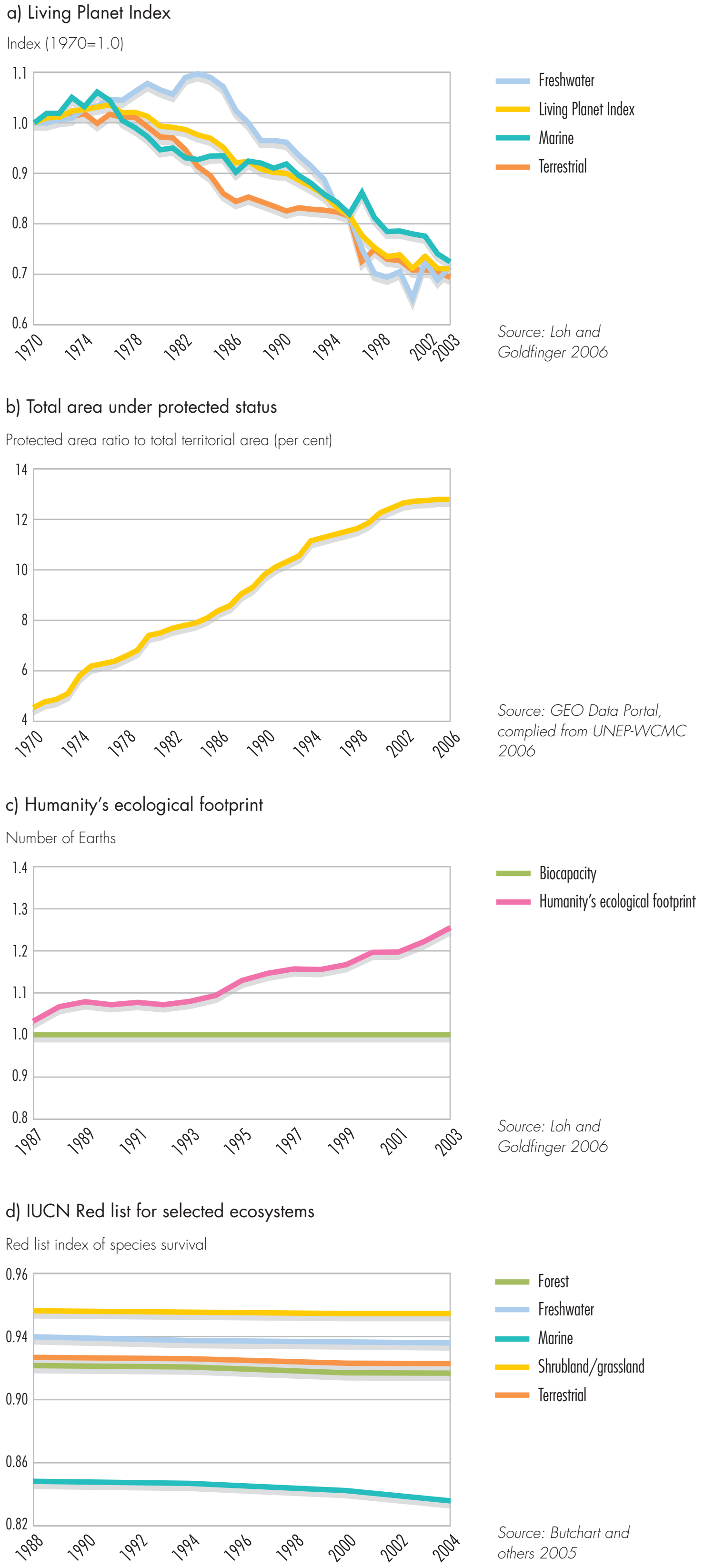
Over the past two decades, many of the world's most important agricultural crops have lost genetic diversity due to changes in agricultural practices (Heal and others 2002). The continued loss of genetic diversity of such crops may have major implications on food security (see Agriculture section). The amount or rate of loss of genetic diversity is poorly known, but inferences can be made from documented extinctions and population declines, which suggest that substantial genetic loss is occurring (IUCN 2006).

Global responses to curb biodiversity loss

In 2002, parties to the CBD committed themselves to actions to "achieve, by 2010, a significant reduction of the current rate of biodiversity loss at the global, regional and national levels as a contribution to poverty alleviation and to the benefit of all life on earth" (Decision VI/26, CBD Strategic Plan). Setting this target has helped to highlight the need for improved biodiversity indicators, capable of measuring trends in a range of aspects of global biodiversity. It has also helped to galvanize the scientific community to try to develop indicators capable of measuring trends in the various aspects or levels of biodiversity. Figure 5.2 provides a sample of global biodiversity indicators that will be used to measure progress towards the 2010 target. They measure trends in vertebrate populations, extinction risks for birds, global consumption and the establishment of protected areas (SCBD 2006).

The population and extinction risk indices demonstrate a continuing decline in biodiversity, and the ecological footprint indicates that consumption is rapidly and unsustainably increasing. These trends do not bode well for meeting the 2010 biodiversity target at

Figure 5.2 Examples of state, pressure and response indicators that have been adopted by the Convention on Biological Diversity to measure progress towards the 2010 target



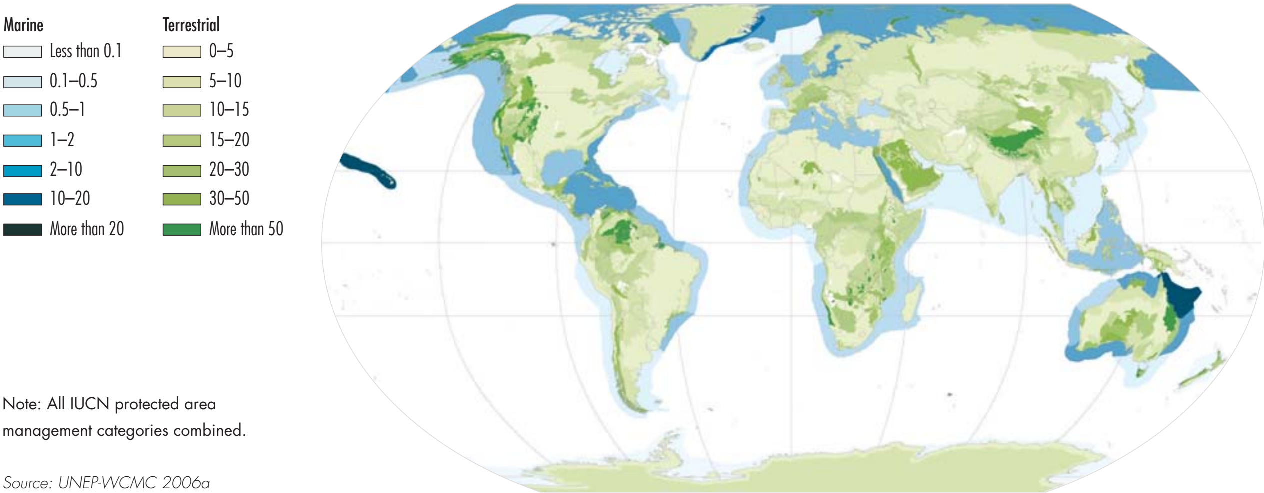
a global scale. Responses to the continuing loss of biodiversity are varied, and include further designation of land and areas of water within protected areas, and increasingly, the improved management for biodiversity in production landscapes and seascapes. The protected areas coverage indicator demonstrates a promising trend in the form of a steady increase in the area under protection.

During the past 20 years, the number of protected areas grew by over 22 000 (Chape and others 2005) and currently stands at more than 115 000 (WDPA 2006). However, the number of protected areas and their coverage can be misleading indicators of conservation (especially for marine areas), as their establishment is not necessarily followed by effective management and enforcement of regulations (Mora and others 2006, Rodrigues and others 2004). Also the percentage and degree to which each ecosystem is protected varies greatly. Roughly 12 per cent of the world's land surface is included within some kind of protected area, but less than one per cent of the world's marine ecosystems are protected, with the Great Barrier Reef and the northwestern Hawaiian islands making up one-third the area of all marine protected areas (Figure 5.3) (Chape and others 2005, SCBD 2006).

In addition to ensuring the effective management of protected areas, emphasis will increasingly need to be placed on the conservation of biodiversity outside protected areas, and in conjunction with other land uses if the rate of loss of biodiversity is to be reduced. The establishment of new policies and processes at all scales, the re-emergence of sustainable agricultural practices, the further development of collaboration among sectors, including corporate partnerships between conservation organizations and extractive industries, and the mainstreaming of biodiversity issues into all areas of decision making, will all contribute to a more secure future for biodiversity, and for sustainable development.

Over the last 20 years environmental issues have increasingly been recognized as important in the development sector at a global scale. The commitment by parties to the CBD to achieve a significant reduction in the rate of biodiversity loss by 2010 as a contribution to poverty alleviation and the benefit of all life on Earth, the endorsement by the 2002 Johannesburg World Summit on Sustainable Development (WSSD) of the CBD's 2010 target, and the incorporation of the 2010 biodiversity target into the Millennium Development Goals as a new target under Goal 7 on environmental sustainability are some examples. A framework for action was proposed at WSSD to implement sustainable development policies, which covered five key areas (water, energy, health, agriculture and biodiversity), This "WEHAB" framework provided a focus, and confirmed the recognition of biodiversity as a key component of the sustainable development agenda.

Figure 5.3 Degree of protection of terrestrial ecoregions and large marine ecosystems (per cent)



Note: All IUCN protected area management categories combined.

Source: UNEP-WCMC 2006a

DRIVERS OF CHANGE AND PRESSURES

Currently, population growth and patterns of consumption, which lead to increased demand for ecosystem services and energy, are the most important drivers affecting biodiversity. These drivers result in pressures that have direct impacts on ecosystems, species and genetic resources (see Table 5.1). Human activities cause changes in both the living and non-living components of ecosystems, and these pressures have increased dramatically over the past few decades.

Drivers and pressures seldom act in isolation. They tend to interact in synergistic ways, and their impacts on biodiversity are more than the sum of the effects of the individual drivers and pressures themselves (MA 2005). Additionally, the interaction shows considerable regional variation (see Chapter 6). Drivers and pressures act at different temporal and spatial scales. For example, sediments from deforestation in the headwaters of the Orinoco River, deep in South America, have impacts far out in the Wider Caribbean Sea basin, changing the nutrient availability and turbidity of the waters (Hu and others 2004).

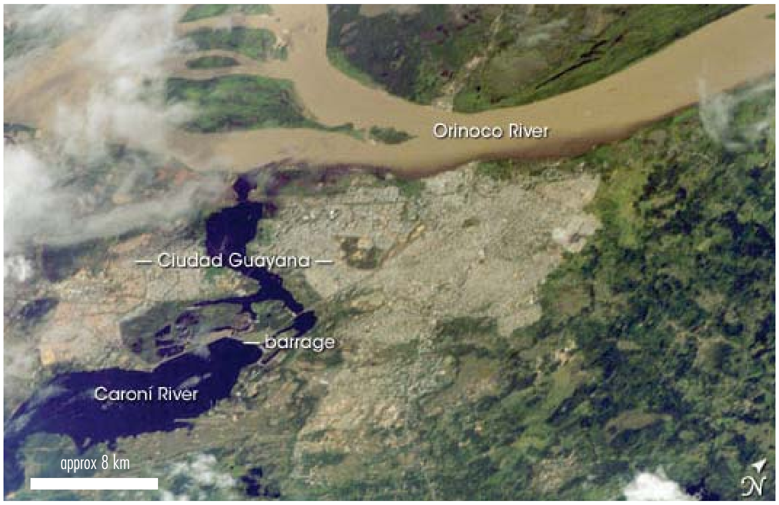
Since the Brundtland Commission report, the globalization of agriculture and inappropriate agricultural policies have emerged as leading drivers influencing the loss of species and ecosystem services. Globalization is leading to major changes in where, how and who produces food and other agricultural commodities. Global market demand for high value commodities such as soybeans, coffee, cotton, oil palm, horticultural crops and biofuels has resulted in substantial habitat conversion and ecosystem degradation. This has replaced diverse smallholder farms with larger monoculture enterprises. In other cases, globalization has concentrated and intensified production on the most productive lands, reducing net deforestation rates.

Virtually all of the factors leading to the accelerating loss of biodiversity are linked to the development of and increasing demand for energy by society. Of particular importance are the high levels of per capita energy use in the developed world, and the potential growth in energy use in the large emerging economies. The rapid increase in demand for energy has profound impacts on biodiversity at two levels (Guruswamy and McNeely 1998, Wilson 2002): impacts from the production and distribution of energy, and those resulting from the use of energy. Exploration for hydrocarbons, pipeline construction, uranium and coal mining, hydroelectric dam construction, harvesting for fuelwood and, increasingly, biofuel plantations can all lead to significant biodiversity loss, both on land and at sea.

Deforestation in Serra Parima, Orinoco River basin.

Credit: Mark Edwards/Still Pictures

The widespread anthropogenic changes to the environment have altered patterns of human disease, and increased pressures on human well-being. The loss of genetic diversity, overcrowding and habitat fragmentation all increase susceptibility to disease outbreaks (Lafferty and Gerber 2002). Some ecosystem changes create new habitat niches for disease vectors, for example, increasing the risk of malaria in Africa and the Amazon Basin (Vittor and others 2006).



The Orinoco River carries sediment that originates from land degradation far away in the Andes all the way to the Caribbean. By contrast, the Caroní river water is clear blue, as it drains the ancient landscapes of the Guyana Highlands, where erosion is much slower.

Credit: NASA 2005

Trends in biodiversity over the next few decades will largely depend on human actions, especially those relating to land-use changes, energy production and conservation. These actions will, in turn, be affected by various factors including advances in our understanding of ecosystem services, development of viable alternatives to natural resources (especially fossil fuels), and the emphasis placed on the environment and conservation by developed and developing country governments alike. Efforts made to predict the prospects for species-level biodiversity have indicated that extinctions are likely to continue at a pace well above the background rate, with as many as 3.5 per cent of the world's birds (BirdLife International 2000), and perhaps a greater proportion of amphibians and freshwater fish, being lost or committed to extinction by the middle of the century.

Climate change is likely to play an increasing role in driving changes in biodiversity, with species' distributions and relative abundances shifting as their preferred climates move towards the poles and higher altitudes, leaving those endemic to polar and high mountain regions most at risk. In addition, changes in the ranges of vector species may facilitate the spread of diseases affecting humans and other species, for example, malaria and the amphibian fungal disease, chytridiomycosis.

Further pressure on biodiversity will result from the continuing increase in the global human population, which is predicted to reach 8 billion by 2025 (GEO Data Portal, from UNPD 2007). All will require access to food and water, leading to an unavoidable increase in stresses on natural resources. The increased infrastructure required to support such a global population of more than 8 billion people will likely have particular effects on biodiversity in the future (see Chapter 9). The increased need for agricultural production to feed the population will likely be met largely by commercial intensification, with negative consequences for the genetic diversity of agricultural crops and livestock. Extensification will also help to meet the need, with a predicted additional 120 million hectares required by 2030 in developing countries, including lands of high biodiversity value (Bruinsma 2003).

Tropical forests are the terrestrial system likely to be the most affected by human actions in the first half of this century, largely through habitat conversion for agricultural expansion (including the growth of biofuel plantations). Ongoing fragmentation will result in the degradation of the largest remaining areas of species-rich forest blocks in Amazonia and the Congo basin. Marine and coastal ecosystems are also expected to continue to be degraded, with existing impacts, such as fishing, eutrophication from terrestrial activities and coastal conversion for aquaculture, increasing (Jenkins 2003). Large species, including top predators, will be particularly affected, with considerable declines and some extinctions likely.

Changes, both positive and negative, in biodiversity trends over the next few decades are inevitable, yet the details of these changes are not yet set in stone. Their magnitude can be somewhat reduced and mitigated by the further integration of biodiversity considerations into national policies, increasing corporate social responsibility activities and conservation actions. With commitment from governments, the private sector, scientific institutions and civil society, action can be taken to ensure progress towards the CBD 2010 target, the Millennium Development Goals, and beyond.

The *Telestes polylepis*, a critically endangered freshwater species found in Croatia.

Credit: Jörg Freyhof

ENVIRONMENTAL TRENDS AND RESPONSES

Biodiversity is closely linked to livelihood security, agriculture, energy, health and culture, the five themes analysed in this chapter. Of these themes, agriculture (in terms of food security) and energy were explicitly considered in the Brundtland Commission report, and with a focus on water and health, tie together the WEHAB framework for action arising from WSSD. These linkages are likely to emerge as the most critical in implementing actions that will result in truly sustainable development. Table 5.1 summarizes some of the impacts of major drivers on biodiversity, ecosystems and human well-being.

LIVELIHOOD SECURITY

Ecosystems provide critical services

Biodiversity contributes directly and indirectly to livelihood security (MA 2005). Functioning ecosystems are crucial buffers against extreme climate events, and act as carbon sinks and filters for water-borne and airborne pollutants. For example, the frequency of shallow landslides appears to be strongly related to vegetation cover, as roots play an important role in slope stability, and can give the soil mechanical support at shallow depth. In coastal areas, mangroves and other wetlands are particularly effective in providing shoreline stability, reducing erosion, trapping sediments, toxins and

Table 5.1 Impacts on biodiversity of major pressures and associated effects on ecosystem services and human well-being

Pressures	Impacts on biodiversity	Potential implications for ecosystem services and human well-being	Examples
Habitat conversion	■ Decrease in natural habitat ■ Homogenization of species composition ■ Fragmentation of landscapes ■ Soil degradation	■ Increased agricultural production ■ Loss of water regulation potential ■ Reliance on fewer species ■ Decreased fisheries ■ Decreased coastal protection ■ Loss of traditional knowledge	Between 1990 and 1997, about 6 million hectares of tropical humid forest were lost annually. Deforestation trends differ from region to region, with the highest rates in Southeast Asia, followed by Africa and Latin America. Additionally, about 2 million ha of forest are visibly degraded each year (Achard and others 2002). (See Chapter 3.)
Invasive alien species	■ Competition with and predation on native species ■ Changes in ecosystem function ■ Extinctions ■ Homogenization ■ Genetic contamination	■ Loss of traditionally available resources ■ Loss of potentially useful species ■ Losses in food production ■ Increased costs for agriculture, forestry, fisheries, water management and human health ■ Disruption of water transport	The comb jelly, *Mnemiopsis leidyi*, accidentally introduced in 1982 by ships from the US Atlantic coast, dominated the entire marine ecosystem in the Black Sea, directly competing with native fish for food, and resulting in the destruction of 26 commercial fisheries by 1992 (Shiganova and Vadim 2002).
Overexploitation	■ Extinctions and decreased populations ■ Alien species introduced after resource depletion ■ Homogenization and changes in ecosystem functioning	■ Decreased availability of resources ■ Decreased income earning potential ■ Increased environmental risk (decreased resilience) ■ Spread of diseases from animals to people	An estimated 1–3.4 million tonnes of wild meat (bushmeat) are harvested annually from the Congo Basin. This is believed to be six times the sustainable rate. The wild meat trade is a large, but often invisible contributor to the national economies dependent on this resource. It was recently estimated that the value of the trade in Côte d'Ivoire was US$150 million/year, representing 1.4 per cent of the GNP (POST 2005). (For more on overexploitation of fish stocks, see Chapter 4.)
Climate change	■ Extinctions ■ Expansion or contraction of species ranges ■ Changes in species compositions and interactions	■ Changes in resource availability ■ Spread of diseases to new ranges ■ Changes in the characteristics of protected areas ■ Changes in resilience of ecosystems	Polar marine ecosystems are very sensitive to climate change, because a small increase in temperature changes the thickness and amount of sea ice on which many species depend. The livelihoods of indigenous populations living in sub-arctic environments and subsisting on marine mammals are threatened, since the exploitation of marine resources is directly linked to the seasonality of sea ice (Smetacek and Nicol 2005). (For more on climate change, see Chapter 2.)
Pollution	■ Higher mortality rates ■ Nutrient loading ■ Acidification	■ Decreased resilience of service ■ Decrease in productivity of service ■ Loss of coastal protection, with the degradation of reefs and mangroves ■ Eutrophication, anoxic waterbodies leading to loss of fisheries	Over 90 per cent of land in the EU-25 countries in Europe is affected by nitrogen pollution greater than the calculated critical loads. This triggers eutrophication, and the associated increases in algal blooms and impacts on biodiversity, fisheries and aquaculture (De Jonge and others 2002). (See Chapters 4 and 6.)

Source: Adapted from MA 2005

Pita, *Aechmea magdalane*, a thorny-leaved terrestrial bromeliad, grows naturally in lowland forests of southeast Mexico. It is harvested for the commercial extraction of fibre used in the stiching and embroidering of leatherwork. One hectare of forest can provide up to 20 kilogrammes of pita fibre per year, generating an average cash income of US$1 000/ha.

Credit: Elaine Marshall

nutrients, and acting as wind and wave breaks to buffer against storms. The role of inland wetlands in storing water and regulating stream-flow is both a function of their vegetative composition, which helps to maintain soil structure, and their characteristically gentle slopes.

Current trends in land degradation and habitat loss continue to contribute to reducing livelihood options while heightening risks. Changes in land management, particularly the replacement of fire-adapted systems with other forms of land cover, can increase the intensity and extent of fires, increasing the hazard to people. Land-use change also influences climate at local, regional and global scales. Forests, shrub and grasslands, freshwater and coastal ecosystems provide critical sources of food and complementary sources of income (see Box 5.2). Fish and wild meat provide animal protein, while other forest resources provide dietary supplements. These ecosystem goods act as critical safety nets for millions of rural poor. Traditionally, access rights and tenure arrangements for these public goods have evolved to enable equitable distribution of such extractive activities. More recently, due to increased population densities and the introduction of market models, access to these common property resources has been increasingly restricted, with resulting impacts on rural livelihoods. With reliable access to markets, the commercialization of many wild-harvested products can be extremely successful in contributing to sustaining rural livelihoods (Marshall and others 2006).

Box 5.5 Coral reefs in the Caribbean

The global net value of coral reefs relating to fisheries, coastal protection, tourism and biodiversity, is estimated to total US$29.8 billion/year. However, nearly two-thirds of Caribbean coral reefs are reported to be threatened by human activities. The predominant pressure in the region is overfishing, which affects approximately 60 per cent of Caribbean reefs. Other pressures include large quantities of dust originating from deserts in Africa, which are blown across the Atlantic Ocean and settle on reefs in the Caribbean, leading to significant coral mortality. It has been proposed that this phenomenon led to a coral bleaching event that began in 1987, correlating with one of the years of maximum dust flux into the Caribbean. Coral degradation has negative impacts on coastal communities, including the loss of fishing livelihoods, protein deficiencies, loss of tourism revenue and increased coastal erosion.

Sources: Burke and Maidens 2004, Cesar and Chong 2004, Griffin and others 2002, MA 2005, Shinn and others 2000

Environmental degradation, combined with heightened exposure and vulnerability of human settlements to risk, contributes to vulnerability to disasters. Almost 2 billion people were affected by disasters in the last decade of the 20th century, 86 per cent of them due to floods and droughts (EM-DAT). Long spells of drought associated with the El Niño Southern Oscillation phenomenon (ENSO) contributed to forest fires in the Amazon Basin, Indonesia and Central America in 1997–1998. In Indonesia alone, an estimated 45 600 square kilometres of forest were destroyed (UNEP 1999). In Central America, the loss of over 15 000 km^2 of forests due to wildfires reduced the capacities of natural forests to buffer the impacts of heavy rainfall and hurricanes, and contributed to the devastating impact of Hurricane Mitch in 1998 (Girot 2001). These impacts spread beyond the tropics, as the large forest fires of California, Spain, Portugal and other Mediterranean countries in 2005 illustrated (EFFIS 2005). Furthermore, coral degradation has negative impacts on coastal communities (see Box 5.5).

The clustering of climate-related and biological risks will also contribute to impacts on human well-being through events such as heat waves and crop failures. The impact on human health has been addressed in greater detail in the Health section.

Ecosystems minimize risks

The linkages between biodiversity and livelihood security are complex, and based on the intrinsic relationship between societies and their environment. Policies that can address both the risks and opportunities posed by rapid environmental changes will require a combined focus on ecosystem management, sustainable livelihoods and local risk management. For example, policies aimed at the improved management of water resources and the non-structural mitigation of weather-related hazards can contribute to the reduction of disaster risks by enhancing landscape restoration, coastal forest management and local conservation and sustainable use initiatives. In coastal ecosystems, restoring mangroves in cyclone-prone areas increases physical protection against storms, creates a reservoir for carbon sequestration and increases livelihood options by generating much-needed income for local communities (MA 2005). Although the evidence base is varied, communities hit by the 2004 tsunami in South Asia reported less damage in areas with healthy mangrove forests than those with few natural sea defences (Dahdouh-Guebas and others 2005). India and Bangladesh have come to recognize the importance of the Sunderbans mangrove forest in the Gulf of Bengal, not only as a source of livelihoods for fishing communities, but also as an effective mechanism for coastal protection. Viet Nam is also investing in mangrove restoration as a cost-effective means for increased coastal protection (see Box 5.6). Similar benefits can be derived from coral reefs (UNEP-WCMC 2006b).

Box 5.6 Mangrove restoration for buffering storm surges in Viet Nam

In Viet Nam, tropical cyclones have caused a considerable loss of livelihood resources, particularly in coastal communities. Mangrove ecosystem rehabilitation along much of Viet Nam's coastline is an example of a cost-effective approach to improving coastal defences while generating local livelihoods. Since 1994, the Viet Nam National Chapter of the Red Cross has worked with local communities to plant and protect mangrove forests in northern Viet Nam. Nearly 120 km^2 of mangroves have been planted, with substantial resulting benefits. Although planting and protecting the mangroves cost approximately US$1.1 million, it saved US$7.3 million/year in dyke maintenance.

During the devastating typhoon Wukong in 2000, project areas remained unharmed, while neighbouring provinces suffered huge losses in lives, property and livelihoods. The Viet Nam Red Cross has estimated that some 7 750 families have benefited from mangrove rehabilitation. Family members can now earn additional income from selling crabs, shrimp and molluscs, while increasing the protein in their diets.

Source: IIED 2003

AGRICULTURE

Links between biodiversity and agriculture

Agriculture is defined broadly here to include crops and agroforestry products, livestock and fisheries production. Of some 270 000 known species of higher plants about 10 000–15 000 are edible, and about 7 000 of them are used in agriculture. However, increased globalization threatens to diminish the varieties that are traditionally used in most agricultural systems. For example, only 14 animal species currently account for 90 per cent of all livestock production, and only 30 crops dominate global agriculture, providing an estimated 90 per cent of the calories consumed by the world's population (FAO 1998). Despite its crucial importance in supporting societies, agriculture remains the largest driver of genetic erosion, species loss and conversion of natural habitats around the world (MA 2005) (see Figure 5.4).

Figure 5.4 Contemporary extent of agricultural systems

Agriculture <20% of land area or no growing season

Ratio of cropland vs grazing land

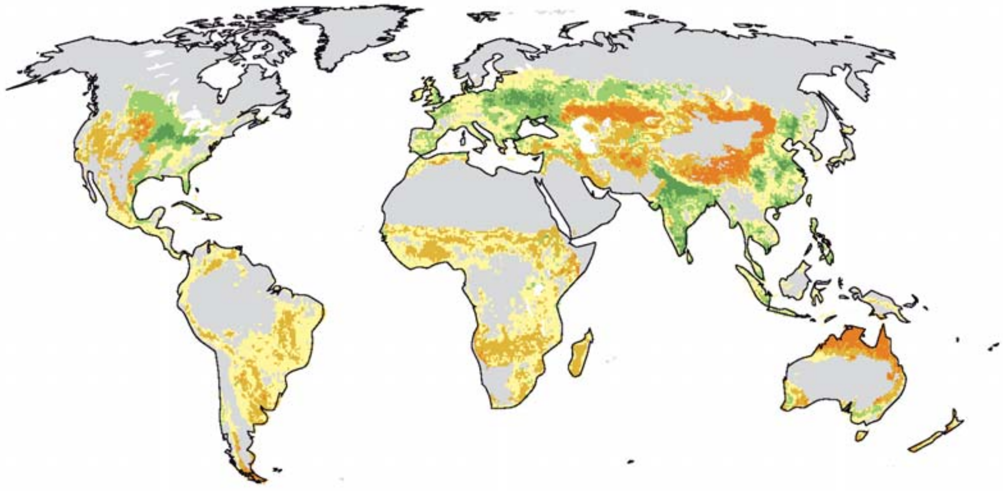
Cropland/grazing land mosaic

Cropland, > 50%

Cropland, > 85%

Grazing land, > 50%

Grazing land, > 85%



Sources: Re-drawn from Sebastian 2006, derived from FAO and IIASA 2000, Ramankutty 2002, Ramankutty 2005, and Sieber and others 2006

Both cultivated and wild biodiversity provide services necessary for agriculture (see Table 5.2). Although seldom valued in economic terms, these services play a very significant role in national and regional economies. Different types of agricultural production systems (such as commercial intensive, smallholder, pastoralism and agroforestry systems) use these services to varying degrees and intensity. For example, the use of nitrogen-fixing legume trees in maize-based systems of Eastern and Southern Africa is helping local farming populations to increase per hectare production of maize without otherwise investing in inorganic fertilizers (Sanchez 2002). In addition, environmental benefits are gained through carbon sequestration and provision of fuelwood.

Habitat conversion is often justified as essential to increasing agricultural production, and trends in agricultural land use over the past 20 years are presented in Chapters 3 and 6. Although more than 300 000 km^2 of land have been converted to agricultural use in the tropics alone (Wood and others 2000), much of this is of marginal use for agriculture or particular crops. This has led to inefficient use of resources, often resulting in degradation of land and ecosystem services (see Chapter 3). Some 1.5 billion people, about half of the world's total labour force and nearly one-quarter of the global population, are employed in agriculture, or their livelihoods are directly linked to it (MA 2005), and women make up the majority of agricultural workers. When agriculture on marginal lands is reduced and these lands are appropriately managed, ecosystems can recover, as demonstrated by the expansion of forests in parts of Europe, North America, Japan, China, India, Viet Nam, New Zealand and Latin America (Aide and Grau 2004, Mather and Needle 1998).

Table 5.2 Biodiversity benefits to agriculture through ecosystem services

Provisioning	Regulating	Supporting	Cultural
■ Food and nutrients ■ Fuel ■ Animal feed ■ Medicines ■ Fibres and cloth ■ Materials for industry ■ Genetic material for improved varieties and yields ■ Pollination ■ Pest resistance	■ Pest regulation ■ Erosion control ■ Climate regulation ■ Natural hazard regulation (droughts, floods and fire)	■ Soil formation ■ Soil protection ■ Nutrient cycling ■ Water cycling	■ Sacred groves as food and water sources ■ Agricultural lifestyle varieties ■ Genetic material reservoirs for improved varieties and yields ■ Pollinator sanctuaries ■ Erosion control

Source: MA 2005

Meeting global food needs poses increasing challenges, and will require either intensification or extensification to increase agricultural productivity (Tillman and others 2002). Intensified systems tend to be dominated by only a few varieties. This approach is usually associated with higher levels of inputs, including technology, agrochemicals, energy and water use. The latter three, at least, have serious negative impacts on biodiversity.

Extensification relies on lower inputs, and generally on more land being used, often through habitat conversion. In many parts of the world, agricultural extensification involves converting more land for the cultivation of major commodities such as soybeans (Latin America and the Caribbean), oil palm and rubber (Asia and the Pacific), and coffee (Africa, Latin America and Asia), and it is exacerbated by the emergence of new markets for export. In Brazil, for example, the area of land used for growing soybeans (most of which are exported to China) grew from 117 000 km^2 in 1994 to 210 000 km^2 in 2003. This was driven by a 52 per cent increase in world consumption of soybeans and soybean products (USDA 2004), and these figures continue to rise dramatically.

A major agricultural biotechnology innovation during the past two decades is the use of "transgenic" or living modified organisms (LMOs) to provide new attributes in different crops and breeds (FAO 2004, IAASTD 2007). The technology is very young, and major investments are being made to enhance its contributions to human well-being and business stability. Research on LMOs has focused mainly on mitigating the impacts of pests and diseases, and there is evidence of reduced needs for pesticides and herbicides in some crops, such as cotton and maize, through genetic modification (FAO 2004). The global production of genetically modified crops (mainly maize, soybean and cotton) was estimated to cover more than 900 000 km^2 in 2005 (James 2003). The use of LMOs is, as for many new technologies, highly controversial, specifically in relation to the uncertain impacts on ecosystems (through escape and naturalization in the landscape), human health and social structures. There are concerns about how its introduction will affect poor people, whose livelihoods depend primarily on traditional low input agricultural practices. Increased research, monitoring and regulation are needed to ensure these negative impacts are avoided as this technology is developed (see Chapter 3). The Cartagena Protocol on Biosafety was negotiated and adopted under the CBD to develop a global framework for managing and regulating LMOs (FAO 2004, Kormos 2000).

More recently, increasing attention is being given to the existing and potential impacts of climate change on agriculture. Issues include the timing of growth, flowering and maturing of crops, and the impacts of (and on) pollinators, water resources and the distribution of rainfall. There are also issues of changes in market structures, yields for different crops and strains, and the impacts of extreme weather events on traditional methods and livelihoods (Stige and others 2005). Models show that in some areas, specifically where low temperature is a growth-limiting factor, agricultural productivity may increase with climate change. In other areas, where water and heat are limiting factors, productivity may be severely curtailed (IPCC 2007).

Changes in production practices and loss of diversity in agro-ecosystems can undermine the ecosystem services necessary to sustain agriculture. For example, pollinator diversity and numbers are affected by habitat fragmentation (Aizen and Feinsinger 1994, Aizen and others 2002), agricultural practices (Kremen and others 2002, Partap 2002), the land-use matrix surrounding agricultural areas (De Marco and Coelho 2004, Klein and others 2003) and other land-use changes (Joshi and others 2004). Although some of the crops that supply a significant proportion of the world's major staples do not require animal pollination (such as rice and maize), the decline of pollinators has long-term consequences for those crop species that serve as crucial sources of micronutrients and minerals (such as fruit trees and vegetables) in many parts of the world.

Genetic erosion, loss of local populations of species, and loss of cultural traditions are often intimately intertwined. While rates of genetic erosion are poorly known, they generally accompany the transition from traditional to commercially developed varieties (FAO 1998). In crop and livestock production systems throughout the developing world, genetic erosion reduces smallholder farmer options for mitigating impacts of environmental change and reducing vulnerability, especially in marginal habitats or agricultural systems that are predisposed to extreme weather conditions (such as arid and semi-arid lands of Africa and India).

Implications for agricultural technologies and policy

Methodological and technological innovation

Since the Brundtland Commission report, agricultural research and development has made major advances in integrating conservation and development to mitigate loss of biodiversity, reverse land degradation and foster environmental sustainability. Much remains to be done to create the appropriate enabling environment in many countries, rich and poor alike, especially in eliminating anti-conservation regulations and inappropriate agricultural production subsidies.

A particular area of advancement is the use of innovative agricultural practices to enhance production while conserving native biodiversity (Collins and Qualset 1999, McNeely and Scherr 2001, McNeely and Scherr 2003, Pretty 2002). Efforts to foster biodiversity-friendly practices by integrating trees on farms (agroforestry), conservation agriculture, organic agriculture and integrated pest management are all contributing towards the sustainability of production landscapes (see Chapter 3). Agroforestry, for example, has emerged as a major opportunity for achieving biodiversity conservation and sustainability in production landscapes (Buck and others 1999, McNeely 2004, Schroth and others 2004), through three major pathways: reducing pressure on natural forests, providing habitat for native plant and animal species and serving as an effective land use in fragmented landscapes (see Box 5.7).

Integrated land management approaches are also helping to enhance ecosystem resilience through participatory processes that engage and empower farmers, strengthen local institutions and create options for value-added income generation. These approaches offer significant prospects for restoring degraded lands to enhance habitat connectivity and ecosystem processes. In the tropical forest margins, where slash-and-burn farming is a major cause of deforestation, knowledge of land-use dynamics has helped to identify practical options that are profitable for small-scale farmers and at the same time environmentally sustainable (Palm and others 2005). However, a major challenge to wide-scale implementation of these approaches is the lack of appropriate policy frameworks that align rural and agricultural policies with the protection of biodiversity and ecosystem services. Without such links, the value of integrated natural resource management (Sayer and Campbell 2004) and ecoagriculture (McNeely and Scherr 2003) innovations will remain marginal in ensuring the long-term viability of biodiversity.

Very substantial collections of plant genetic resources for food and agriculture are now maintained

Agriculture in a rain forest in Ghana, growing cassava and fruits such as bananas and papayas.

Credit: Ron Giling/Still Pictures

around the world through the Consultative Group on International Agricultural Research (CGIAR) system. These institutional gene banks are vital for safeguarding germplasm. Farmers have much to contribute at the local level in maintaining the viability of different varieties, such as is being done in an innovative partnership between the International Potato Center and local communities in Peru, an approach that produces income for the farmers while conserving genetic variability. This also helps maintain local ecological knowledge.

Policy options and governance mechanisms

Local and community initiatives remain crucial for supporting agricultural approaches that maintain biodiversity. It is challenging to expand these initiatives, since they are based on local differentiation and diversity, rather than homogenization and mass production. The development of recognized standards and certification for production methods can help give producers in these initiatives greater weight and value in the global market.

However, little progress has been made overall on institutionalizing a more diverse approach to production systems, and in monitoring its effects. The techniques that would support reduced pesticide or herbicide use, for example, have yet to be adopted in most countries, and the full value of the ecosystem services provided by ecologically oriented agricultural systems are only very slowly being recognized. Increased research, and the adoption of techniques, such as integrated pest management, can reduce the use of chemicals while providing important biodiversity conservation services. Similarly, remedial measures required to restore productivity to degraded lands are not being implemented on the scale required. The ecosystem approach can provide a framework for developing practices, such as riparian buffer systems, to both support biodiversity conservation, and assist in water management and purification.

National level legislative and policy measures on land tenure and land-use practices will be key to facilitating wide-scale adoption of proven biodiversity-supporting methodologies and technological options in agriculture. The options offer practical solutions that reduce the impacts of agriculture on biodiversity, but need to be considered within a supportive policy framework that encompasses both commercial and small-scale agricultural production landscapes.

Box 5.7 Serenading sustainability: rewarding coffee farmers in Central America for biodiversity-friendly practices

Research into the disappearance of songbirds in the US Midwest is leading to innovations in the production practices and marketing of high-value coffee produced in Central America. Smithsonian Institution researchers found that conversion of forests in Central America for coffee plantations substantially reduced the winter habitats for many migratory birds, reducing their breeding success and their numbers. They worked with coffee producers to test methods of "bird friendly" planting, using intact or minimally-thinned forests for coffee tree planting. This method of planting produces somewhat fewer coffee beans, but they are of higher quality, and require fewer pesticide and fertilizer inputs. Additionally, the coffee can be marketed as coming from environmentally-friendly sources, potentially bringing in higher prices. Different certification systems, for example for Bird Friendly® and Shade Grown coffee, show the development and limitations of markets for more sustainably grown crops.

Sources: Mas and Dietsch 2004, Perfecto and others 2005

Box 5.8 Initiatives for implementation by biodiversity Multilateral Environmental Agreements

In 1996, parties to the CBD adopted a programme of work on conservation and sustainable use of agricultural biological diversity. In addition, the CBD has established the International Initiative for the Conservation and Sustainable Use of Pollinators, and the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity, both to be implemented in cooperation with FAO and the Global Strategy for Plant Conservation. Although much remains to be done, global policy processes are helping national governments, particularly in developing countries, to better understand the implications of globalization in agriculture for national policies and development priorities. The entry into force in June 2004 of the International Treaty on Plant Genetic Resources for Food and Agriculture represents another step in governance of the conservation and use of crop genetic resources, especially for large-scale commercial agriculture. This provides for a multilateral system of exchange for some 30 crops and 40 forage species, and should greatly facilitate use and stimulate the development of effective benefit sharing mechanisms.

At the global scale, ongoing international negotiations are addressing imbalances in markets, subsidies and property rights, all of which have direct links to land use in agriculture (see Box 5.8). However, there are still major challenges to the conclusion and implementation of the kind of agreements that would generate tangible impacts on biodiversity and agriculture, particularly in the developing world.

ENERGY

Links between biodiversity and energy

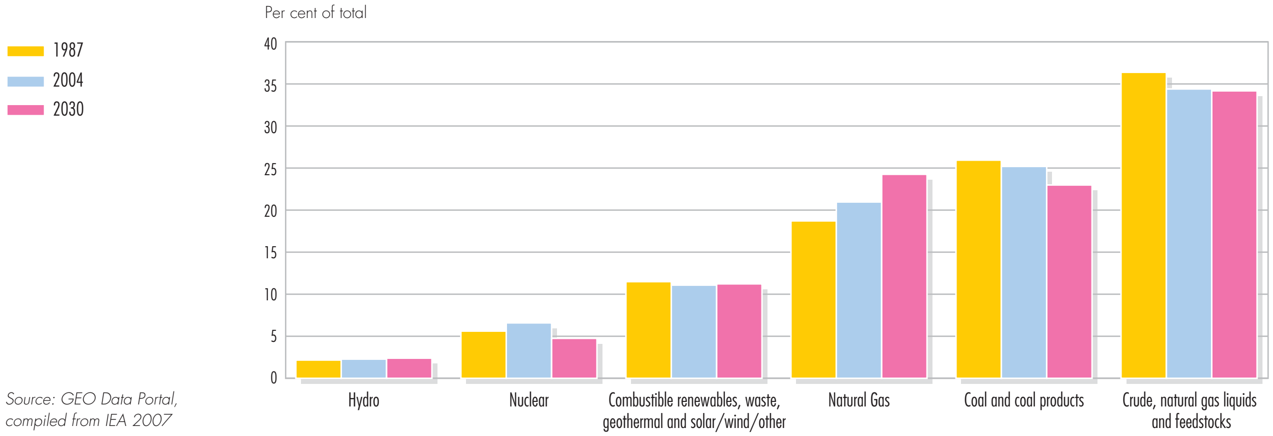
Many forms of energy are the result of a service provided by ecosystems, now or laid down in the form of fossil fuels far in the past. Conversely, society's growing requirements for energy are resulting in significant changes in those same ecosystems, both in the search for energy sources, and as a result of energy use patterns. Given that energy is a fundamental requirement for supporting development in all economies, the challenge is to sustainably provide it without driving further loss of biodiversity. It is necessary to define the trade-offs required, and develop appropriate mitigation and adaptation strategies.

Demand for energy is projected to grow at least 53 per cent by 2030 (IEA 2006). Energy from biomass and waste is projected to supply about 10 per cent of global demand until 2030 (see Figure 5.5). However, this assumes that adequate fossil fuels will be available to address the majority of the increase in demand, and some have suggested this may not be realistic (Campbell 2005). Energy-related carbon dioxide emissions are expected to increase slightly faster than energy use by 2030 (see Chapter 2).

Energy use has impacts at local, national and global levels. Pollution from burning fossil fuels, and the associated effects of acid rain have been a problem for European and North American forests, lakes and soils, although the impacts on biodiversity have not been as significant or widespread as cautioned in the Brundtland Commission report. While emission controls in Europe and North America led to a reversal of acidification trends, there is now a risk of acidification in other areas of the world, particularly Asia (see Chapters 2 and 3). Use of thermal and nuclear power results in waste disposal problems, as do solar cells, which can result in soil contamination by heavy metals. Desertification in the Sahel and elsewhere in sub-Saharan Africa has been linked in part to fuel demand from biomass (see Box 5.9) (Goldemberg and Johansen 2004). Indirect effects of energy use include both overexploitation of natural resources and greatly facilitated spread of invasive alien species through global trade, both made possible through cheap and easily-available energy for transport.

The impacts noted above are relatively localized and small in comparison to the potential impacts of climate change, which results largely from energy use (see Chapters 2, 3 and 4). As a result of climate change, species ranges and behaviour are changing (see Box 5.10 and Chapter 6), with consequences for human well-being, including changing patterns of human disease distribution, and increased opportunities for invasive alien species. Species most likely to be affected include those that already are rare or threatened, migratory species, polar species, genetically impoverished species, peripheral populations and specialized species, including those restricted to alpine areas and islands. Some amphibian species extinctions have already been linked with climate change (Ron and others 2003, Pounds and others 2006), and a recent global study estimated that 15–37 per cent of regional endemic species could be committed to extinction by 2050 (Thomas and others 2004 b).

Figure 5.5 Primary energy supply from various sources and projections to 2030



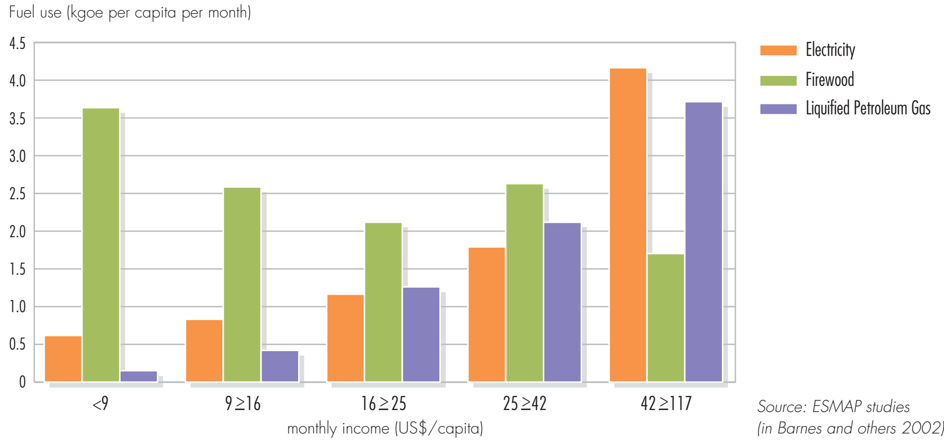
Source: GEO Data Portal, compiled from IEA 2007

Box 5.9 Biodiversity and energy supply for the poor

Biodiversity-based energy sources include both traditional biomass and modern biofuels. Ecosystems provide relatively inexpensive and accessible sources of traditional biomass energy, and therefore have a vital role to play in supporting poor populations (see Figure 5.6). If these resources are threatened, as is the case in some countries with extreme deforestation, poverty reduction will be an even greater challenge. Use of fuelwood can cause deforestation, but demand for fuelwood can also encourage tree planting, as occurs, for example, in Kenya, Mali and several other developing countries.

Source: Barnes and others 2002, FAO 2004

Figure 5.6 Relationship between income and energy use in urban areas of 12 developing countries



Source: ESMAP studies (in Barnes and others 2002)

Climate change is also having impacts at ecosystem scales. By 2000, 27 per cent of the world's coral reefs had been degraded in part by increased water temperatures, with the largest single cause being the climate-related coral bleaching event of 1998. For some reefs recovery is already being reported (Wilkinson 2002). Mediterranean-type ecosystems found in the Mediterranean basin, California, Chile, South Africa and Western Australia are expected to be strongly affected by climate change (Lavorel 1998, Sala and others 2000).

Managing energy demand and biodiversity impacts

Few energy sources are completely biodiversity neutral, and energy choices need to be made with an understanding of the trade-offs involved in any specific situation, and the subsequent impacts on biodiversity and human well-being (see Table 5.3). Biodiversity management is emerging as a key tool for the mitigation of and adaptation to the impacts of climate change – from avoided deforestation to biodiversity offsets – while contributing to the conservation of a wide range of ecosystem services.

Box 5.10 Examples of climate change impacts on species

Reports of extinctions

- Amphibians (Pounds and others 2006)

Reports of changes in species distribution

- Arctic foxes (Hersteinsson and MacDonald 1992)
- Mountain plants (Grabbherr and others 1994)
- Intertidal organisms (Sagarin and others 1999)
- Northern temperate butterflies (Parmesan and others 1999)
- Tropical amphibians and birds (Pounds and others 1999)
- British birds (Thomas and Lennon 1999)
- Tree distributions in Europe (Thuiller 2006)

Reports of changes in species behaviour

- Earlier flight times in insects (Ellis and others 1997, Woiwod 1997)
- Earlier egg laying in birds (Brown and others 1999, Crick and Sparks 1999)
- Breeding in amphibians (Beebee 1995)
- Flowering of trees (Walkovsky 1998)
- Ant assemblages (Botes and others 2006)
- Salamanders (Bernardo and Spotila 2006)

Reports of changes in population demography

- Changes in population sex ratios in reptiles (Carthy and others 2003, Hays and others 2003, Janzen 1994)

There are a number of management and policy responses to the increasing demand for energy and the impacts on biodiversity. One important response to the rising price of oil is increasing interest in other energy sources. Prime among these are biofuels, with several countries investing significant resources in this field (see Box 5.11). The world output of biofuels, assuming current practice and policy, is projected to increase almost fivefold, from 20 million tonnes of oil equivalent (Mtoe) in 2005 to 92 Mtoe in 2030. Biofuels, which are produced on 1 per cent of the world's arable land, support 1 per cent of road transport demand, but that is projected to increase to 4 per cent by 2030, with the biggest increases in United States and Europe. Without significant improvement in productivity of biofuel crops, along with similar progress in food crop agricultural productivity, achieving 100 per cent of transport fuel demand from biofuels is clearly impossible (IEA 2006). In addition, large-scale biofuel production will also create vast areas of biodiversity-poor monocultures, replacing ecosystems such as low-productivity agricultural areas, which are currently of high biodiversity value.

Current actions to address the impacts of climate change can be both beneficial and harmful to biodiversity. For example, some carbon sequestration programmes, designed to mitigate impacts of greenhouse gases, can lead to adverse impacts on biodiversity through the establishment of monoculture forestry on areas of otherwise high biodiversity value. Avoiding deforestation, primarily through forest conservation projects, is an adaptation strategy that may be beneficial, with multiple benefits for climate change mitigation, forest biodiversity conservation, reducing desertification and enhancing livelihoods. It must be recognized that some "leakage" in the form of emissions resulting from those conservation efforts can occur (Aukland and others 2003). Climate change will also affect current biodiversity conservation strategies (Bomhard and Midgley 2005). For example, shifts from one climate zone to another could occur in about half of the world's protected areas (Halpin 1997), with the effects more pronounced in those at higher latitudes and altitudes. Some protected area boundaries will need to be flexible if they are to continue to achieve their conservation goals.

The impacts of energy production and use on biodiversity have been addressed as a by-product of several policy responses in the past few decades. Examples include Germany's effort to reduce subsidies in the energy and transport sectors, promoting increases in the proportion of organic farming and reducing nitrogen use in agriculture (BMU 1997, OECD 2001). However, responses have not been comprehensive, coordinated or universal. Commitments, including shared plans of action, have been made in various fora, but implementation has proved to be extremely challenging, due both to problems of securing required finance and lack of political will or vision.

Box 5.11 Top biofuel producers in 2005 (million litres)

Biodiesel	
Germany	1 920
France	511
United States	290
Italy	270
Austria	83
Bio-ethanol	
Brazil	16 500
United States	16 230
China	2 000
European Union	950
India	300

Source: Worldwatch Institute 2006

The world output of biofuels, assuming current practice and policy, is projected to increase almost fivefold. Above, an experimental farm for the production of biodiesel in Gujarat, India.

Credit: Joerg Boethling/Still Pictures

Table 5.3 Energy sources and their impacts on biodiversity		
Energy source *	**Impacts on biodiversity**	**Subsequent impact on human well-being**
Fossil fuels Crude oil Coal Natural gas	■ Global **climate change** and associated disturbances, particularly when coupled with human population growth and accelerating rates of resource use, will bring losses in biological diversity. ■ **Air pollution** (including acid rain) has led to damage to forests in southern China amounting to US$14 billion/year. Losses from air pollution impacts on agriculture are also substantial, amounting to US$4.7 billion in Germany, US$2.7 billion in Poland and US$1.5 billion in Sweden (Myers and Kent 2001). ■ The direct impact of **oil spills** on aquatic and marine ecosystems are widely reported. The most infamous case is the Exxon Valdez, which ran aground in 1989, spilling 37 000 tonnes of crude oil into Alaska's Prince William Sound (ITOPF 2006). ■ Impacts also come through the **development of oil fields** and their associated infrastructure, and human activities in remote areas that are valuable for conserving biodiversity (such as Alaska's Arctic National Wildlife Refuge that may be threatened by proposed oil development).	■ Changes in distribution of and loss of natural resources that support livelihoods. ■ Respiratory disease due to poor air quality.
Biomass Combustibles, renewables and waste	■ Decreased amount of land available for food crops or other needs due to greatly **expanded use of land** to produce biofuels, such as sugar cane or fast-growing trees, resulting in possible natural habitat conversion to agriculture, and intensification of formerly extensively developed or fallow land. ■ Can contribute **chemical pollutants** into the atmosphere that affect biodiversity (Pimentel and others 1994). ■ Burning crop residues as a fuel also **removes essential soil nutrients**, reducing soil organic matter and the water-holding capacity of the soil. ■ Intensively managing a biofuel plantation may require **additional inputs of fossil fuel** for machinery, fertilizers and pesticides, with subsequent fossil fuel related impacts. ■ Monoculture of biomass fuel plants can increase **soil and water pollution** from fertilizer and pesticide use, **soil erosion and water run-off**, with subsequent loss of biodiversity.	■ Cardiovascular and respiratory disease from reduced indoor air quality, due to wood-burning stoves, especially among poor women and children. ■ Decreased food availability.
Nuclear energy	■ Water used to cool reactors is released to environment at **significantly above ambient temperatures**, and accentuates ecological impacts of climatic extremes, such as heat waves, on riverine fauna. ■ Produces relatively small **amounts of greenhouse gases** during construction. ■ Because of the potential risks posed by nuclear energy, some nuclear plants are surrounded by **protected areas**. For example, the Hanford Site occupies 145 000 ha in southeastern Washington State. It encompasses several protected areas and sites of long-term research (Gray and Rickard 1989), and provides an important sanctuary for plant and animal populations. ■ A nuclear accident would have grave implications for people and biodiversity.	■ Health impacts of ionising radiation include deaths and diseases due to genetic damage (including cancers and reproductive abnormalities).
Hydroelectricity	■ Building large dams leads to **loss of forests, wildlife habitat and species populations, disruption of natural river cycles, and the degradation of upstream catchment areas** due to inundation of the reservoir area (WCD 2000). ■ Dam reservoirs also emit **greenhouse gases** due to the rotting of vegetation and carbon inflows from the basin. ■ On the positive side, some dam reservoirs provide **productive fringing wetland ecosystems** with fish and waterfowl habitat opportunities.	■ Building large dams can result in displacement of people. ■ Alterations in availability of freshwater resources (both improved and declining, depending on the situation) for human use.
Alternative energy sources Geothermal Solar, wind, tidal and wave	■ **Ecosystem disruption** in terms of desiccation, habitat losses at large wind farm sites and undersea noise pollution. ■ Tidal power plants may **disrupt migratory patterns** of fish, **reduce feeding areas** for waterfowl, **disrupt flows of suspended sediments** and result in various other changes at the ecosystem level. ■ Large photovoltaic farms **compete for land** with agriculture, forestry and protected areas. ■ Use of **toxic chemicals** in the manufacture of solar energy cells presents a problem both during use and disposal (Pimentel and others 1994). ■ Disposal of water and wastewater from geothermal plants may cause significant **pollution** of surface waters and groundwater supplies. ■ Rotors for wind and tidal power can cause some **mortality** for migratory species, both terrestrial and marine (Dolman and others 2002). ■ Strong **visual impact** of wind farms.	■ Decreased species populations to provide basic materials of life. ■ Toxins released to the environment may cause public health problems. ■ Decreased economic value of lands near wind farms, due to strong visual impacts.

* See Figure 5.5 for percentage of total primary energy supply

There are also attempts to address this issue through impact management within the private sector, and especially in the energy industry. The private sector is increasingly accepting its responsibilities as a steward of the environment. It is collaborating with non-governmental organizations, through fora such as the Energy and Biodiversity Initiative (EBI 2007), to better understand impacts and possible mitigation and adaptation strategies that make business sense. Beyond legislation and regulation, the use of payments for ecosystem services, as exemplified by the emerging carbon market, represents an innovative though somewhat controversial approach to addressing the impacts of energy use on the environment. The *State of the Carbon Market 2006*, which covers the period from 1 January, 2005 to 31 March, 2006, records a burgeoning global carbon market, worth over US$10 billion in 2005, 10 times the value of the previous year, and more than the value (US$7.1 billion) of the entire US wheat crop in 2005 (World Bank 2006).

Ensuring access to energy while maintaining biodiversity and vital ecosystem services will require an integrated multi-sectoral approach (see Chapters 2 and 10) that includes:

- an ecosystem approach to management of biodiversity and natural resources that ensures inclusion of lessons learned in ongoing management of natural resources affected by energy production and use;
- a major shift in environmental governance to incorporate policies and incentives promoting energy production and use that mainstreams action to address biodiversity concerns, especially with respect to climate change; and
- increasing partnership with the private sector, including extractive industries and the financial sector, to promote energy programmes that internalize the full costs on biodiversity and livelihoods.

HEALTH

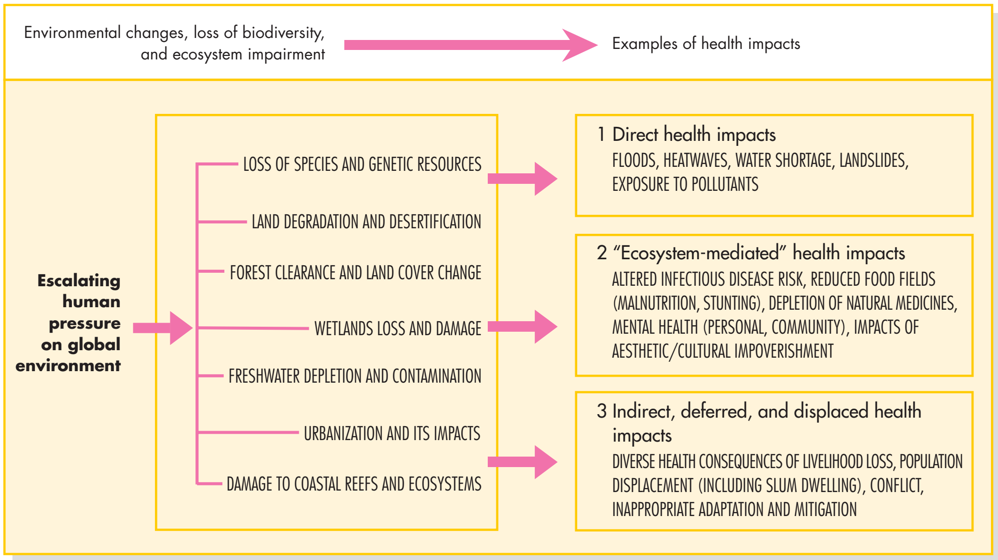
Biodiversity change affects human health

Although there is limited understanding of the consequences of many specific changes in biodiversity for health and the incidence of disease in people and other species, the conceptual links between broader environmental changes and human health are well understood, as seen in Figure 5.7. Emerging diseases resulting from the destruction and fragmentation of tropical forests and other ecosystems, wildlife-human disease linkages (for example, Lyme disease, West Nile virus and avian influenza), the many known and as yet undiscovered pharmaceutical products found in nature, the contribution of ecosystem services to human health and the increasing recognition of the impacts of endocrine disrupters on both animal and human health, all underline the links between biodiversity and human health (Chivian 2002, Osofsky and others 2005).

About 1 billion people live a subsistence lifestyle, and loss of ecosystem productivity (for example through loss of soil fertility, drought or overfishing) can rapidly lead to malnutrition, stunted childhood growth and development, and increased susceptibility to other diseases. There is a profound global nutritional imbalance, with a billion overnourished (mainly rich) people and a similar number undernourished (mainly poor people). Historically, this imbalance has been driven primarily by social and economic factors, but ecological factors will probably play an increasingly important role in the future. Some 70 per cent of infectious diseases originate in animals, and conservation issues are central to their epidemiology. Increased risks of infectious disease spread and crossover can result from land-use changes, many forms of intensive animal production, invasive alien species and the international wildlife trade. Climate change is expanding the range and activity level of disease vectors, particularly insect-borne vectors. The recent international scares over Sudden Acute Respiratory Syndrome (SARS) and avian influenza have brought a dramatic new dimension to the global health debate.

Along with biodiversity changes, there are a number of other factors that are increasing the exposure to and risk of disease. An increasing human population provides an increased number of hosts for disease agents; climate change raises temperatures, altering the wider distribution of disease vectors, such as mosquitoes; drug resistance to conventional treatments is increasing; and continuing poverty and malnutrition make many people more susceptible to disease. Recent experiences with West Nile virus, hantavirus, avian influenza and tuberculosis provide evidence that disease causing micro-organisms are rapidly adapting to changing circumstances, and emerging or increasing rates of infectious diseases are the result (Ayele and others 2004, Campbell and others 2002, Harvell and others 2002, Zeier and others 2005). However, changes to ecosystems

Figure 5.7 Harmful effects of ecosystem changes on human health



Note: This figure describes the causal pathway from escalating human pressures on the environment through to ecosystem changes resulting in diverse health consequences. Not all ecosystem changes are included. Some changes can have positive effects (such as food production).

Source: Adapted from WHO 2005

and their services, especially freshwater sources, food-producing systems and climatic stability, have been responsible for significant adverse impacts on human health in the past 20 years, predominantly in poor countries. Wealthy communities are often able to avoid the effects of local ecosystem degradation by migration, substitution or by appropriation of resources from less-affected regions.

Biodiversity is also the source for many cures. In 2002–2003, 80 per cent of new chemicals introduced globally as drugs could be traced to or were inspired by natural products. Profits from such developments can be enormous. For example, a compound derived from a sea sponge to treat herpes was estimated to be worth US$50–100 million annually, and estimates of the value of anti-cancer agents from marine organisms are up to US$1 billion a year (UNEP 2006a).

Traditional medicines, mainly derived from plants, are a mainstay of primary health care for a significant proportion of the population in developing countries. It is speculated that some 80 per cent of people in developing countries rely on traditional medicines, mostly derived from plants, and more than half of the most frequently prescribed drugs in developed countries derive from natural sources.

Loss of biodiversity may decrease our options for new treatments in the future. WHO has identified 20 000 species of medicinal plants for screening, and there are many more species whose medicinal values are only just being discovered, or may prove important in the future. The value of the global herbal medicine market was estimated at roughly US$43 billion in 2001 (WHO 2001).

The capacity of ecosystems to remove wastes from the environment is being degraded, due to both increased loading of wastes and degradation of ecosystems, leading to local and sometimes global waste accumulation (MA 2005). Examples include the accumulation of particles and gases in the air, and of microbial contaminants, inorganic chemicals, heavy metals, radioisotopes and persistent organic pollutants in water, soil and food. Such wastes have a wide range of negative health impacts.

Managing biodiversity change and human health impacts

Access to ecosystem services is not equitably distributed, and far from optimal from a population health perspective. Essential resources, such as shelter, nutritious food, clean water and energy supplies, are top priorities in effective health policies. Where ill health is directly or indirectly a result of excessive consumption of ecosystem services, substantial reductions in consumption would have major health benefits, and simultaneously reduce pressure on ecosystems (WHO 2005). For example, in rich countries, where overconsumption is causing increasing health impacts, the reduced consumption of animal products and refined carbohydrates would have significant benefits for both human health and for ecosystems globally (WHO 2005). Integration of national agricultural and food security policies with the economic, social and environmental goals of sustainable development could be achieved, in part, by ensuring that the environmental and social costs of production and consumption are reflected more fully in the price of food and water.

Responses that mitigate the impacts of ecosystem changes on human health often involve policies and actions outside the health sector. Action to mitigate impacts of climate change will require cooperation across multiple sectors. However, the health sector bears responsibility for communicating the health impacts of ecosystem changes, and of effective and innovative interventions. Where there are trade-offs, such as between mitigation of negative health impacts and economic growth in other sectors, it is important that the health consequences are well understood, so that they can be included when setting priorities and determining trade-offs.

CULTURE

Interactions between biodiversity and culture

Over the past two decades, there has been growing recognition of the relevance of culture and cultural diversity for the conservation of biodiversity and for sustainable development, as made explicit during the WSSD in 2002 (Berkes and Folke 1998, Borrini-Feyerabend and others 2004, Oviedo and others 2000, Posey 1999, Skutnabb-Kangas and others 2003, UNDP 2004, UNEP and UNESCO 2003).

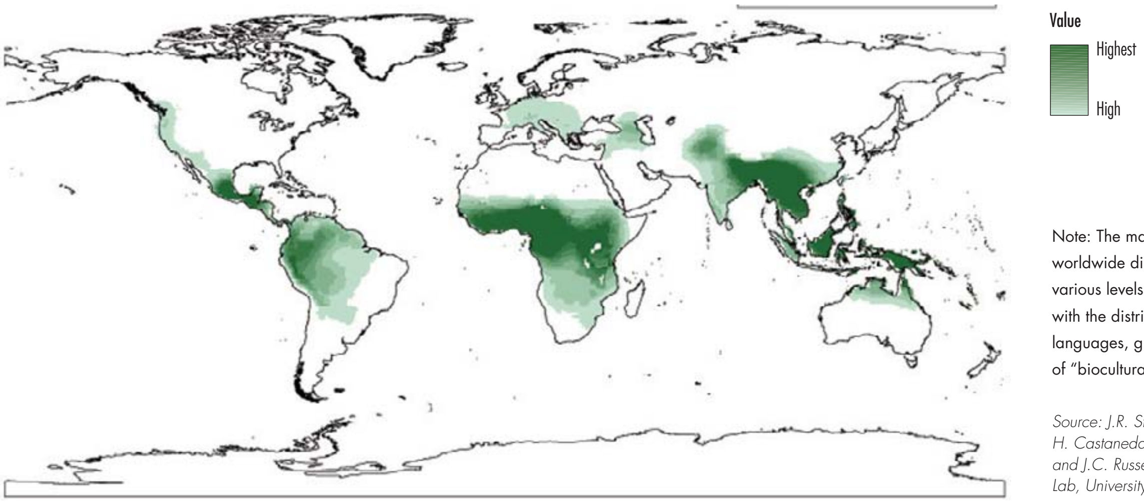
In each society, culture is influenced by locally specific relationships between people and the environment, resulting in varied values, knowledge and practices related to biodiversity (Selin 2003). Cultural knowledge and practices have often contributed specific strategies for the sustainable use and management of biodiversity (see Anderson and Posey 1989, Carlson and Maffi 2004, Meilleur 1994, for examples). The diversity of cultures that have developed globally provides a vast array of responses to different ecosystems, and to variation and change in environmental conditions within them. This cultural diversity forms an essential part of the global pool of resources available to address the conservation of biodiversity (ICSU 2002, UNESCO 2000). However, cultural diversity is being rapidly lost, in parallel to biological diversity, and largely in response to the same drivers (Harmon 2002, Maffi 2001). Taking linguistic diversity as an indicator of cultural diversity, over 50 per cent of the world's 6 000 languages are currently endangered (UNESCO 2001), and it has been speculated that up to 90 per cent of existing languages may not survive beyond 2100 (Krauss 1992). With loss of languages comes the loss of cultural values, knowledge, innovations and practices, including those related to biodiversity (Zent and López-Zent 2004).

In addition to the importance of culture for the conservation and sustainable use of biodiversity, human societies everywhere are themselves dependent on biodiversity for their livelihoods, as well as for cultural identity, spirituality, inspiration, aesthetic enjoyment and recreation (MA 2005). Loss of biodiversity thus affects both material and non-material human well-being.

Although societies in industrialized countries may be further removed from the immediate impacts of biodiversity loss, they are nevertheless adversely affected by loss or decline in ecosystem services. Certain categories of people are especially vulnerable to drastic environmental and social change. They include the poor, women, children and youth, rural communities, and indigenous and tribal peoples. The latter constitute the majority of the world's cultural diversity (Posey 1999).

Correlations have been identified between the respective geographic distributions of cultural and biological globally and regionally (Harmon 2002, Oviedo and others 2000, Stepp and others 2004, Stepp and others 2005). Figure 5.8 highlights this, showing the worldwide distributions of plant diversity and linguistic diversity. Areas of high biodiversity tend to be areas of a higher concentration of distinct cultures. Meso-America, the Andes, Western Africa, the Himalayas, and South Asia and the Pacific, in particular, present this pattern of high "biocultural" diversity. This pattern is supported by research that combines indicators of cultural diversity with indicators of biodiversity into a global biocultural diversity index (Loh & Harmon 2005).

Figure 5.8 "Biocultural" diversity in the world



Note: The map combines the worldwide distribution of various levels of plant diversity with the distribution of languages, giving a gradient of "biocultural" diversity.

Source: J.R. Stepp, E. Binford, H. Castaneda, J. Reilly-Brown, and J.C. Russell. Ethnobiology Lab, University of Florida 2007

While correlations are evident at the global level, the identification of any causal links between biodiversity and cultural diversity requires research at the local level. Empirical evidence that supports the interrelationships between cultures and biodiversity includes:

- anthropogenic creation and maintenance of biodiverse landscapes through traditional low-impact resource management practices (Baleé 1993, Posey 1998, Zent 1998);
- large contribution of traditional farmers to the global stock of plant crop varieties and animal breeds (Oldfield and Alcorn 1987, Thrupp 1998);
- customary beliefs and behaviours that contribute directly or indirectly to biodiversity conservation, such as sustainable resource extraction techniques, sacred groves, ritual regulation of resource harvests and buffer zone maintenance (Moock and Rhoades 1992, Posey 1999); and
- dependence of socio-cultural integrity and survival of local communities on access to and tenure of traditional territories, habitats and resources, which also importantly affect food security (Maffi 2001).

These findings point to significant ecological and societal implications of the increasing threats to the world's cultural diversity. Global social and economic change (see Chapter 1), is driving the loss of biodiversity, and disrupting local ways of life by promoting cultural assimilation and homogenization. Cultural change, such as loss of cultural and spiritual values, languages, and traditional knowledge and practices, is a driver that can cause increasing pressures on biodiversity, including overharvesting, widespread land-use conversion, overuse of fertilizers, reliance on monocultures that replace wild foods and traditional cultivars, and the increase and spread of invasive alien species that displace native species (MA 2005). In turn, these pressures impact human well-being. The disruption of cultural integrity also impedes the attainment of the Millennium Development Goals (MDGs) (see Table 5.4).

Table 5.4 Impacts of loss of cultural diversity

Impact on vulnerable groups dependent on local resources	Relevance to MDGs
■ Local food insecurity due to reduction of traditional varieties of crops and access to wild foods (IUCN 1997)	■ Goal 1 Eradicate extreme poverty and hunger
■ Devaluation of gender-specific knowledge of biodiversity, especially women's knowledge of medicines and food sources (Sowerwine 2004)	■ Goal 3 Promote gender equality and empower women
■ Loss of traditional and local knowledge, practices and language relevant to conservation and sustainable use of biodiversity (Zent and Lopez-Zent 2004)	■ Goal 7 Ensure environmental sustainability

The spread of invasive alien species such as the water hyacinth can have adverse impacts on biodiversity.

Credit: Ngoma Photos

Managing biological and cultural diversity

The growing recognition over the past two decades of the importance of culture and cultural diversity to the environment and human well-being has led to significant developments in terms of policy and other responses relevant to sustainable development and biodiversity conservation at international, national and local levels (see Chapter 6, Arctic). The policies and activities of UNEP, UNESCO, IUCN and the CBD now include a focus on the interrelationships between biodiversity and cultural diversity, and the indicators for measuring progress towards meeting the CBD's 2010 target include a focus on trends in cultural diversity. In 2006, the UN Human Rights Council adopted the UN Declaration on the Rights of Indigenous Peoples, recognizing that "respect for indigenous knowledge, cultures and traditional practices contributes to sustainable and equitable development and proper management of the environment."

National policies have also taken the initiative to strengthen the links between biodiversity and cultures in accord with the CBD. For example, the Biological Diversity Act of India (2002) stipulates that central government shall endeavour to respect and protect the knowledge of local people relating to biodiversity. In doing so, the act provides that forests protected as sacred groves in the context of local communities' belief systems may be recognized as heritage sites. In Panama, legal recognition has been given in the form of sovereignty to the seven major groups of indigenous peoples in that country. Panama was the first government in Latin America to recognize this class of rights for its indigenous populations, and 22 per cent of the national territory is now designated as sovereign indigenous reserves.

Effective biodiversity conservation, particularly that outside of protected areas, relies on integrating local participation, knowledge and values in land-use planning, for example in the co-management of forests, watersheds, wetlands, coastal areas, agricultural lands and rangelands, fisheries, and migratory bird habitats (Borrini-Feyerabend and others 2004). Successful co-management often involves partnerships between local communities and governments, international and local organizations (see Chapter 6, the Polar Regions) and the private sector, including ecotourism ventures.

Incorporating local and traditional knowledge in policy decisions and on-the-ground action calls for mainstreaming the links between biodiversity and culture into social and sectoral plans and policies (UNESCO 2000). This approach involves developing and strengthening institutions at all scales, so that local knowledge for the conservation and sustainable use of biodiversity can be successfully transferred to landscape and national scales. It also involves strengthening the retention of traditional knowledge through education, conservation of languages and support for passing on knowledge between generations.

An integrative approach to biodiversity conservation for sustainable development takes into account the importance of maintaining the diversity of culturally-based knowledge, practices, beliefs and languages that have contributed to the conservation and sustainable use of local biodiversity. The adoption of this integrative approach in international and national policy directives and on-the-ground interventions signals positive change. Further recognition of impacts on the most vulnerable societies and social categories of people, and efforts to strengthen the contribution of local and traditional ecological knowledge to policy recommendations (Ericksen and Woodley 2005), will assist in the maintenance of sustainable relationships between people and biodiversity.

CHALLENGES AND OPPORTUNITIES

CHALLENGES

Undervaluation of biodiversity

Biodiversity loss continues because the values of biodiversity are insufficiently recognized by political and market systems. In part this is due to the costs of biodiversity loss not being borne solely by those responsible for its loss. An added complexity is that the global nature of many biodiversity values results in the impact of biodiversity loss being felt far beyond national boundaries. Losses of biodiversity, such as the erosion of genetic variability in a population, are often slow or gradual, and are often not seen or fully recognized until it is too late. The dramatic and immediate problems typically receive greater policy attention and budgetary support, so funding is often more available for charismatic megafauna, such as tigers or elephants, than for the wider, yet less celebrated variety of biodiversity that forms key components of the planet's infrastructure, and makes the most substantial contribution to delivering the wide range of ecosystem services from which people benefit.

Many of the attempts to calculate the values of biodiversity consider transaction values of the individual components of biodiversity, the price paid for particular goods-and-services. Although this incorporates some of biodiversity's values, it consistently undervalues many ecosystem functions that are essential for the delivery of ecosystem services. In addition, some elements of biodiversity are irreplaceable when lost, for example through species extinction, or gene loss. Economic valuation and new market mechanisms need to be part of a larger policy toolbox, to take account of such irreversible changes to biodiversity, and although more complete economic valuation is necessary to help create important incentives and opportunities for conservation, it will be insufficient to fully conserve biodiversity for future generations. Traditional conservation programmes, focused on protecting components of biodiversity from exploitation and other drivers, will remain an important policy tool to protect the irreplaceable and many of the intangible values of biodiversity (see Box 5.12).

Society can only develop without further loss of biodiversity if market and policy failures are corrected, including perverse production subsidies, undervaluation of biological resources, failure to internalize environmental costs into prices, and failure to recognize global values at the local level. Most policy sectors have impacts on biodiversity, and biodiversity change has significant implications for those sectors. However, biodiversity concerns are rarely given sufficient standing when industrial, health, agricultural, development or security policies are developed. Although any society or economy that continues to deplete biodiversity is, by definition, unsustainable,

Box 5.12 Payments for ecosystem services: reforesting the Panama Canal Watershed

An April 2005 cover article in *The Economist* entitled "Rescuing Environmentalism" led with a analysis of the work by PRORENA, a Panamanian NGO, to establish a diverse native forest cover across extensive areas of deforested lands in the Panama Canal watershed. There has been heavy support from the reinsurance industry, which sees that a regular water flow is necessary for the long-term working of the canal. The project works with local communities to identify a mix of useful tree species, and to research optimal rearing and planting options. It provides income streams for the communities, while improving water retention and flow dynamics for the canal region. It has demonstrated that large-scale ecological restoration in the tropics is technically feasible, socially attractive and financially viable.

Source: The Economist 2005

mainstreaming biodiversity concerns effectively into broader policy making so that all policy supports environmental sustainability remains a key challenge.

Reducing the rate of biodiversity loss will require multiple and mutually supportive policies of conservation and sustainable use, and the recognition of biodiversity values. New policies of integrated landscape and watershed management and sustainable use – the ecosystem approach – can be effective in reducing biodiversity loss (see Box 4.9). In recent years, legal structures such as "biodiversity easements" and "payments for biodiversity services" have been developed to use market mechanisms to provide additional financial resources, and new markets for biodiversity-friendly products are developing new options for producers. These present new opportunities to recognize and mainstream the value of biodiversity, and can address many of the drivers of biodiversity loss. With a supportive policy framework, such changes will initiate market and behavioural corrections that will move society towards increased sustainability. Although they only make up a small fraction of total market share, organic and sustainably produced agricultural products, such as "bird-friendly" coffee and cocoa, are clear examples of this. However, each of these attempts also has to be cost-effective in the local or global marketplace, and comply with other obligations, such as international trade rules, which often remain perversely disconnected from environmental needs and policies.

Box 5.13 Key questions to assist a fuller consideration of biodiversity and governance in policy development and implementation

Nations, communities, public and private organizations, and international processes have been grappling with how to implement policies that take biodiversity concerns into account. A list of questions best indicates the kinds of information that are useful to collate and consider with stakeholders:

- What are the local, national and global values of biodiversity?
- How can biodiversity concerns be integrated into all sectoral decision making?
- How does the ecosystem approach at the landscape level that is necessary to protect biodiversity and ecosystem services fit with existing land tenure and governmental jurisdictions?
- What does sovereignty over genetic resources actually mean? Because many, if not most, genetic resources occur in multiple jurisdictions, how can potential (and likely) multiple claims over the same or related resources be addressed?
- How can biodiversity effectively be both used and conserved?
- What are the potential and plausible environmental impacts of living modified organisms, and what are the appropriate regulatory regimes for them?
- How should the standards of invention, usefulness and non-obviousness be applied in terms of patenting genes, gene expressions and life forms?
- Will the benefits from use of genetic resources justify the costs and the restrictions on research and access?
- How does the enclosure of biodiversity fit within national legal and property rights systems? And, how does this affect the rights of traditional and indigenous communities who may have more communal approaches and traditions to resource management and appropriation?
- Who should be the beneficiaries of such benefits: governments, communities, patent holders, inventors, local people or biodiversity itself?

Ineffective governance systems

Political authority and power often reside far from where decisions that affect biodiversity conservation and sustainable use are taken. This includes disjuncture between and within countries, where different ministries frequently take different approaches to the issue of biodiversity management. Biodiversity concerns are dealt with in numerous international and regional agreements, many of which have come into force in the past 20 years. In 2004, five of the key global biodiversity-related conventions (CBD, CITES, CMS, Ramsar and the World Heritage Convention) created the Biodiversity Liaison Group to help facilitate a more coordinated approach to policy development and implementation. UNEP has created the Issues-based Modules project, which aims to assist countries and other stakeholders to understand the intersections of obligations coming from the various conventions. Such actions and projects epitomize the call from the WSSD to shift from policy development to implementation, and provide a start towards an integrated approach to biodiversity management.

Biodiversity governance involves multiple stakeholders, including landholders, community and political jurisdictions (local, national and regional), the private sector, specific arrangements such as fisheries management councils, species protection agreements and the global agreements. Most of these suffer from a lack of financial and human capacity to effectively manage biodiversity. Even very clear policies do not ensure compliance or enforcement, as is evident from the ongoing illegal international trade in species and their parts, in contravention of CITES.

The proliferation of authorities has, in many instances, created confusion, dispersed resources, and slowed policy development and implementation. This has led to coordination problems between and within scales: local to national, inter-ministerial, regional and international. In most countries, biodiversity concerns are the responsibility of relatively weak, underfunded and understaffed environmental ministries. Decisions that severely threaten biodiversity, such as land-use changes and the introduction of potentially invasive species (either by design or accident), are most frequently taken by agriculture, fisheries, commerce or mining ministries. Often this is done without effective consultation with the authorities responsible for the environment, or recognition of the costs of such impacts.

Biodiversity governance is in a major period of flux. Historically, biodiversity was largely considered as a common heritage, and a public good. The late 20th century saw an unprecedented "enclosing" of genetic resources, a shift from considering them common heritage to seeing them as products to be owned in whole or in part. Two components of this recent enclosure movement are the patenting of genes, gene expressions and derived life forms on the one hand, and the fundamental shift to the concept of ownership of genetic resources that arose through the CBD and the FAO International Treaty on Plant Genetic Resources, in terms of national sovereignty over biological diversity (Safrin 2004). At the same time, the importance of biodiversity is better recognized, not only as a source of new products, but also as fundamental for the supply of the full range of ecosystem services (see Box 5.13).

In 2002, the CBD adopted the Bonn Guidelines on Access to Genetic Resources and Fair and Equitable Sharing of the Benefits Arising out of their Utilization (ABS), and the WSSD subsequently called for further elaboration of the international regime on access and benefit sharing. Although the resulting negotiations have since dominated much of the international biodiversity discourse, the "green gold" predicted by the early advocates of the issue within the CBD, and the "gene gold" predicted by the rush to patent genetic information have not materialized. Whether this reflects an early market or overinflated predictions is not clear. However, these ABS discussions are likely to continue to dominate international negotiations, not only on biodiversity, but also on trade and intellectual property, distracting discussion from other fundamental issues of greater importance to the sustainable supply of ecosystem services for development. Further research and understanding on how to capture and distribute the benefits arising from the use of biodiversity will contribute to these discussions, as illustrated by the Indian case outlined in Box 5.14.

The CBD has taken a novel and progressive approach to identify a mechanism to respect the breadth of traditional knowledge on the uses for biodiversity. The strengthened voices of indigenous communities have brought forward important and as yet unresolved issues, including tensions between different ways of knowing (western science and community cosmology), valuing (economically based and culturally based) and governing (formalized written and customary law). Local and indigenous communities, and women within them, have been and will continue to be important stewards of biodiversity, and national systems of land tenure and respect for indigenous communities are intertwined with biodiversity policy making at the local and international levels.

Box 5.14 Access and benefit sharing in India

The Kani-TBGRI model of benefit sharing with local communities relates to an arrangement between the Kani tribe from the southern and western Ghat region of Kerala State, India and the Tropical Botanic Garden and Research Institute (TBGRI). Under this agreement the Kani tribe receives 50 per cent of the licence fee and royalties resulting from the sale of the manufacturing licence for Jeevni, an anti-fatigue drug, by TBGRI to the pharmaceutical company Aryavaidya Pharmacy Coimbatore Ltd. Jeevni is a formulation based on molecules found in the leaves of a wild plant, *Trichophus zeylanicus*, used by the Kani to keep them energetic and agile. In 1997 a group of Kani tribal members, with assistance from TBGRI, developed the Kerala Kani Samudaya Kshema Trust. The trust's objectives include welfare and development activities for the Kani, preparation of a biodiversity register to document the Kani's knowledge base, and the evolution of and support for methods to promote the sustainable use and conservation of biological resources.

Source: Anuradha 2000

OPPORTUNITIES

New and evolving concepts of ownership over biodiversity and genetic resources, protection of traditional knowledge, the ecosystem approach, ecosystem services and valuation, have created policy challenges for all of the actors. Governments at all levels, communities and businesses are grappling with how to incorporate environmental, social and cultural concerns more effectively into their decision making processes. In order to achieve sustainable development, biodiversity needs to be mainstreamed into energy, health, security, agricultural, land use, urban planning and development policies.

Management interlinkages

At the international level, the biodiversity-related conventions have increased their collaboration, and are attempting to link more closely with economic instruments such as World Intellectual Property Organization and the World Trade Organization. Each of these processes has developed strategies and action plans that need to be implemented nationally, and there is a clear need to find which approaches work best, under which circumstances, and to deliver more effective advice at each level.

Private sector interventions

Some private corporations have started to build biodiversity concerns into their planning and implementation, but many more still need to analyse and minimize the negative impacts of infrastructure development, and operations, such as processing and transportation, on biodiversity. Seemingly good policy may mask environmental degradation elsewhere, such as the movement of polluting industries to, or sourcing of wood products from, less-regulated areas. Codes of conduct, certification schemes, transparency through triple-bottom line accounting and international regulatory standards are key policy options for creating incentives and level playing fields that will minimize these cost-shifting behaviours. Regional organizations, such as the European Community, NAFTA and SADC, play important roles in creating such level playing fields, and collaboration across sectors within government is also required. Interagency coordination is needed to bring coherence to international negotiations, and to bring biodiversity concerns into national policy development.

Market mechanisms

Appropriately recognizing the multiple values of biodiversity in national policies is likely to require new regulatory and market mechanisms, such as:

- better valuation and the creation of markets for ecosystem services;
- more widespread certification systems;
- payment programmes to increase incentives for conservation and protection of biodiversity and ecosystems;
- new policies providing tax incentives for low biodiversity impact operations;
- reducing and eliminating perverse incentives for biodiversity loss;
- developing conservation easements; and
- mechanisms for upstream-downstream transfers.

Pro-poor policies

Implementing policies that benefit the poorest in society will be challenging, but necessary. Raising the profile and representation of direct biodiversity users and stewards, especially smallholders, will be key in developing effective implementation mechanisms. Recognizing the role women play in protecting, using and understanding biodiversity in many parts of the world can lead to the mutual benefit of empowering communities and ensuring sustainable use of biodiversity. Including all stakeholders in the shaping and testing of policies will be necessary to ensure long-term viability and acceptance of the policy changes. Generalizing and scaling up inclusive projects is a key challenge and opportunity for the international community.

Conservation measures

Natural disasters in recent years – tsunamis, hurricanes and earthquakes – have highlighted a range of environmental and biodiversity concerns. Preservation and restoration of coastal mangroves, seagrasses, coastal wetlands and reef systems protect shorelines from the power of storms. Forests regulate water flow, and soil structure and stability. Policies that help protect biodiversity also protect people and infrastructure. Taking the range of biodiversity and environmental concerns into account in land-use planning, and enforcing rules and regulations are key to success.

New governance structures

The understanding of biodiversity, its role and uses, and the governance structure of enclosure is all in its infancy, as nations and localities are testing options, and finding opportunities and obstacles (see Box 5.15). Further analysis and assessment of valuation programmes, mainstreaming attempts, and new governance structures are needed to develop best practices and share lessons learned. As more policy tools and mechanisms based on success are developed, new ways will emerge to conserve and use the world's biodiversity. However, enough is already known to make better decisions on the conservation and wise use of biodiversity. Given the documented rate of habitat conversion and degradation, and declines in populations and genetic resources, much more action is needed immediately to conserve biodiversity so that future generations will have the full range of opportunities to benefit from its use.

Box 5.15 Information gaps and research needs

Due to the complexity of the concept of biodiversity there is no simple list of information gaps that, if filled, would answer the majority of the questions this chapter has raised. However, each level has some significant information needs, and addressing these would provide multiple benefits:

What exists on Earth and where?

These fundamental questions of description and biogeography underpin all biodiversity and ecosystem research. The discovering, naming, describing and ordering of the different species on Earth is a science called taxonomy. It is needed, for example, to identify invasive species, differentiate between different disease vectors and reservoirs, and identify likely candidates for new medicines and other useful chemicals and enzymes. However, the majority of the world's species have not been identified, and some key groups, such as invertebrates and micro-organisms, are especially poorly understood. The CBD has created the Global Taxonomy Initiative (GTI) to try to overcome this impediment, and the Global Biodiversity Information Facility (GBIF) has been created to pull together the disparate data from taxonomic institutions around the world for integrated use, leveraging each country's investment for the common good. However, greater financial and collaborative support from governments and civil society is needed for these efforts.

How do biological resources function?

From the genetic level through to research on how different organisms move, and process food, water, salt and other inputs (including pollutants), there is an increasing understanding of the range of processes that nature has developed, and that can be used to move towards a more sustainable development path. Examples include:

- the increasing understanding of the genetics of key agricultural organisms, such as rice and potato, which should contribute to the development of more hardy and prolific strains;
- the study of the ability of different classes of microbes to perform a range of functions, from breaking down pollutants to isolating and purifying metals; and
- the identification of processes that will allow people to most effectively develop technologies, such as biofuels, without further damaging the environment or harming food security.

Considerable resources are going into this range of research, frequently driven by specific economic interests, but the work is often hampered by a lack of taxonomic and biogeographic understanding.

How does the system interact?

The multitude of questions about ecology range from the very local (how do soil microbes support plant growth) to global (how do forest and ocean organisms sequester carbon and regulate climate systems). Answering these questions, and understanding the dynamics within them frequently takes many years' research with repeated observations. In many areas increased research is needed, for example, on:

- the impacts of fragmentation on biodiversity structure and functioning, resiliency of ecosystems to change (such as from climate change and human interventions);
- the role of biodiversity in mitigating and responding to climate change;
- the role of restoration ecology in remediating changed and degraded lands; and
- reservoirs and vectors of pathogens and zoonotic diseases.

New mechanisms are also needed to bring together the vast research results in a way to use the data for new modelling and research questions.

How do people use and understand biodiversity?

The vast array of different cultures, and the associated range of knowledge about biodiversity, contributes key understanding for conservation and sustainable use of biodiversity. Many new governance structures and techniques are being developed, and these need to be understood more clearly if their effectiveness and synergies are to be maximized, and the spread of perverse incentives is to be avoided. There is a need for increased capacity building, to convert knowledge into practice in many parts of the world. Increased understanding of how people relate to biodiversity, and how to move towards greater stewardship of biodiversity may be the biggest question the world still must answer.

How can biodiversity be valued?

Substantial research on internalizing the values of biodiversity, and the adoption of new indices of global and national wealth based on functioning ecosystems are required, including clear and consistent rules and processes that cross economic and political jurisdictions, such as are emerging in areas of forest and organic certification.

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