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OECD Environmental Outlook to 2030
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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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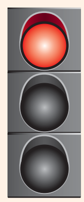
Introduction

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).

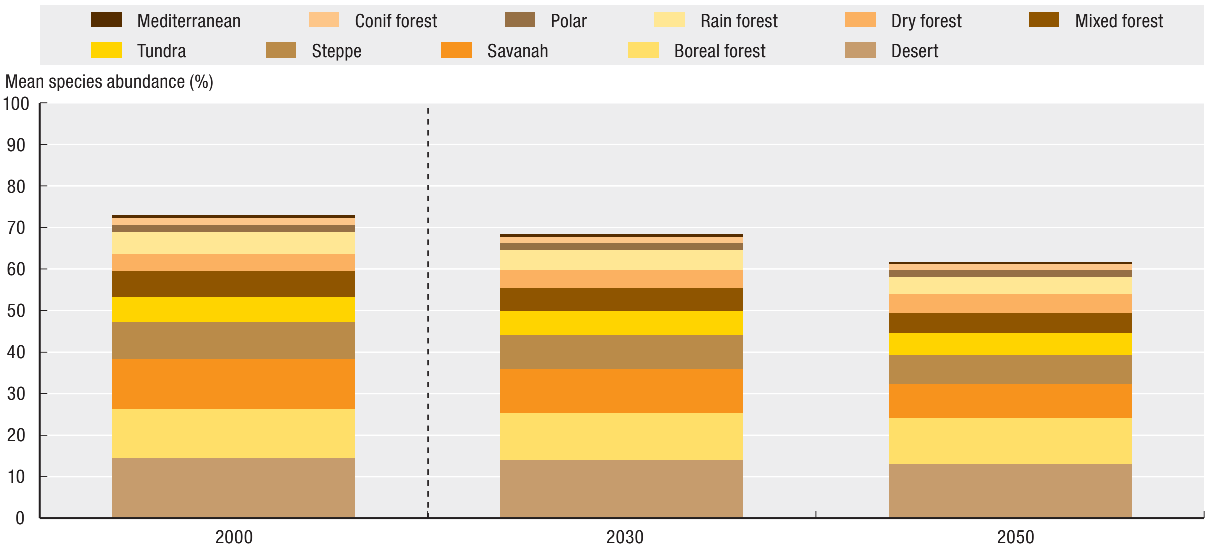
Future pressures on biodiversity are closely linked to increases in economic activity, with associated changes in consumption and production patterns. Under the *OECD Environmental Outlook* Baseline, world population is expected to be 30% higher in 2030 and, when coupled with increasing material well-being (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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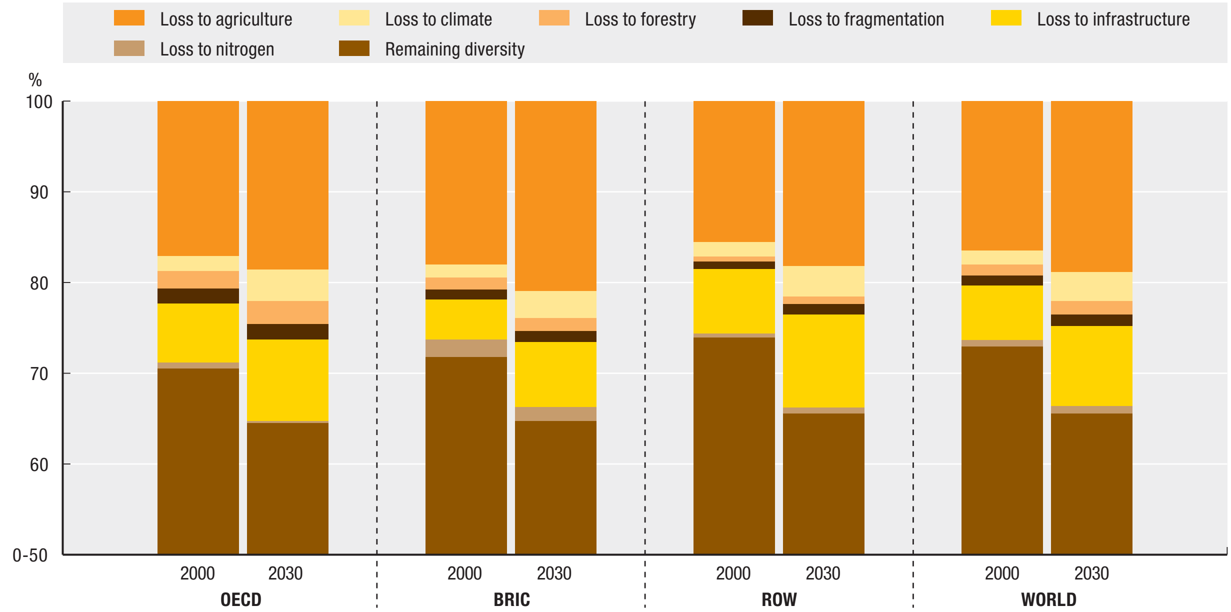
Note (with indicated change): Boreal forest (–5%); Desert (–6%); Tundra (–7%); Polar (–2%); Conif forest: temperate coniferous forest (–8%); Mixed forest: temperate broadleaf and mixed forest (–12%); Mediterranean: Mediterranean forest, woodland and shrub (–10%); Dry forest: tropical dry forest (0%); 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.

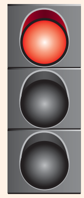
The Russian and other former Soviet Union economies featured a relatively high MSA biodiversity score in 2000 (roughly 83% of pristine state) with only limited further losses (down to roughly 78% of pristine state) projected by 2030. This is mainly because of the vast natural and sparsely populated areas 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.



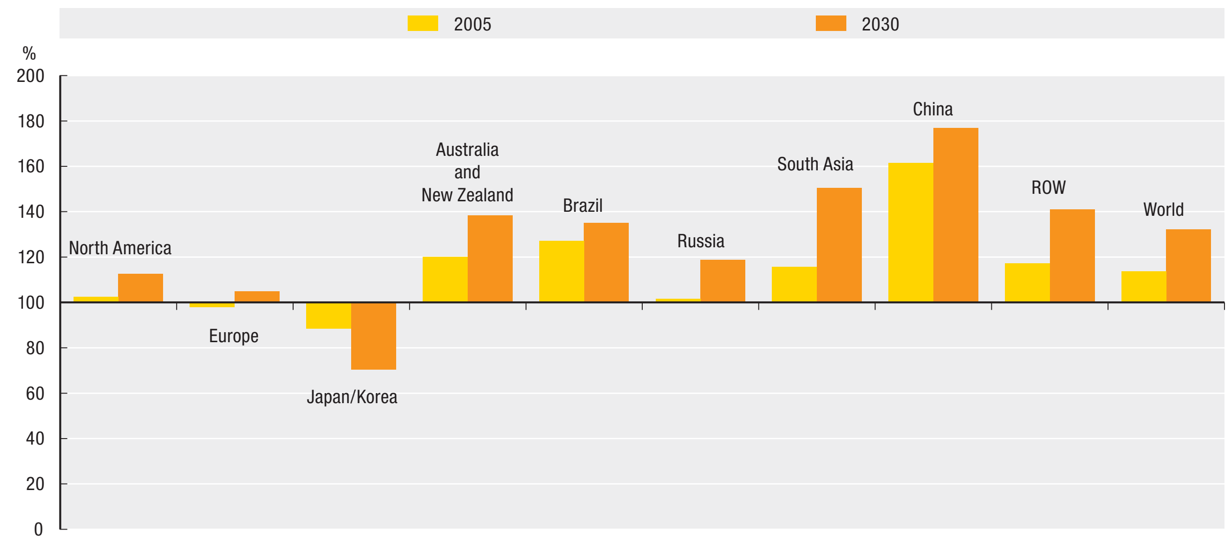
Land use change for agriculture is the main source of biodiversity loss worldwide.

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.

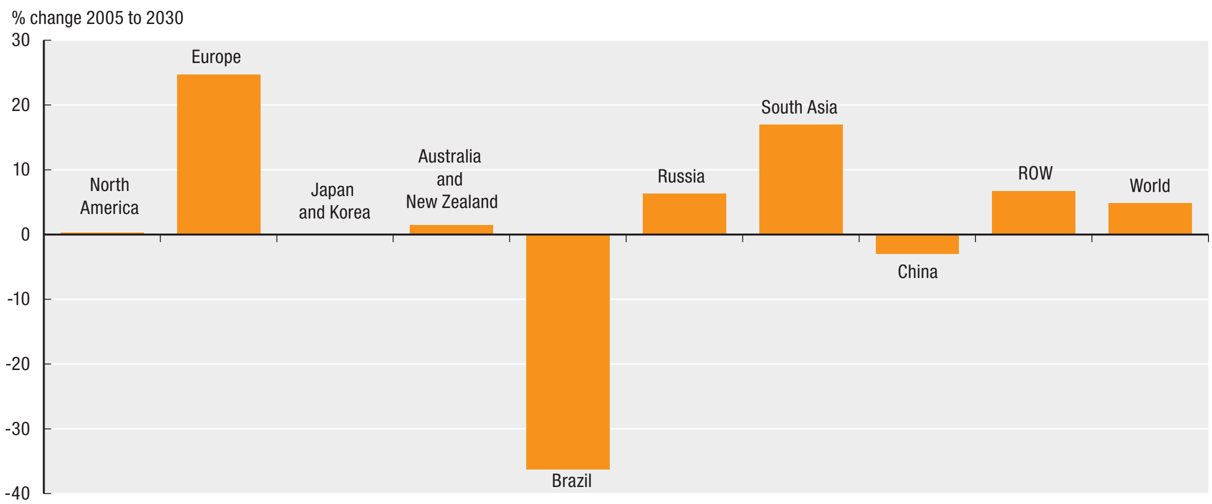
Desertification

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**



StatLink http://dx.doi.org/10.1787/261203583084

Source: OECD Environmental Outlook Baseline.

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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**

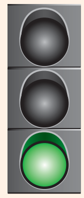
Policies to protect biodiversity aim directly or indirectly to move the cost of biodiversity-affecting activities to levels that reflect social values for biodiversity. With market-based instruments, it is the market price that is being targeted.

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).



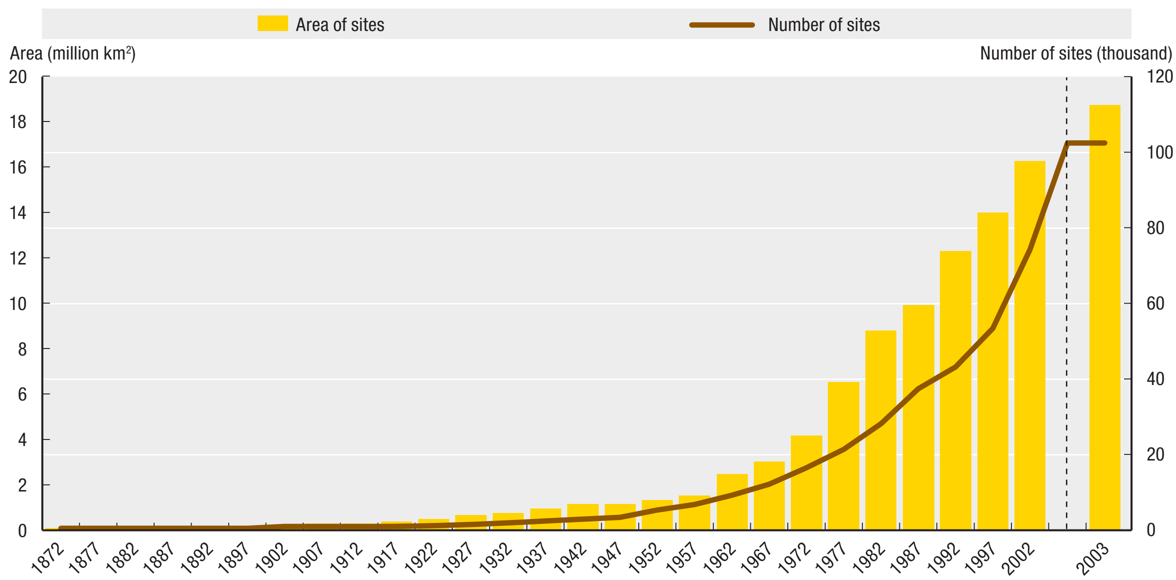
Worldwide, almost 12% of land area is devoted to protected areas.

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.

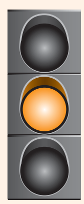
Protecting an area from certain types of development is only one of a number of regulatory measures that can be used to achieve biodiversity goals. Though in the past regulatory measures were often the instrument of choice and were over-used in many public policy areas, they nonetheless have a place 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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Introduction: Context and Methodology

Purpose of the report

The purpose of the *OECD Environmental Outlook* is to help government policy-makers to identify the key environmental challenges they face, and to understand the economic and environmental implications of the policies that could be used to address those challenges.

The *Outlook* provides a baseline projection of environmental change to 2030 (referred to as "the Baseline"), based on projected developments in the underlying economic and social factors that drive these changes. The projections are based on a robust general equilibrium economic modelling framework, linked to a comprehensive environmental modelling framework (see below, and Annex B, for more details). Simulations were also run of specific policies and policy packages that could be used to address the main environmental challenges identified, and their economic costs and environmental benefits compared with the Baseline.

This is the second *Environmental Outlook* produced by the OECD. The first *OECD Environmental Outlook* was released in 2001, and provided the analytical basis on which ministers adopted an *OECD Environmental Strategy for the First Decade of the 21st Century*. This second *Outlook:*

- extends the projected baseline used in the first *Outlook* from 2020 to 2030, and even 2050 for some important areas;
- is based on a stronger and more robust modelling framework;
- focuses on the policies that can be used to tackle the main challenges;
- expands the country focus to reflect developments in both OECD and non-OECD regions and their interactions.

Many of the priority issues and sectors identified in this *Outlook* are the same as those highlighted as needing most urgent policy action in the first *OECD Environmental Outlook* (2001) and in the *OECD Environmental Strategy for the First Decade of the 21st Century*. These include the priority issues of climate change, biodiversity loss and water scarcity, and the key sectors exerting pressure on the environment (agriculture, energy and transport). Added to these is a new priority issue: the need to address the health impacts of the build-up of chemicals in the environment. The 2001 *Outlook* indicated the environmental challenges expected in the next couple of decades; this *Outlook* not only deepens and extends this analysis, it also focuses on the policy responses for addressing these challenges. It finds that the solutions are affordable and available if ambitious policy action is implemented today, and if countries work together in partnership to ensure comprehensive action, avoid competitiveness concerns and share the responsibility and costs of action fairly and equitably. This latest *Outlook* analyses the policies that can be used to achieve the *OECD Environmental Strategy*. It will provide the main analytical material to support discussions on further implementation of the *OECD Environmental Strategy* at the OECD Meeting of Environment Ministers planned for early 2008.

Policy context

Why develop an environmental outlook? Many of the economic or social choices that are being made today – for example, investments in transport infrastructure and building construction, fishing fleets, purchase of solar heating panels – will have a direct and lasting affect on the environment in the future. For many of these, the full environmental impacts will not be felt until long after the decisions have been taken. These factors make policy decisions difficult: the costs of policy action to prevent these impacts will hit societies today, but the benefits in terms of improved environmental quality or damage avoided may only be realised in the future. For example, the greenhouse gases released today continue to build up in the atmosphere and will change the future climate, with serious impacts for the environment, the economy and social welfare.

But politicians tend to reflect the short-term interests of the voting public, not the long-term needs of future generations. They also tend to focus on the immediate costs and benefits to their own populations of a given policy approach, rather than on the global impacts. But many of the main environmental challenges countries face in the early 21st century are global or transboundary in nature, including global climate change, biodiversity loss, management of shared water resources and seas, transboundary air pollution, trade in endangered species, desertification, deforestation, etc. Building public understanding and acceptance of the policies that are needed to address these challenges is essential for policy reform.

These political challenges are exacerbated by uncertainty about the future. Often the exact environmental impacts of social and economic developments are poorly understood or disputed. In some cases, scientific uncertainty about environmental or health impacts is a main cause of policy inaction, while in others it is used as a justification for precautionary action. Scientific understanding and consensus about environmental change has been developing rapidly in a number of areas in recent years, for example through the 2005 Millennium Ecosystem Assessment and the 2007 IPCC Fourth Assessment Report on the Science of Climate Change. Despite the improvements in the scientific understanding of such issues, a gap remains in the development and implementation of effective environmental policies based on this scientific understanding.

This *Environmental Outlook* examines the medium to long-term environmental impacts of current economic and social trends, and compares these against the costs of specific policies that could be implemented today to tackle some of the main environmental challenges. The purpose is to provide more rigorous analysis of the costs and benefits of environmental policies to help policy-makers take better, more informed policy decisions now.

Many environmental problems are complex and inter-connected. For example, species loss is often the result of multiple pressures – including hunting, fishing or plant harvesting, loss of habitat through land use change or habitat fragmentation, impacts of pollutants – and thus a mix of policy instruments is needed to tackle the various causes of this loss. These policy packages need to be carefully designed in order to achieve the desired environmental benefits at the lowest economic cost. This *Outlook* examines the policy packages that could be used to tackle some of the key environmental challenges, and the framework conditions needed to ensure their success.

The transboundary or global nature of many of the most pressing environmental challenges identified in this *Outlook* require countries to increasingly work together in partnership to address them. The ways in which OECD environment ministries can work together in partnership with other ministries, stakeholder partners and other countries are explored in this *Outlook*.

A special focus on the emerging economies in the *Outlook*

This *Outlook* identifies the main emerging economies as the most significant partners for OECD countries to work with in the coming decades to tackle global or shared environmental problems. This is because these countries are responsible for an increasingly large share of the global economy and trade, and thus have an increasing capacity to address these challenges, in part because their economies are so dynamic. Moreover, the pressures that they exert on the environment are also growing rapidly.

In some chapters, where data are available and relevant, the BRIICS countries (Brazil, Russia, India, Indonesia, China and South Africa) are highlighted for attention as a country grouping. In other chapters, the smaller country grouping of BRIC (Brazil, Russia, India and China) is examined, or even further disaggregated to each of these four countries individually. The BRIC grouping is used for most of the modelling projections and simulations in the *Outlook*.

Modelling methodology and sources of information

The analysis presented in this *Environmental Outlook* was supported by model-based quantification. On the economic side, the modelling tool used is a new version of the OECD/World Bank JOBS/Linkages model, operated by a team in the OECD Environment Directorate and called ENV-Linkages. It is a global general equilibrium model containing 26 sectors and 34 world regions and provides economic projections for multiple time periods. It was used to project changes in sector outputs and inputs of each country or region examined to develop the economic baseline to 2030. This was extended to 2050 to examine the impacts of policy simulations in specific areas, such as biodiversity loss and climate change impacts. The economic baseline was developed with expert inputs from, and in co-operation with, other relevant parts of the OECD, such as the Economics Department, the International Energy Agency and the Directorate for Food, Agriculture and Fisheries.

The Integrated Model to Assess the Global Environment (IMAGE) of the Netherlands Environmental Assessment Agency (MNP) was further developed and adjusted to link it to the ENV-Linkages baseline in order to provide the detailed environmental baseline. IMAGE is a dynamic integrated assessment framework to model global change, with the objective of supporting decision-making by quantifying the relative importance of major processes and interactions in the society-biosphere-climate system. The IMAGE suite of models used for the *Outlook* comprises models that also appear in the literature as models in their own right, such as FAIR (specialised to examine burden sharing issues), TIMER (to examine energy), and GLOBIO3 (to examine biodiversity). Moreover, for the *Outlook* the IMAGE suite included the LEITAP model of LEI at Wageningen and the WaterGap model of the Center for Environmental Systems Research at Kassel University. IMAGE and associated models provided the projections of impacts on important environmental endpoints to 2030, such as climate, biodiversity, water stress, nutrient loading of surface water, and air quality. Annex B provides a more detailed description of the modelling framework and main assumptions used for the *Outlook* report.

The Baseline Reference Scenario presents a projection of historical and current trends into the future. This Baseline indicates what the world would be like to 2030 if currently existing policies were maintained, but *no new policies* were introduced to protect the environment. It is an extension of current trends and developments into the future, and as such it does not reflect major new or different developments in either the drivers of environmental change or environmental pressures. A number of major changes are possible in the future, however, that would significantly alter these projections. A few of these were examined as "variations" to the Baseline, and their impacts are described in Chapter 6 to show how these changes might affect the projections presented here.

Because the Baseline reflects no new policies, or in other words it is "policy neutral", it is a reference scenario against which simulations of new policies can be introduced and compared. Simulations of specific policy actions to address key environmental challenges were run in the modelling framework. The differences between the Baseline projections and these policy simulations were analysed to shed light on their economic and environmental impacts.

The simulations undertaken for the *Environmental Outlook* exercise are illustrative rather than prescriptive. They indicate the type and magnitude of the responses that might be expected from the policies examined, rather than representing recommendations to undertake the simulated policy actions. As relevant, some of the policy simulation results are reflected in more than one chapter. The table below summarises the policy simulation analyses and lists the different chapters containing the results.

Sensitivity analysis was undertaken to test the robustness of key assumptions in ENV-Linkages, and some of the results of this analysis are presented in Annex B. This, in conjunction with the Baseline variations described in Chapter 6, provides a clearer picture for the reader of the robustness of the assumptions in the Baseline.

Throughout the *Outlook*, the analysis from the modelling exercise is complemented by extensive data and environmental policy analysis developed at the OECD. Where evidence is available, specific country examples are used to illustrate the potential effects of the policies discussed. Many of the chapters in this *Outlook* have been reviewed by the relevant Committees and Expert Groups of the OECD, and their input has strengthened the analysis.

The *Outlook* is released at about the same time as a number of other forward-looking environmental analyses, such as UNEP's Fourth Global Environment Outlook (GEO-4); the IPCC Fourth Assessment Report (AR-4); the International Assessment of Agricultural Science and Technology for Development supported by the World Bank, FAO and UNEP; and the CGIAR Comprehensive Assessment of Water Use in Agriculture. Through regular meetings and contacts, efforts have been made by the organisations working on these reports to ensure co-ordination and complementarity in the studies, and to avoid overlap. The *OECD Environmental Outlook* differs from most of the others in its emphasis on a single baseline reference scenario against which specific policy simulations are compared for the purpose of policy analysis. Most of the others explore a range of possible "scenarios", which provide a useful communication tool to illustrate the range of possible futures available, but are less amenable to the analysis of specific policy options. The *OECD Environmental Outlook* also looks at developments across the full range of environmental challenges, based strongly on projected developments in the economic and social drivers of environmental change, while many of the other forward-looking analyses focus on a single environmental challenge.

Table I.1. **Mapping of the *OECD Environmental Outlook* policy simulations by chapter**

Simulation title	Simulation description	Chapters in which the results are reflected	Models used
Baseline	The "no new policies" Baseline used throughout the *OECD Environmental Outlook*.	All chapters	ENV-Linkages; IMAGE suite
Globalisation variation	Assumes that past trends towards increasing globalisation continue, including increasing trade margins (increasing demand by lowering prices in importing countries) and reductions in invisible costs (*i.e.* the difference between the price at which an exporter sells a good and the price that an importer pays).	4. Globalisation 6. Key variations to the standard expectation	ENV-Linkages; IMAGE suite
High and low growth scenarios	Variation 1: High economic growth – examines impacts if recent high growth in some countries (*e.g.* China) continues, by extrapolating from trends from the last 5 years of growth rather than the last 20 years. Variation 2: Low productivity growth – assumes productivity growth rates in countries converge towards an annual rate of 1.25% over the long-term, rather than 1.75% as in the Baseline. Variation 3: High productivity growth – assumes productivity growth rates in countries converge towards an annual rate of 2.25% over the long-term.	6. Key variations to the standard expectation	ENV-Linkages
Greenhouse gas taxes	Implementation in participating countries of a tax of USD 25 on CO_2eq, increasing by 2.4% per annum. OECD 2008: only OECD countries impose the tax, starting in 2008. Delayed 2020: all countries apply the tax, but starting only in 2020. Phased 2030: OECD countries implement the tax from 2008; BRIC countries from 2020, and then the rest of the world (ROW) from 2030 onwards. All 2008: in a more aggressive effort to mitigate global GHG emissions, all countries implement the USD 25 tax from 2008.	7. Climate change 13. Cost of policy inaction (Delayed 2020) 17. Energy 20. Environmental policy packages	ENV-Linkages; IMAGE suite
Climate change stabilisation simulation (450 ppm)	Optimised scenario to reach a pathway to stabilise atmospheric concentrations of GHG at 450 ppm CO_2eq over the longer term and limit global mean temperature change to roughly 2 °C. A variation on this case was developed to explore burden-sharing, using a cap and trade approach to implementation.	7. Climate change 13. Cost of policy inaction 17. Energy 20. Environmental policy packages	ENV-Linkages; IMAGE suite
Agriculture support and tariff reform	Gradual reduction in agricultural tariffs in all countries to 50% of current levels by 2030. Gradual reduction in production-linked support to agricultural production in OECD countries to 50% of current levels by 2030.	9. Biodiversity 14. Agriculture	ENV-Linkages
Policies to support biofuels production and use	Demand for biofuels growing in line with the IEA *World Energy Outlook* (2006) scenario. DS: a scenario whereby growth in biofuel demand for transport is driven by exogenous changes, keeping total fuel for transport close to the Baseline. OilS: a high crude oil price scenario to determine the profitability of biofuel in the face of increasing costs of producing traditional fossil-based fuels. SubS: a subsidy scenario in which producer prices of biofuels are subsidised by 50%.	14. Agriculture	ENV-Linkages
Fisheries	Global fisheries cap and trade system, representing a 25% reduction in open fisheries catch, with trading allowed within six geographical regions.	15. Fisheries and aquaculture	ENV-Linkages
Steel industry CO_2 tax	Implementation of a carbon tax of 25 USD per tonne CO_2, applied respectively to OECD steel industry only, all OECD sectors, and all sectors worldwide.	19. Selected industries – steel and cement	ENV-Linkages
Policy mix	Three variations of policy packages were modelled, depending on the participating regions: OECD countries only OECD + BRIC Global The policy packages included: • reduction of production-linked support and tariffs in agriculture to 50% of current levels by 2030. • tax on GHG emissions of USD 25 tax CO_2eq, increasing by 2.4% per annum (phased with OECD starting in 2012, BRIC in 2020, ROW in 2030). • moving towards, although not reaching, Maximum Feasible Reduction in air pollution emissions, phased over a long time period depending on GDP/capita. • assuming that the gap to connecting all urban dwellers with sewerage will be closed by 50% by 2030, and installing, or upgrading to the next level, sewage treatment in all participating regions by 2030.	8. Air pollution 10. Freshwater 12. Health and environment 20. Environmental policy packages	ENV-Linkages; IMAGE suite

Structure of the report

The *OECD Environmental Outlook* is divided into two main parts:

i) *The World to 2030 – the Consequences of Policy Inaction:* describes the Baseline, *i.e.* the projected state of the world to 2030 in terms of the key drivers of environmental change and the developing environmental challenges, as well as analysing some possible variations to the Baseline.

ii) *Policy Responses:* focuses on the policy responses at both the sectoral level and in terms of implementing a more comprehensive and coherent policy package.

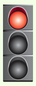
The first part describes the key elements of the Baseline to 2030, including the main drivers of environmental change (consumption and production patterns, technological innovation, population dynamics and demographic change, economic development, globalisation, and urbanisation) and the key environmental challenges (climate change, air pollution, biodiversity, freshwater, waste and material flows, health and environment). For each of these, the key recent trends and projections to 2030 are presented, as well as some of the policy approaches that are being used to address the environmental challenges. Chapter 6 describes some key variations to the Baseline – for example, how the Baseline would differ if key economic drivers (such as economic growth or global trade) were changing faster than projected in the Baseline. The chapter also explores other sources of uncertainty in the *Outlook* projections. Finally, this first part of the report examines the consequences and costs of policy inaction – essentially the environmental, health and economic impacts embodied in the "no new policies" Baseline scenario.

The second part of the *Outlook* report examines the possible policy responses to address the key environmental challenges, and assesses the economic and environmental impact of these responses. The key sectors whose activities affect the environment are examined, with a brief summary of the trends and outlook for their impacts, followed by an assessment of the policy options that could be applied in that sector to reduce negative environmental impacts. This section assesses the environmental benefits of specific policy options and their potential costs to the sector involved and/or economy-wide (and disaggregated by region where appropriate). This analysis can be used by environment ministries in discussing specific policy options for tackling environmental challenges with their colleagues in other ministries, such as finance, agriculture, energy or transport. The sectors examined include those that were prioritised in the *OECD Environmental Strategy* – agriculture, energy and transport – and also other sectors which strongly affect natural resource use or pollution, such as fisheries, chemicals and selected industries (steel, cement, pulp and paper, tourism and mining).

In addition to analysing sector-specific policies, this part of the *Outlook* also examines the effects of a package of policies (the EO policy package) to tackle the main environmental challenges. The analysis of this EO policy package highlights the potential synergies between policies (*i.e.* where the benefits of combining two or more policies may be greater than the simple sum of their benefits as separate policies), or potential conflicts where policies may undermine each other. Chapter 21 outlines the key framework conditions needed to ensure the successful identification and implementation of appropriate environmental policies at the national level, in particular institutional capacity and policy implementation concerns. Chapter 22, on global environmental co-operation, highlights the issues for which OECD countries will need to work together in partnership with other countries in order to reduce overall costs of policy implementation and maximise benefits. It also assesses the costs of inaction.

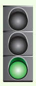
Traffic lights in the *OECD Environmental Outlook*

As with the 2001 *Outlook*, this report uses traffic light symbols to indicate the magnitude and direction of pressures on the environment and environmental conditions. Traffic lights are used to highlight the key trends and projections in the summary table in the Executive Summary, in the Key Messages boxes at the start of each chapter and throughout the chapters. The traffic lights were determined by the experts drafting the chapters, and then refined or confirmed by the expert groups reviewing the report. They represent the following ratings:



Red lights are used to indicate environmental issues or pressures on the environment that require urgent attention, either because recent trends have been negative and are expected to continue to be so in the future without new policies, or because the trends have been stable recently but are expected to worsen.

Yellow lights are given to those pressures or environmental conditions whose impact is uncertain, changing (*e.g.* from a positive or stable trend toward a potentially negative projection), or for which there is a particular opportunity for a more positive outlook with the right policies.



Green lights signal pressures that are stable at an acceptable level or decreasing, or environmental conditions for which the outlook to 2030 is positive.

While the traffic light scheme is simple, thus supporting clear communication, it comes at the cost of sensitivity to the often complex pressures affecting the environmental issues examined in this *Outlook*.

While each of the individual chapters discusses the regional developments for the drivers or environmental impacts analysed, Annex A also provides an easily accessible "summary" of the economic, social and environmental developments in the Baseline for each region. Annex B provides a more detailed analysis of the modelling framework used in the development of the *OECD Environmental Outlook*. A number of background working papers, which provide further information on specific issues addressed in the *Outlook*, were developed to complement the report (see: *www.oecd.org/environment/outlookto2030*).

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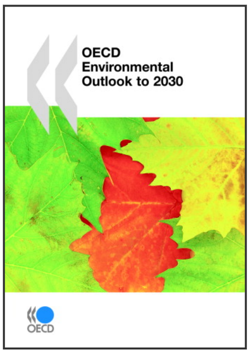
Acronyms and Abbreviations

BRIC	Brazil, Russia, India and China
BRIICS	Brazil, Russia, India, Indonesia, China and South Africa
CBD	Convention on Biological Diversity
CCS	Carbon capture and storage
CDM	Clean Development Mechanism
CFC	Chlorofluorocarbon
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2eq	Carbon dioxide equivalents
CSD	Commission on Sustainable Development
DAC	OECD Development Assistance Committee
EJ	Exajoules
EU15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom
EU25	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom
EUR	Euro (currency of European Union)
FAO	Food and Agriculture Organization of the United Nations
GBP	Pound sterling
GDP	Gross domestic product
GHG	Greenhouse gas
GJ	Gigajoules
GNI	Gross national income
Gt	Giga tonnes
GW	Gigawatt
HFC	Hydrofluorocarbon
IEA	International Energy Agency
IMAGE	Integrated Model to Assess the Global Environment
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land use, land use change and forestry
MAD	Mutual Acceptance of Data
MDGs	Millennium Development Goals
MEA	Multilateral environmental agreement
MNP	Netherlands Environmental Assessment Agency
MSA	Mean species abundance

Mt	Million tonnes
MWh	Megawatt-hour
NO_2	Nitrogen dioxide
N_2O	Nitrous oxide
NO_x	Nitrogen oxides
ODA	Official development assistance
ppb	Parts per billion
ppm	Parts per million
PFC	Perfluorocarbon
PM	Particulate matter
$PM_{2.5}$	Particulate matter, particles of 2.5 micrometres (µm) or less
PM_{10}	Particulate matter, particles of 10 micrometres (µm) or less
ppmv	Parts per million by volume
ROW	Rest of world
RTA	Regional trade agreement
SO_2	Sulphur dioxide
SO_x	Sulphur oxides
SF_6	Sulphur hexafluoride
TWh	Terawatt hour
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States dollar
VOC	Volatile organic compound
WHO	World Health Organization
WSSD	World Summit on Sustainable Development
WTO	World Trade Organization



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