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OECD Environmental Outlook to 2030

Chapter 9

Biodiversity

Biodiversity loss is expected to continue to 2030, particularly in Asia and Africa. This chapter examines the sources of this loss – land use changes, unsustainable use of natural resources, invasive alien species, global climate change and pollution – and explores policy responses to halt further damage. Protected areas, which have grown significantly in number during the past few decades, will become increasingly important in the preservation effort as agricultural and urban land use expands. While many of the biodiversity "hotspots" worldwide are situated in developing countries, OECD countries have a role to play in helping to support their conservation and sustainable use through global and regional agreements, as well as through working together to address market and information failures.

KEY MESSAGES

The *Outlook* Baseline projects continued biodiversity loss to 2030 (as measured by human interference in biomes), with particularly significant losses expected in Asia and Africa.

Continued population and economic growth will put pressure on biodiversity through land use changes, unsustainable use of natural resources and pollution. Climate change will also put pressure on biodiversity in the coming decades.

Agriculture will continue to have major impacts on biodiversity. It is projected from 2005 levels that, in order to meet increasing demands for food and biofuels, world agricultural land use will need to expand by about 10% to 2030 – for crops and livestock together.

Although protected areas have expanded rapidly during the past few decades, the biomes represented in that coverage are uneven. Marine areas are thought to be under-represented in all categories of protected areas.

Many policy instruments are available to governments to mitigate the impact of economic growth on biodiversity. Since studies generally show that biodiversity has considerable direct and indirect value – and markets often fail to fully capture that value – additional pro-biodiversity policies are needed, for which governments have the necessary tools at their disposal.

The number and extent of protected areas have been increasing rapidly worldwide in recent decades; they now cover almost 12% of global land area.

Policy options

- Work toward sustainable use of biodiversity in the long term, but expand the biomes covered by some level of protection so as to ensure that the widest possible range of biodiversity is being preserved.
- Improve existing policy frameworks to minimise impacts of further economic growth on biodiversity.
- Expand policies (market-based approaches) so that current values of biodiversity are reflected in market activities.
- Enhance programmes to combat the spread of invasive alien species.
- Help support the conservation and sustainable use of biodiversity "hotspots" in developing countries through global and regional agreements, as well as through working together to address market and information failures.
- Ensure that trade liberalisation is not harmful to biodiversity in countries expected to expand output.

Consequences of inaction

- The loss of biodiversity through continued policy inaction is expected to be significant both in measurable economic loss and difficult-to-measure non-marketed terms.
- Inaction to halt biodiversity loss can lead to further losses in essential ecosystem services – such as carbon sequestration, water purification, protection from meteorological events, and the provision of genetic material.

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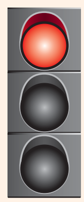
Introduction

Biodiversity worldwide is being lost, and in some areas at an accelerating rate (Pimm *et al.* 1995). According to the Millennium Ecosystem Assessment (MEA 2005a), the main sources of biodiversity loss are land use changes (usually associated directly or indirectly with increasing populations, *e.g.* conversion to agriculture); unsustainable use and exploitation of natural resources (especially fisheries and forestry); invasive alien species; global climate change; and pollution (*e.g.* nutrient loading). While these are the immediate sources of the loss of biodiversity, the underlying problem is that biodiversity is usually not fully accounted for by consumers in the market place – there is often no distinction between biodiversity-friendly goods and those that damage biodiversity. Without government intervention, the market place has difficulty making that distinction. That so few policies have been enacted to mitigate biodiversity loss is an indicator of the strength of the underlying market failure, especially since there is considerable evidence for direct and indirect values of biodiversity that are not reflected in the market (*e.g.* OECD, 2002).



Further losses in biodiversity and ecosystem services are expected to 2030.

Looking forward, many factors will affect biodiversity in ways that will either harm or help it. Nowhere is this potential for changes in biodiversity greater than in two areas: *i)* the increase and extension of agricultural activity, which often results in biodiversity loss; and *ii)* the creation and sustainable use of protected areas, which mitigate further biodiversity loss. Agriculture has historically had the largest impact on biodiversity, and it is expected to continue to be a major factor in the future. Protected areas are a fairly recent phenomenon, but their importance for biodiversity in the future will become key. Over longer time horizons, a source of biodiversity loss whose potential looms very large is climate change. However, the uncertainty around its impact is also large at this stage and its impact within the time frame under consideration here may be small compared with other sources (see also Chapter 13, Cost of policy inaction).

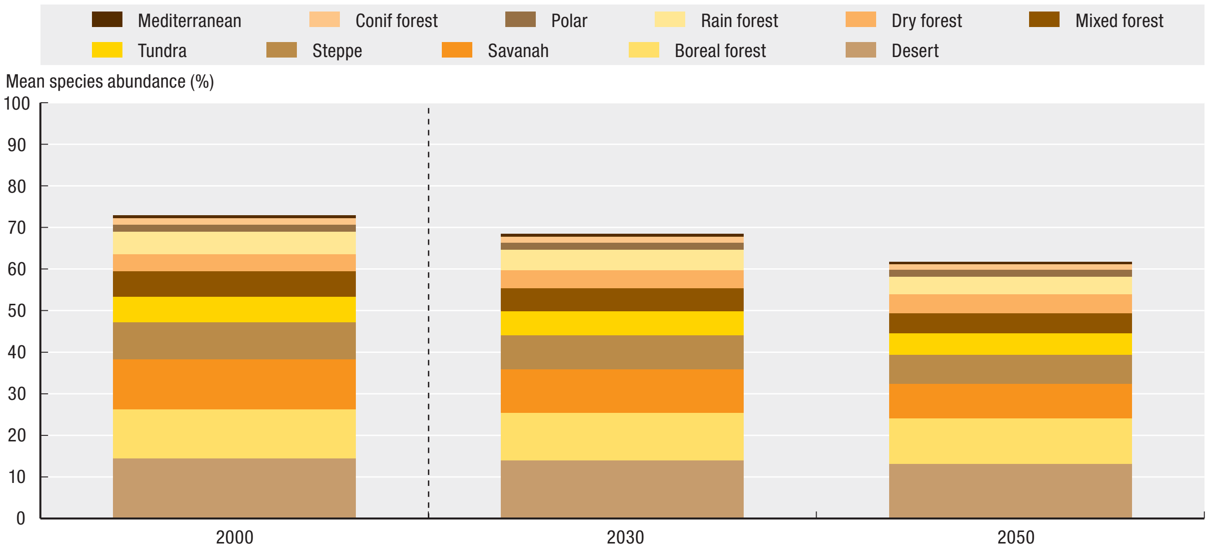
Future pressures on biodiversity are closely linked to increases in economic activity, with associated changes in consumption and production patterns. Under the *OECD Environmental Outlook* Baseline, world population is expected to be 30% higher in 2030 and, when coupled with increasing material well-being (the world economy may be twice as big in 2030 as it was in 2005), this is likely to exacerbate current pressures on ecosystems. Ensuring that economic development is sustainable will require satisfying human needs and wants in such a way that valuable biodiversity and ecosystem functions are not lost, in particular as many of these ecosystem functions – including carbon sequestration, water purification, and the provision of genetic material – directly support economic and social well-being. While many of the biodiversity "hotspots" worldwide are situated in developing countries, OECD countries have a role to play in helping to support their conservation and sustainable use through global and regional agreements, as well as through working together to address market and information failures.

Key trends and projections

A rough measure of biodiversity loss can be obtained using a relatively simple indicator called mean species abundance.[1] Figure 9.1 compares biodiversity (MSA) in 2000 and 2050 with a hypothetical level chosen to reflect low human interference. The results for 2000 are based on data available in the IMAGE model, while those for 2050 are based on the combined results of ENV-Linkages and IMAGE. The MSA on a global basis is projected to decline by 10% between 2000 and 2030 (7 percentage points).

Figure 9.1. **Historical and projected future changes indicated by mean species abundance, 2000-2050**

Potential = 100%



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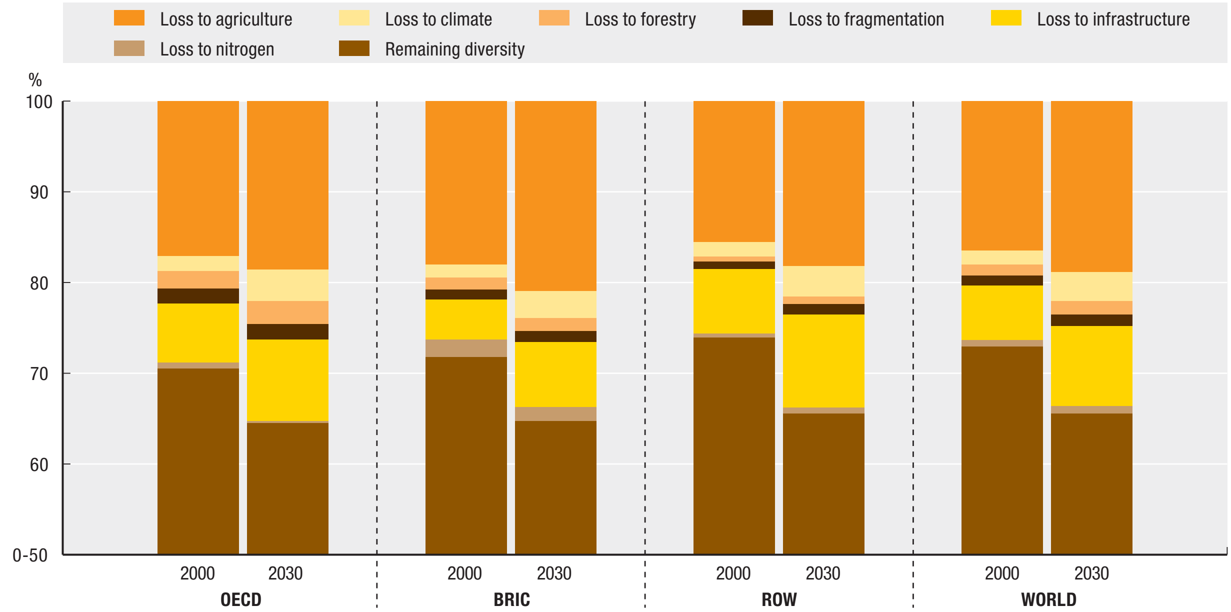
Note (with indicated change): Boreal forest (–5%); Desert (–6%); Tundra (–7%); Polar (–2%); Conif forest: temperate coniferous forest (–8%); Mixed forest: temperate broadleaf and mixed forest (–12%); Mediterranean: Mediterranean forest, woodland and shrub (–10%); Dry forest: tropical dry forest (0%); Rain forest: tropical rain forest (–14%); Steppe: temperate grassland and steppe (–15%); Savannah: tropical grassland and savannah (–20%).

Source: OECD Environmental Outlook Baseline.

In April 2002 the Conference of the Parties to the Convention on Biological Diversity adopted a strategic plan. This committed parties to significantly reduce the current rate of biodiversity loss (by "mainstreaming" biodiversity concerns) at the global, regional and national level by 2010 (Decision VI/26). This objective was subsequently endorsed by the World Summit on Sustainable Development, and was reinforced by G8 environment ministers following their meeting in Potsdam in March 2007. That target would certainly change the trend outlined in Figure 9.1, but has not been reflected in the Baseline because the specific policies that would be needed to achieve it are not yet in place.

Figure 9.2 shows that according to the Baseline, future biodiversity loss to 2030 (as measured by MSA) is likely to mainly come from pressures from agriculture (32%) and infrastructure (38%). Infrastructure development includes urbanisation, transportation networks and other elements of human settlement. The significant loss to infrastructure is

Figure 9.2. **Sources of losses in mean species abundance to 2030**



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Source: *OECD Environmental Outlook* Baseline.

an indication that increased population with increased wealth will lead to a spreading out of people that will affect natural areas more heavily.

To 2030, growth in agricultural production is expected to lead to further pressures on biodiversity through land use changes in the vast natural areas of North America and Australia/New Zealand. In the densely populated regions of Western Europe and Japan we are already seeing high levels of human encroachment on nature. All OECD regions, however, show further decline due to expanding infrastructure and other influences.

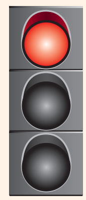
The Russian and other former Soviet Union economies featured a relatively high MSA biodiversity score in 2000 (roughly 83% of pristine state) with only limited further losses (down to roughly 78% of pristine state) projected by 2030. This is mainly because of the vast natural and sparsely populated areas of this region. By contrast, from an already low starting point, biodiversity in OECD Europe (48%) is projected to deteriorate further to 40% in 2030. Expansion of agricultural land in new EU member states and infrastructure are the main drivers of this downward trend.

Significant differences in both levels and trends for biodiversity are also found between different developing regions. In East Asia agricultural areas are projected to decrease, but quickly expanding infrastructure, high levels of nitrogen deposition and some mild early impacts of climate change more than offset that effect. In both South and Southeast Asia, biodiversity declines (as measured by MSA) of at least 10 percentage points are anticipated. In South Asia, expanding agriculture is the main cause, while in densely populated Southeast Asia infrastructure expansion and fragmentation play a bigger role. In all developing regions climate change, notably changes in precipitation, are also expected to affect biodiversity.

Land use changes

Conversion of land away from biodiversity-rich natural conditions is perhaps the greatest pressure on ecosystems and biodiversity. The 2005 *Millennium Ecosystem*

Assessment suggests that "Most changes to ecosystems have been made to meet a dramatic growth in the demand for food, water, timber, fibre and fuel" (MEA, 2005a). Forestry activity and agriculture have been the primary drivers of this biodiversity loss. The MEA found that more land was converted to agriculture in the 30 years following 1950 than during the 150 year period between 1700 and 1850. Similarly, the *Global Biodiversity Outlook* 2 (SCBD, 2006) also identifies habitat loss – or land use change – arising from agriculture as the leading cause of biodiversity loss in the past, as well as in projections for the future.



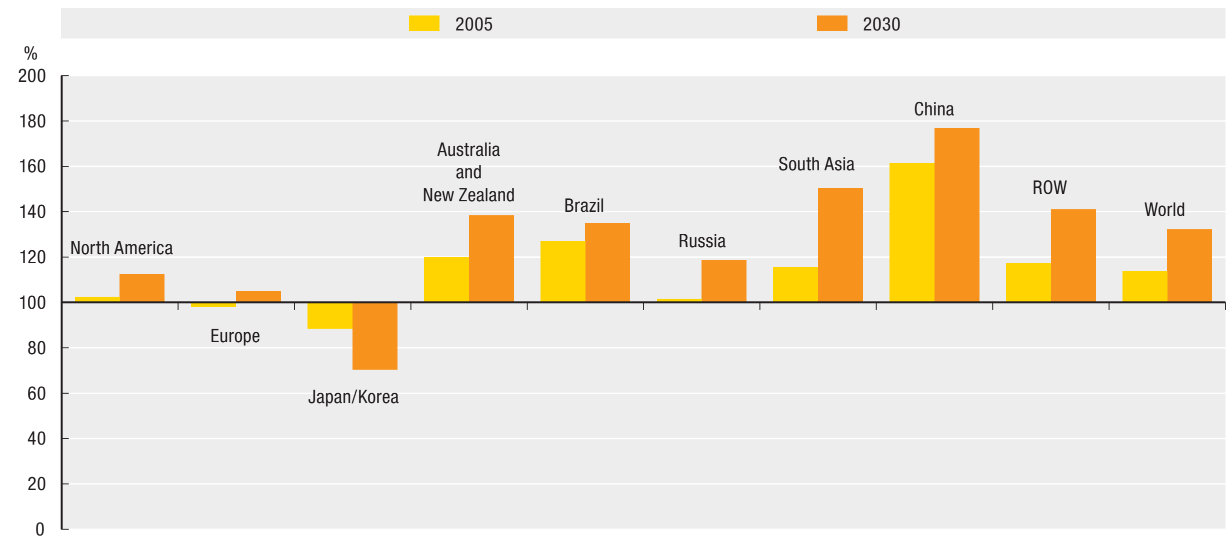
Land use change for agriculture is the main source of biodiversity loss worldwide.

The further increase in food crop lands worldwide of 16% to 2030 (from 2005) expected under the Baseline will continue to be an important factor in biodiversity loss, mostly through the conversion of grasslands and forested areas to farmland. Projected increases in crop lands are particularly notable in Russia, South Asia, developing Africa and some (but not all) OECD countries (see Figure 9.3). Agricultural land area is expected to decrease to 2030 in the Asian OECD region (Japan and Korea). It should be emphasised that these results reflect minimal changes in policy and technology. Changing those assumptions could result in large changes in some of these trends. For example, the location of these increases is driven in part by continuing tariffs and other agricultural policy measures. A policy simulation was undertaken with ENV-Linkages to reflect the gradual removal of agricultural tariffs, and the impacts of this on land use examined (Box 9.1).

Furthermore, Heilig *et al.* (2000) use FAO/IIASA data to show that by applying existing technologies already in use elsewhere, China could feed itself in 2025 using less land than it did at the turn of the century. However, many of those technologies are unlikely to be implemented while labour costs are low and government policy does not encourage high-productivity farm production.

Figure 9.3. **Change in food crop area, 1980-2030**

1980 = 100%



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Source: *OECD Environmental Outlook* Baseline.

Box 9.1. **Modelling the impact of agricultural tariff reductions**

Under the Baseline for the *Outlook*, it is expected that increasing demand for food (and biofuels) will lead to more than a 10% increase in all agricultural lands worldwide (16% increase for food crops, 6% increase for grass and fodder, and 242% increase for biofuels). The location of these increases is driven in part by continuing tariffs and other agricultural policy measures. A policy simulation was undertaken with ENV-Linkages to reflect the gradual reduction of agricultural tariffs, and the impacts of this on land use examined. These results are primarily useful in drawing attention to areas where biodiversity policy may need reinforcing: though measuring changes in land use for agriculture can be indicative of changes in pressure on biodiversity, a thorough analysis of impacts on biodiversity would have to account for some counteracting factors.

In the simulation, all countries are postulated to lower their tariffs by 50% by 2030, thus significantly affecting agriculture in a number of sectors in countries where tariffs are high – the simulation reduced only direct tariffs as they existed in 2001.

Total agricultural land use under this simulation of tariff reform would be increased by around 1.8% compared to the Baseline in 2030. This implies that instead of agricultural land increasing by 10%, it would increase by 11.8%. This is combined with the economic benefits that the reforms would bring, and other environmental benefits of more efficient markets and rational land use. While the global trend is upwards, this masks some regional variation, such as increases in some areas (especially Brazil and parts of Southern Africa) and decreases in others (especially those OECD countries where tariffs are high). The decrease shown for Japan in response to this policy would be in addition to the roughly one-third decrease in agricultural land use that occurred between 1980 and 2000.

Whether the increase in agricultural land in Brazil *versus* the reduction elsewhere represents a net loss of biodiversity is not easily answered. Some studies show that Brazil can significantly expand agricultural lands without losing additional rainforest because the expansion is likely to occur instead in the Cerrado region. But the Cerrado region of Brazil also has its own unique biodiversity and does not currently have sufficient protected areas to ensure that biodiversity will not be lost. Adequate protection of the Cerrado and enforcement of the existing policies protecting the rainforest could accompany such agricultural trade liberalisation to ensure sustainable use of biodiversity-related resources even with expanded agriculture. Such a strategy could lead to gains both in worldwide agricultural efficiency, as well as more sustainable use of biodiversity. SCBD (2007) obtained the result that global biodiversity would be damaged by trade liberalisation, mainly as a result of the impacts in Brazil.

Table 9.1 outlines the types of agricultural land use changes that might be associated with tariff reductions in regions with the largest impact – 10 of the models' 34 regions are shown. The changes are relative to the Baseline, meaning that they should be compared to a world which is using 10% more land for agriculture than today.

Table 9.1. **Impact on land types in 2030 of agricultural tariff reform (compared to Baseline)**

Country/region	Change in livestock	Change in crops	Comment
Iceland\Norway\Switzerland	–8.7%	–13.0%	Gain in forested areas, some loss of semi-natural grassland
Japan	2.6%	–21.6%	Gain in forested areas
Korea	0.3%	–14.5%	Switch in crop composition, gain in forested areas
Turkey	–1.3%	–2.4%	Some gain in forested areas, natural pastures
Mexico	0.1%	–3.3%	Less pressure on rainforest
. .	. .	. .	. .
USA	0.0%	2.4%	Increased use of marginal cropland
EU members non-OECD	2.8%	1.3%	Loss of forested areas
Australia and New Zealand	4.3%	1.4%	Some loss of forested areas and natural pastureland
Rest of South Africa	6.0%	0.6%	Some loss of forested areas and natural pastureland
Brazil	10.0%	0.0%	Loss of natural pastureland; potential loss of rainforest

StatLink http://dx.doi.org/10.1787/257177550380

Source: *OECD Environmental Outlook* Baseline and policy simulations.

While biofuel expansion is included in the Baseline, it plays a small role in land use change to 2030. This is in part because the price of oil in the Baseline is assumed to return to levels that do not encourage heavy use of biofuels for transport. Should governments continue to increase support for biofuels, or should oil prices remain significantly above USD 60 indefinitely, there is very large potential for significant shifts of land use to agriculture for biofuel production (see Chapter 14 on agriculture).[2]

While agriculture has had predominantly negative impacts on biodiversity, this is not a universal outcome in all circumstances. The Mediterranean basin, for example, is considered a biodiversity hotspot largely because the conditions that agriculture has created have been conducive to maximising diversity. Alpine meadows are another example of how farming activity can sustain biodiversity. Organic agriculture can also be more biodiversity-friendly than other forms of agriculture because of the lower levels of homogenisation of plant and animal life in and around the farm. However, at very large scales it is not clear whether these benefits can be maintained (Hole *et al.,* 2005). Similar observations can also be made in many regions, both within and outside OECD countries. While they do not change the overall observation that clearing land for agricultural use is generally detrimental to biodiversity, they do call for a more nuanced view in some cases.

It should also be noted that biodiversity can be considerably enhanced through the "greening of agriculture". For example, recent trends in OECD countries towards payments for environmental services to farmers hold out the prospect of achieving increases in biodiversity while simultaneously maintaining or increasing agricultural output (see also Chapter 14 on agriculture).

Unsustainable use and exploitation of natural resources

Over-harvesting of species (especially when it is illegal) reduces biodiversity by decimating specific plant or animal species, as well as by affecting habitats and species' interdependence. For example, over-harvesting of cod in the North Atlantic has led to cascading impacts on the overall food chain in the ecosystem, with resulting impacts on other fish stocks (Frank *et al.*, 2005). Over-harvesting of trees has led to the loss of significant sources of biodiversity in rainforests in both South America and Asia. In the past, over-harvesting of particular species has led to their extinction.

Marine biodiversity is experiencing pressure from both fishing activity and non-fishing sources (see Chapter 15 on fisheries and aquaculture). Given the growth in demand for fish products, increases in pollution and eutrophication of marine environments, alteration of physical habitat, exotic species invasion, and effects of other human activities, the pressure on marine biodiversity from anthropogenic sources will continue to increase to 2030 (see Committee on Biological Diversity in Marine Systems, 1995, for more detail on how each of these sources affects biodiversity). There are also early signs of climate change affecting marine biodiversity, and this is likely to intensify, *e.g.* through increased acidification of oceans (Gattuso *et al.*, 1998).

Roughly 40% of forest area has been lost during the industrial era, and forests continue to be lost in many regions. Between 2005 and 2030, a further 13% of naturally forested area is expected to be lost worldwide under the Baseline, with the greatest rates of deforestation occurring in South Asia and Africa (excluding recent regrowth). This reflects the increasing demand for forest products, with global timber production having increased by 60% in the last four decades (see Box 9.2). However, forests have been recovering in some temperate

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Box 9.2. **Environmental impacts of forestry**

Forests are the most biodiversity-rich terrestrial ecosystem. They provide a wide range of values to humans, varying from timber, pulp and rubber, to environmental services. At the global level, forests play a crucial role in regulating the climate and represent a significant carbon reservoir. However forest biodiversity is threatened by deforestation, degradation and fragmentation. The main factors driving biodiversity depletion in forests include pressures from increasing land use for farming and livestock grazing, unsustainable forest management, introduction of invasive alien species, mining and infrastructure development. For the most part, industrial logging and the development of tree plantations are not direct causes of deforestation, but major contributors to forest degradation and fragmentation, which in turn can increase the risk of deforestation.

Demand for wood production

In 2005, about half the world forest area was designated for production of wood and non-wood forest products. Rapidly increasing demands for wood, notably from paper and pulp industries due to growing paper consumption, and from the energy generation sector to supply biofuels, is expected to put further pressures on forest resources and survival. Global roundwood production in 2005 amounted to over 3.5 billion m^2. Industrial roundwood accounted for about half of the total roundwood production, and increased by about 18% between 1980 and 2005. Of all industrial roundwood products, paper and paperboard production grew most rapidly – doubling between 1980 to 2005 as a result of surging demand for paper in developing countries (see also Chapter 19 on selected industries: pulp and paper). Over half of the world's roundwood is used as fuel wood or charcoal, supplying about 10% of the world's energy. Woodfuels are also used as modern biofuels to generate electricity, gases and transportation fuel. Demand for biofuels as primary inputs for electricity is expected to increase by 19% to 2030.

Environmental effects of forestry on forest areas

Forest area and deforestation

Global forest area accounted for about 4 billion hectares or 30% of total land area in 2005. The *OECD Environmental Outlook* Baseline projects that natural forest areas will decrease by a further 13% worldwide from 2005 to 2030, with the greatest rates of deforestation occurring in South Asia and Africa. Primary forests were lost or modified to other forest types at an average rate of 6 million ha per year over the past 15 years, and the rate of loss is increasing.

There are three major forest types according to latitude: boreal/taiga (found throughout the high northern latitudes), temperate and tropical forests. Temperate forests, mostly secondary and plantation forests, have been slightly increasing over a long period due to natural reforestation and forest plantations on abandoned agricultural land. Tropical and boreal forests, however, are under pressure from deforestation and forest degradation in primary forests. With some exceptions, most of the logging in the topical and boreal regions involves "cut-and-go" operations in primary forests, *i.e.,* short-term exploitation of industrial wood products without caring for the long-term regeneration of the forest. Severe degradation of forests can occur due to impacts of felling damage and residual wastes on water, soil, nutrient cycles and species richness. In the tropics, most logging is followed by subsequent transition to other land uses, such as crop production and livestock grazing.

Increasing plantation forests

The increasing development of intensive forest plantations for wood production is another threat to forest biodiversity. Productive forest plantations covered 109 million hectares in 2005, having increased annually by about 2 million hectares between 2000 and 2005. Although the total extent of productive plantation areas is relatively small, they provide 22% of world industrial wood supply (FAO, 2006). The area of productive plantation is expected to increase over the coming decades to meet the growing demand for wood products.

Box 9.2. **Environmental impacts of forestry** *(cont.)*

Forest biodiversity in plantation forests is much less than in natural forests. Plantation forests can affect the soil structure, chemical composition, regional hydrological cycle (and regional ecosystems), and cause significant water depletion in the basin. Other environmental issues in monoculture plantations include genetic impoverishment and increased risk of spread of insects and disease. However, it has been argued that increasing wood production from plantations can reduce the pressures on natural forests for industrial wood extraction. Sustainably managed plantation forests can also play a vital role in conservation of biodiversity by acting as buffer zones for fragmented remaining forests.

Illegal and unauthorised industrial wood production and trade

Illegal logging continues to threaten forest biodiversity, with as much as 8 to 10% of global industrial roundwood production estimated to be sourced illegally (Seneca Creek Associates and World Resources International, 2004). Illegal logging takes place in both developed and developing countries. Illegal logging can have serious environmental, social and economic costs and jeopardise international and national efforts to achieve sustainable forest management. Some cases of illegal logging have been reported as taking place in forest protected areas. The economic costs of illegal logging are tremendous: global market losses of USD 10 billion annually, and government losses may amount to USD5 billion in lost revenues (World Bank, 2006a).

Direct driving forces of illegal logging are the higher profits obtainable than for legal logging, coupled with often low risk of apprehension and/or low penalty costs. These are exacerbated by weak forest legislation. The pressures behind illegal logging are the increasing international demand for wood products and a highly developed international supply chain. At the supply end, it is surprisingly easy for consumers to buy illegally logged products as the origin of most wood products is unverifiable.

Policy responses

Meeting increasing demands for forest resources while maintaining forest coverage and ecosystem quality is a major policy challenge, especially in tropical and boreal regions. There have been considerable international efforts to promote and ensure sustainability in forest management and to tackle illegal logging. Policies that address problems in forestry are particularly beneficial for the environment since this is one area where all three environment-related conventions interact (climate change, biodiversity and desertification).

In order to encourage sustainable forest management further and reduce illegal logging, forest legislation and associated policy systems urgently need to improve. A range of regulatory instruments can be used, including allocating concession rights; regulating inputs and processes such as the use of chemical fertilisers and water; setting standards for intensity and species of harvesting and logging; and the obligatory implementation of environmental impact assessments. It is important that the regulations are based on the best available scientific knowledge on the forest quality and possible impacts of forest activities, and that they are followed by close monitoring of changes in forest quality. Whilst a number of OECD countries have long adopted reduced-impact techniques for wood production, such sustainable practices have not been widely introduced in tropical and boreal forests due to the associated increased production costs and need for investments in training and planning.

Economic instruments – including fees or charges for harvesting and trading of industrial roundwood, charges or non-compliance fees related to certain types of forestry activities, taxation on the conversion of forest land to other uses, and subsidies for afforestation – can be used to encourage more sustainable forest management. At the same time, it is essential to remove or reform existing subsidies which promote excessive logging and access to natural forests, such as subsidies for establishing plantation forests or agricultural fields on natural forested land.

Eco-certification is another important instrument for reducing consumers' demand for wood products from unsustainably managed forests. Various certification schemes have been developed by the forest industry, environmental NGOs and the EU. It is important to develop a clear set of indicators to ensure sustainability of the forests managed under each of the certification schemes.

countries in recent decades, with much of this in forest plantations. Plantations are providing an increasing proportion of harvested roundwood, amounting to 22% of the global harvest in 2000. However, plantation forests are often monocultures, and so exhibit much less biological diversity and richness of ecosystems than natural forests. Demand for forest products is expected to continue to rise in coming years, in particular for emerging economies such as China and India, and with it the pressures of illegal logging and a continuing trend toward plantation forests.

Invasive alien species

Invasive alien species are a human-induced problem that is thought to rank high as a contributor to past biodiversity loss (see Wilson, 2002) and which is unlikely to abate by 2030. Many of the human vectors that have contributed to species migration are strengthening with increased economic wealth. For example, trade and travel are both expected to grow strongly in the future, and both have been prominent as agents for moving species outside their natural ranges (ballast water used by ships, and seeds or animals carried on vehicles are classic examples). Historically, many species have also been deliberately introduced for economic benefit: it is estimated that some 98% of the world's agricultural production results from sources that are not native to the areas where they are currently grown or raised. This includes crops and animal species. The combination of purposeful and accidental transplants of species that are in some cases harmful has led to a large human-induced impact on species distribution.

Invasive species can have an impact on biodiversity both within an ecosystem, by disturbing the balance of species in the ecosystem, and globally, by making the worldwide distribution of species more monolithic. This is particularly evident on the island of Hawaii, where only one-quarter of the original (pre-European contact) bird species remain, and where almost one-half of the free-living flowering plants are aliens introduced since European contact (Wilson, 2002). These new species make Hawaii look similar to many other tropical areas, whereas its isolation had once made it unique.

Table 9.2 illustrates the magnitude of environmental impacts of a small sample of invasive alien species. A few estimates put the number of alien species in the tens of thousands for just a handful of countries (Atkinson and Cameron, 1993; Perrings *et al.*, 2000; Pimentel *et al.*, 1999).

Table 9.2. **Environmental impact of invasive alien species**

Invasive species	Some impacts
Crazy ant (*Anoplolepis gracilipes*)	Forms multi-queen super-colonies in rainforests in Pacific Islands. Kill arthropods, reptiles, birds and mammals on the forest floor and canopy. Eats leaves of trees and farms sap-sucking insects.
Brown tree snake (*Boiga irregularis*)	Arrival in Guam caused the near-total extinction of native forest birds.
Avian malaria (*Plasmodium relictum*)	Arrival and spread through mosquitoes has contributed to the extinction of at least 10 native bird species in Hawaii and threatens many more.
Miconia (*Miconia calvescens*)	Spread in Pacific has led to its taking over of large areas, displacing native vegetation, and increasing landslides due to its superficial root structure.
Water hyacinth (*Eichhornia crassipes*)	Now found in more than 50 countries on five continents. Its shading and crowding of native aquatic plants dramatically reduces biological diversity in aquatic ecosystems.

Source: ISSG, 2000.

Table 9.3 shows some of the economic costs associated with the disruption caused by invasive alien species. While this table gives only some of the associated costs, it is clear that they can be very large. These economic impacts also do not account for many aspects of invasive species that are known to be important but were not measured in the studies; for example, the irreversible impacts of invasive species on local ecosystems.

Table 9.3. **Sample economic impact of invasive species**

Species	Economic variable	Economic impact
Introduced disease organisms	Annual cost to human, plant, animal health in USA	USD 41 billion per year
A sample of alien species of plants and animals	Economic costs of damage in USA	USD 137 billion per year
Salt cedar (*Tamarix* spp.)	Value of ecosystem services lost in western USA	USD 7-16 billion over 55 years
Knapweed (*Centaurea* spp), and leafy spurge (*Euphorbia esula*)	Impact on economy in three US states	USD 40.5 million per year direct costs USD 89 million indirect
Zebra mussel (*Dreissena polymorpha)*	Damages to US and European industrial plants	Cumulative costs 1988-2000 = USD 750 million to 1 billion
Most serious invasive alien plant species	Costs 1983-92 of herbicide control in the UK	USD 344 million/year for 12 species
Six weed species	Costs in Australian agro-ecosystems	USD 105 million/year
Pinus, *hakeas* and *acacia* spp.	Costs to restore South African floral kingdom to pristine state	USD 2 billion
Water hyacinth (*Eichhornia crassipes*)	Costs in 7 African countries	USD 20-50 million/year
Rabbits	Costs in Australia	USD 373 million/year (agricultural losses)
Varroa mite	Economic cost to beekeeping in New Zealand	USD 267-602 million

Source: GISP (2001), and references therein.

Global climate change

The Intergovernmental Panel on Climate Change (IPCC) notes that numerous long-term changes in climate have already been observed (IPCC, 2007). Further changes in climate are expected in the coming decades, driven in part by past emissions, but also by the impossibility of reducing emissions immediately to zero (see Chapter 7, Climate change). These changes to climate have direct impacts on ecosystems and individual species.

Small-scale studies linking changes in climate to biodiversity are growing in number (Parmesan, 2005), but most look at particular species and focus on population changes within a particular ecosystem or biome.[3] A few of those studies link climatic changes and biodiversity through changes in the geographical distribution of species. Species are generally limited by climate to areas where either they – or their food-source – can survive. Small increases in temperature have generally (though not always) been found to cause migration either northwards in latitude, or higher in altitude (Parmesan, 1996). These changes will cause some ecosystems to shrink and others to expand. For example, most ecosystem models predict that tundra will shrink with warming as boreal forests push up from the south. Species dependent on the tundra ecosystem will experience a shrinking habitat and their populations will decline. The northern migration is caused by changes in both maximum daytime temperatures, and minimum night time temperatures. The maximum temperature can determine whether a species is able to find suitable habitat during the feeding and breeding season, whereas minimum temperature can determine whether a species survives the winter chill.

Changing temperatures will also cause mountain ecosystems to change. Warming would put pressure on species to move to higher altitudes. An analysis of ecosystems in California reveals that alpine forests will likely shrink in future climate scenarios (Lenihan *et al.,* 2003). Species dependent on these forests will be at risk. Aquatic ecosystems can also

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be affected by climate change since some have been shown to be sensitive to small changes in temperature. Cod, for example, can only tolerate a small temperature change before their ability to reproduce is compromised because spawning is triggered by a narrow range of water temperatures. Strong impacts have been observed in coral reef systems that are thought to be linked to the limited climate change that has occurred over the past few decades (Hughes *et al.,* 2003).

The threat of climate change also raises concerns for conservation efforts. Current conservation efforts are geographically static, tending to protect an area rather than a geographically mobile ecosystem. However, if there is a threat from climate change, it may be important to anticipate where future habitat should be, not just where current habitat exists. Conservation efforts may have to consider dynamic strategies to either adjust to moving habitats over time, or create buffer zones and ecological corridors. Given current and evolving land use around many protected areas, leaving enough space for biodiversity to adapt to changes in climate will clearly be difficult. Mitchell *et al.* (2007) identify a number of measures for enhancing adaptation in the UK so that future climate change does not compromise the government's ability to achieve its biodiversity goals. Resilient natural systems will not only benefit biodiversity, but will preserve the "services" that ecosystems provide and could be costly to replace: soil conservation, clean air and water, agricultural productivity, and other less direct economic and social benefits, such as leisure activity (see Chapter 13 for further discussion).

Current model analyses suggest that sufficient warming may occur over the coming decades to put pressure on many species (IPCC, 2007). The impact on biodiversity will depend on the ecosystem. But climate change pressure will be in addition to existing impacts on species and ecosystems from factors such as land use change, invasive alien species, habitat fragmentation from infrastructure development, and nitrogen deposition or other wide-dispersion pollutants.

Industrial and agricultural pollution

Since the 1950s, nutrient loading – *i.e.* anthropogenic increases in nitrogen, phosphorus, sulphur, and other nutrient-associated pollutants – has emerged as a potentially important driver of ecosystem change in terrestrial, freshwater and coastal ecosystems. Moreover, it is projected to increase substantially in the future (see also Chapter 10 on freshwater). Synthetic production of nitrogen fertiliser has been a key driver of the remarkable increase in food production during the last 50 years, but this and other smaller anthropogenic sources of nitrogen now produce more reactive (biologically available) nitrogen than is produced by all natural pathways combined. The damage done by these fertilisers (and other pollutants) has been documented, as has the increasing numbers of marine "dead zones" that are associated with eutrophication (*e.g.* Diaz *et al.*, 2003; Howarth *et al.*, 1996). Some of these impacts are permanent and require substantial human intervention to reverse. The acidification of lakes is known to diminish (though slowly) once sources of acid rain are removed, but the restoration of pre-impact species can only be approximated by restocking efforts (Keller *et al.*, 1999).

While total OECD nitrogen surpluses entering the environment (*i.e.* total nitrogen inputs from fertilisers, manure and atmospheric deposition *less* uptake by agriculture) declined between 1990 and 2002, they have increased in some, mainly non-European, OECD countries. Developing countries showed a decrease in the efficiency of fertiliser use between 1970 and 1995. In some cases this may simply reflect diminishing returns, but in others more of it ended up in the environment rather than being taken up by crops (*e.g.* in China). Nonetheless, some developing countries show a nitrogen deficit balance (particularly Africa), which can translate into a loss of soil productivity through depletion of soil nitrogen and phosphorous pools.

The *Outlook* Baseline projects that nitrogen surpluses will continue to increase for the world as a whole to 2030 as agricultural production expands (and intensifies), and as a result of pressures from untreated wastewater discharges in rapidly growing urban areas. The largest increases in nitrogen surpluses are expected in the Asian region. The impact of other pollutants has been decreasing in North America and Europe, but remains an increasing problem in other regions.

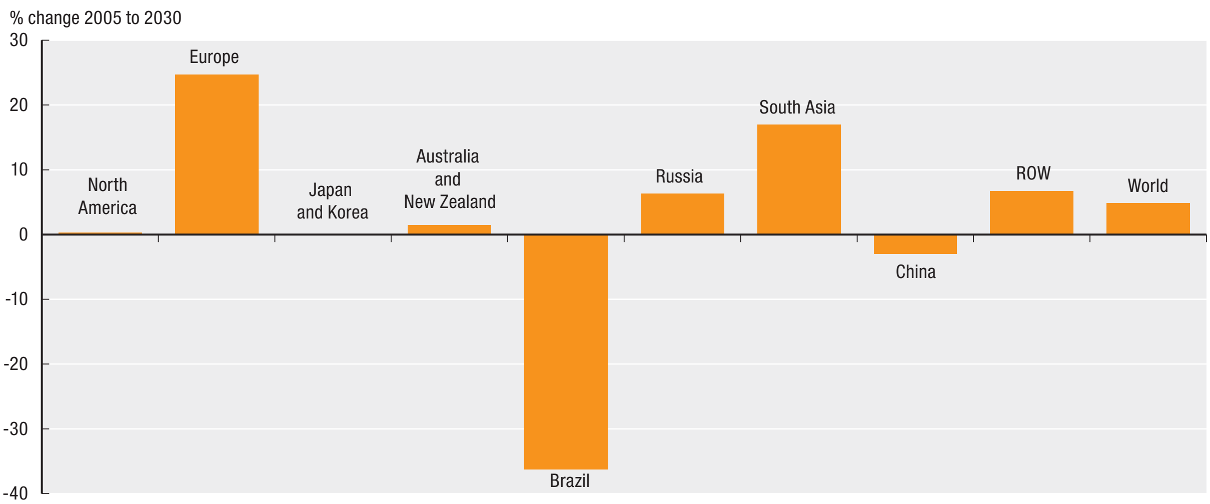
Desertification

Drylands – arid, semi-arid and dry sub-humid – comprise some 41% of global lands (MEA, 2005b). It is thought that at least a quarter of drylands are already degraded and heading toward desertification (Safriel, 1997).

Human activity contributes directly to dryland degradation (and desertification) through changes in the use of the topsoil in vulnerable areas. This leads to the loss of recycled minerals, organic matter, moisture-retention potential and seed bank capacity. In many areas, irrigation causes dryland salinisation: where irrigation water is sufficient to bring up salts under the soil, but not sufficient (partially due to high evaporation) to leach them back down. When such croplands or rangelands are abandoned due to salinisation, the low level of tolerance of the original species to the salty soils makes it impossible to recover the original conditions. Desertification thus becomes irreversible without large scale human intervention.

Climate change is also thought to contribute indirectly to the degradation of drylands, although this is more difficult to quantify rigorously since local climate impacts from GHG emissions are difficult to separate from natural variability.

Figure 9.4. **Change in agricultural activity in arid areas, 2005-2030**



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Source: OECD Environmental Outlook Baseline.

In the *Outlook* Baseline, future agricultural activity is expected to change in response to growing demand; this includes a substantial expansion of agricultural lands. Figure 9.4 shows the part of that expansion that is expected to occur in arid areas. Desertification, of course, is not an automatic outcome, but without special care it becomes a distinct possibility. The change shown for Europe is mostly in Turkey, where a significant expansion is projected in the Baseline. In Brazil, the small amount of agriculture that is in arid zones is gradually being phased out in favour of other, more profitable, areas. The results for Russia and South Asia are explained by a general expansion of agriculture, but because South Asia can only expand into arid zones, the impact is greater there.

Policy implications

While most of the policies to protect biodiversity are enacted at the national or sub-national level, the benefits of biological diversity, and some of the pressures on it, extend beyond national boundaries. By 2006, 190 countries had ratified the Convention on Biological Diversity (CBD) with the aim of conserving biodiversity as well as ensuring the sustainable use of its components. A range of other multilateral environmental agreements also help to protect biodiversity, for example the Convention on International Trade in Endangered Species (CITES), the Convention on Wetlands (Ramsar Convention), the World Heritage Convention, and the Convention on the Conservation of European Wildlife and Natural Habitats. These measures attempt to ensure a co-ordinated process for addressing biodiversity loss. Implementation is generally done at a national level through policies that address the sources of impacts on biodiversity. Valuation helps prioritise and set objectives so that policies are set at the right level and directed at the most pressing issues. Underpinning most of the policy discussion in this section, therefore, is an implicit assumption that priorities and objectives are being addressed through means such as valuation (Box 9.3).

Box 9.3. **The need to value biodiversity**

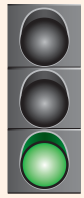
Policies to protect biodiversity aim directly or indirectly to move the cost of biodiversity-affecting activities to levels that reflect social values for biodiversity. With market-based instruments, it is the market price that is being targeted.

For example, taxes impose a cost on users of biodiversity-related resources to reflect the loss faced by others by that use (*i.e.* the social cost). Taxes are "indirect" because they require policy-makers to obtain additional information about the level of this collective loss by some means other than observing the market itself – the level of tax is meant to exactly internalise the non-marketed cost of the activity. To set the tax at the socially optimum level, information is needed about the (incremental) social cost of using the biodiversity-related resource. Economic *valuation* provides a monetary measure of the (monetary and non-monetary) impacts and thus helps set the tax. Other policy instruments, such as regulations, scientific information provision and gathering, also need to be based on some measure of biodiversity value to justify the expenditure of resources toward stated goals.

Regulatory approaches and protected areas

Restrictions or prohibitions on the harvesting or use of wildlife species are common in many countries to protect threatened or endangered species or specific ecosystems of value. Globally, CITES[4] regulates international trade in products of endangered species of wild animals and plants.

The creation of protected areas is another important policy instrument to conserve biodiversity. Figure 9.5 shows that there has been particularly rapid growth in protected areas in the last three to four decades. By 2003, just under 12% of the world's land area was devoted to protected areas (Chape *et al.*, 2003).



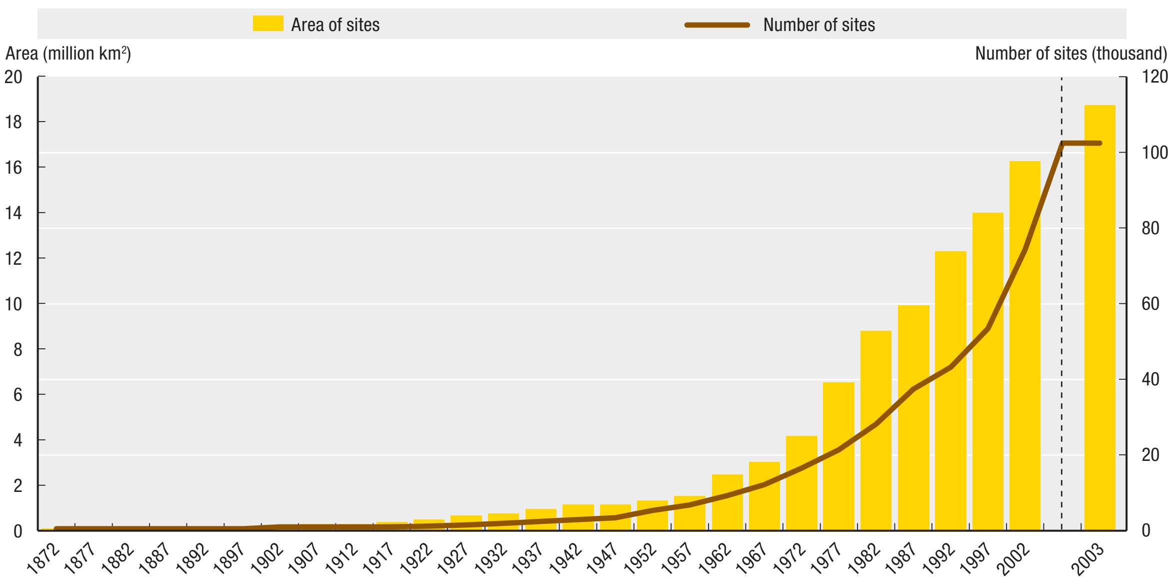
Worldwide, almost 12% of land area is devoted to protected areas.

Of course, the number of locations and the area that is protected are only rough indicators of policy success in conserving and sustainably using biodiversity. Policy optimisation would call for setting the cost of protecting an additional area to its (general) incremental benefit. Such an analysis has not been undertaken as it would require a lot of information, but there is reason to believe that even existing protected areas are under-funded (Balmford *et al.*, 2002). A main reason for this under-funding is the traditional sources of market failure identified by economists: the mismatch between those who benefit from, and those who incur the costs of, maintaining biodiversity (OECD, 2007).

A few biomes are well represented in protected areas, but others less so. Tropical humid forests, subtropical/temperate rainforests and mixed island ecosystems have seen large increases in the area protected, while lake systems and temperate grasslands are poorly covered. One area that is thought to be under-represented is marine ecosystems, for which only a few protected areas exist. Based on a number of studies of marine protected areas, Halpern (2003) shows that in terms of density, biomass, size of organisms and diversity, marine protected areas do deliver benefits.

Some governments are moving towards ecosystem-based fisheries management systems. To appreciate how difficult it will be to fully implement sound management globally, it is worthwhile recalling that the "tragedy of the commons" is often invoked to describe incentives facing fishermen. Unsustainable harvesting in the fisheries industry is thus systemic and changing behaviour to implement good management will be an

Figure 9.5. **Cumulative change in protected areas worldwide, 1872-2003**



StatLink http://dx.doi.org/10.1787/261232663887

Source: Chape *et al.*, 2003.

undertaking of considerable proportions. Given the rate at which marine ecosystems are being disturbed, immediate action through the development of more marine protected areas is justified from a biodiversity perspective, while continuing to work towards sound long-term management (see also Chapter 15 on fisheries and aquaculture).

Of course, establishing a protected area is only a first step. If protection is not enforced then the biodiversity may still be lost. The World Conservation Union (IUCN) has established seven categories of protected areas, ranging from those where human activity is severely limited, to those where only certain aspects of the natural environment are prohibited from being altered. These categories explicitly recognise that protection and sustainable use are complex objectives that have to be achieved in different ways to serve various social goals. Integrating protected areas into an overall sustainable use agenda is important to ensure long-term viability and compatibility with development goals. Often, however, even the level of protection that an area is intended to receive does not actually happen. Adequate resources for the management of protected areas are just as important as the extent of such areas. Some protected areas have been called "paper parks" because there is nothing to distinguish them from other areas; monitoring and enforcement are essentially non-existent.

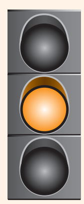
Protecting an area from certain types of development is only one of a number of regulatory measures that can be used to achieve biodiversity goals. Though in the past regulatory measures were often the instrument of choice and were over-used in many public policy areas, they nonetheless have a place in the difficult terrain of biodiversity policy-making. Information and transaction costs may sometimes favour regulatory measures since they can minimise the costs of public administration, monitoring and enforcement, as well as the private costs of implementation. Some regulatory measures available to governments for encouraging biodiversity conservation and sustainable use include:

- Non-compliance fees and penalties (*e.g.* for certain types of forestry activities).
- Liability frameworks for harm to certain species.
- Liability fees for the rehabilitation or maintenance of ecologically-sensitive lands.
- Implementation of biodiversity-related labelling schemes.
- Community-based measures that facilitate regional co-operation.
- Providing research and development that facilitate knowledge expansion of biodiversity.
- Providing rigorous monitoring and enforcement.

Economic incentives and market creation

Incentive measures can be used to try to reconcile differences between the market value of biodiversity-related goods and services to individuals and the value of biodiversity to society as a whole. They can increase the cost of activities that damage ecosystems, and reward biodiversity conservation and enhancement/restoration. Since the main policy problem facing biodiversity conservation is the problem of the global commons, economic incentives that close the gap between private and public values of biodiversity are, in principle, all that are needed.

Markets for biodiversity are created by removing barriers to trade of goods or services derived from biodiversity and creating public knowledge of their special characteristics. Important steps to remove barriers are taken with the



Economic incentives are increasingly used to protect biodiversity, but are clearly insufficient given the scope of continued biodiversity loss.

establishment and assignment of well-defined and stable property and/or use rights, and the creation of information instruments for the products. Market creation is based on the premise that holders of these rights will maximise the value of their resources over long time horizons, thereby optimising biodiversity use, conservation and restoration.

The range of economic incentives available to governments for encouraging biodiversity conservation and sustainable use includes:

- Financial instruments that optimise the purchase of biodiversity "services", *e.g.* auctions.
- Offset schemes that allow an overall level of biodiversity to be maintained, with local tradeoffs.
- Fishing license fees or taxes.
- Levies for the abstraction of surface water or groundwater.
- Charges for:
  - use of public lands for grazing in agriculture;
  - use of sensitive lands;
  - hunting or fishing of threatened species;
  - tourism in natural parks.
- Market-based support for activities that improve biodiversity quality and quantity.
- Access and benefit sharing regimes which create value for high biodiversity areas.

One of the more important approaches to creating markets and incentives for biodiversity is payments for ecosystem services (PES). The idea is that by requiring people to pay for services they otherwise obtained for free (because they were otherwise unsuitable for markets), overuse of these services would diminish. In recent years the use of PES schemes has been increasing and they are expected to continue to grow in popularity. One good example is watershed services. Many cities derive their water from watersheds in which agriculture puts pressure on water quality. Payments to farmers or other watershed users to modify their activities have helped maintain watersheds and reversed downward trends in water quality. Prominent examples can be found in France, Costa Rica and the United States (OECD, 2004).

Information and other instruments

The creation of specific markets for biodiversity-friendly products is based on the premise that informed consumers will choose products friendly to biodiversity. The growing popularity of organic agriculture, eco-labelled timber, fish certified as being sourced from sustainable fisheries, shade-grown coffee, and eco-tourism opportunities are examples of where consumers have chosen to pay more for a good or service because of a perceived environmental benefit.

In general, good physical and economic data and indicators on biological diversity are scarce, and where they do exist there is little comparable information over time or between countries. This has hampered efforts to design appropriate policies to protect biodiversity. Efforts are underway in many countries and international bodies to improve both the physical understanding of ecosystems and biodiversity, and to measure them. The recent Millennium Ecosystem Assessment (2005a) provides a state-of-the-art assessment of the status of different types of ecosystems worldwide, and the pressures on them.

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A number of techniques to value the economic benefits of biodiversity and ecosystems have also been developed, and are gaining in rigour and acceptability in decision-making (OECD, 2002). Once economic values of biodiversity or ecosystem services are established, these can be used to inform policy decisions or in the development of appropriate economic incentives to internalise the full costs of natural resource use.

Costs of inaction

Biodiversity has high economic value. Some of the more obvious sources of value include: bio-prospecting, carbon sequestration, watersheds and tourism. These are direct sources of biodiversity value and do not include indirect aspects such as protection against major pathogens, sources of innovation in agricultural production, the existence value of biodiversity, etc. The pharmacological value of biodiversity may be in the multi-billion dollar range; a successful product can be worth USD 5 to USD 10 billion per year in revenues net of production costs, with a present value over its life of perhaps USD 50 to USD 100 billion. Indeed, finding just a small number of additional blockbuster drugs from the remaining biodiversity would justify significant conservation for bio-prospecting. Biodiversity's carbon storage value may also be in the tens of billions of dollars since it is a significant reservoir of carbon: there are now markets for carbon that allow the implicit pricing of stored carbon. The services provided by biodiversity through watersheds and charismatic megafauna are harder to estimate in total, but again clearly run to billions of dollars. New York City alone saved hundreds of millions of dollars by maintaining its source watershed rather than building a water purification plant (Heal, 2000).

The costs of biodiversity loss through continued policy inaction will thus be significant in both measurable economic loss and difficult-to-measure non-marketed terms. Getting a precise total figure for that loss is not possible, but there is good reason to suspect that it is large.

Notes

1. Mean species abundance (MSA) captures the degree to which biodiversity, at a macrobiotic scale, remains unchanged. If the indicator is 100%, the biodiversity is similar to the natural or largely unaffected state. The MSA is calculated on the basis of estimated impacts of various human activities on "biomes". A reduction in MSA, therefore, is less an exact count of species lost, than an indicator that pressures have increased.
2. In the US, for example, it takes one hectare of maize to produce 3 100 litres of ethanol (IEA, 2004). This is roughly one third of the annual fuel requirement of a small North American car that is driven 18 000 km/year (a rough North American average), so each small car requires three hectares of cropland to support its fuel use. Since the entire US maize crop was 32 million hectares in 2000, this would produce enough fuel to support roughly 10 million small cars – about one tenth of all cars (big and small) in the US.
3. The extinction of a species of mountain-top frog that succumbed to changing precipitation and humidity (Pounds and Savage, 2004) is a good example of this type of study.
4. Convention on International Trade in Endangered Species of Wild Fauna and Flora.

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