Scientific Facts on

Ecosystem Change

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Summary & Details:
GreenFacts

Level 2 - Details on Ecosystem Change

This Digest is a faithful summary of the leading scientific consensus report produced in 2005 by the Millennium Ecosystem Assessment (MA):
"Millennium Ecosystem Assessment General Synthesis Report:"Ecosystems and Human Well-being"

The full Digest is available at: https://www.greenfacts.org/en/ecosystems/

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1. How have ecosystems changed?

1.1 What types of ecosystems have been changed?

1.1.1 Virtually all of Earth's ecosystems have been significantly transformed through human actions. In the second half of the 20th century ecosystems changed more rapidly than at any other time in recorded human history. Some of the most significant changes have been the conversion of forests and grasslands into cropland, the diversion and storage of freshwater behind dams, and the loss of mangrove and coral reef areas.

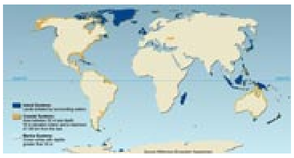
The most rapid changes are now taking place in developing countries, but industrial countries experienced comparable changes in the past. However, current transformations seem to occur at a faster pace than changes prior to the industrial era.

1.1.2 Ten categories of ecosystems have been assessed:

(the links below provide further information and maps)

Urban, Dryland, and Polar Systems [see Annex 51, p. 74]

Inland Water and Mountain Systems [see Annex 30, p. 53]



Marine, Coastal, and Island Systems [see Annex 36, p. 59]

Forest and Cultivated Systems [see Annex 27, p. 51]

See also: Comparative table of the assessed ecosystems [see Annex 39, p. 61]

1.1.3 Within **marine ecoystems [see Annex 36, p. 59]** , populations of fished species have been affected by the world's growing demand for food and animal feed. Since industrial fishing began, the total mass of commercially exploited marine species has been reduced by 90% in much of the world.

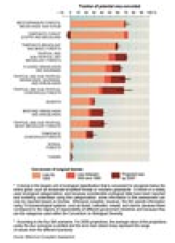


Figure 1.2 Conversion of ecosystems [see Annex 13, p. 38]

Freshwater ecosystems have been modified by the creation of dams and the withdrawal of water for human use, which have changed the flow of many large river systems. This in turn has had other effects such as reducing sediment flows, the main source of nutrients for estuary ecosystems.

Within **terrestrial ecosystems**, more than half of the original area of many types of grasslands and **forests [see Annex 27, p. 51]** has been converted into **farmland**. The only types of land ecosystems which have been changed relatively little are tundra and boreal forests, but climate change has begun to affect them.

1.1.4 Globally, the transformation of ecosystems into farmland has begun to slow down. Opportunities for further expansion of farmland are diminishing in many regions of the world because most of the suitable land has already been converted. Increased agricultural productivity is also reducing the need for more farmland. Moreover, in temperate regions some cropland areas are now reconverted into forest or taken out of production.

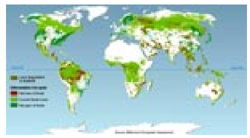


Figure 1.4 Land cover change [see Annex 14, p. 39]

1.2 How have environmental cycles changed?

The capacity of ecosystems to provide benefits to humans, that is to provide ecosystem services, derives from environmental cycles of water, nitrogen, carbon, and phosphorus. These processes have in some cases been significantly modified by human activity. Changes have been more rapid in the second half of the 20th century than at any other time in recorded human history.

1.2.1 **Water cycle**: Water withdrawals from rivers and lakes for irrigation, urban uses, and industrial applications doubled between 1960 and 2000. Globally, humans use slightly more than 10% of the available renewable freshwater supply. However, in some regions such as North Africa, groundwater is withdrawn at a faster pace than it is renewed.

1.2.2 **Carbon cycle**: In the last two and a half centuries, the concentration of carbon dioxide in the atmosphere has increased by one third. Land ecosystems were a net source of carbon dioxide during the 19th and early 20th century and became a net carbon sink sometime around the middle of the last century. This reversal is due to increases in plant growth brought about by, for example, new forest management and agricultural practices.

1.2.3 **Nitrogen cycle**: The total amount of nitrogen made available to organisms by human activities increased nine-fold between 1890 and 1990, especially since 1950 because of the use of synthetic fertilizers. Human activities are now responsible for as much nitrogen made available as all natural sources combined.

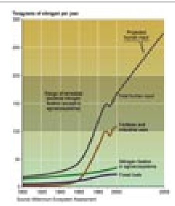


Figure 1.5 Sources of nitrogen [see Annex 15, p. 40]

1.2.4 **Phosphorus cycle**: The use of phosphorus fertilizers and the rate of phosphorus accumulation in agricultural soils nearly tripled between 1960 and 1990, but has declined somewhat since. The flow of phosphorus into the oceans is now three times the natural flow.

1.3 What biodiversity changes have been observed?

See also GreenFacts' digest on Biodiversity [see https://www.greenfacts.org/en/biodiversity/index.htm]

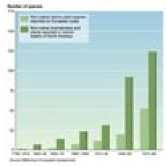


Figure 1.7 Non-native species [see Annex 16, p. 41]

A change in an ecosystem necessarily affects the species which are part of it, and changes in species in turn affect ecosystem processes.

1.3.1 The distribution of species on Earth is becoming more homogeneous. This is caused by the extinction of species or loss of populations that had been unique to particular regions and by the invasion or introduction of species into new areas. For example, of the non-native species in the Baltic Sea, a high proportion are native to the North American Great Lakes. Likewise, some of the non-native species in the Great Lakes can be found naturally in the Baltic Sea.

1.3.2 Within many species groups, the majority of species have faced a decline in the size of their population, in their geographical spread, or both. Certain species may not decline, for instance if they are protected in natural reserves, if particular threats to them are eliminated, or if they thrive in human-modified landscapes. Within well-studied groups (conifers, cycads, amphibians, birds, and mammals), 10 to 50% of species are currently threatened with extinction.

1.3.3 Species extinction is a natural part of Earth's history. However, over the past centuries humans have increased the extinction rate by 50 to 1,000 times compared to the natural rate.

1.3.4 Overall, the range of genetic differences within species has declined, particularly for crops and livestock. This has also been noted for wild species that have been heavily exploited for commercial uses. For other wild species information is limited. In cultivated ecosystems, intensification of agriculture and the lesser use of traditional local species in favor of fewer modern varieties have reduced the genetic diversity of domesticated plants and animals. The permanent loss of genetic diversity has been partially prevented by maintaining seed banks.

2. How have ecosystem services and their uses changed?

2.1 What are ecosystem services?

Ecosystem services are the benefits obtained by people from ecosystems. These include:

- ***provisioning services [see Annex 1, p. 27]*** such as food, water, timber, fiber, and genetic resources;
- ***regulating services [see Annex 1, p. 27]*** such as the regulation of climate, floods, disease, and water quality;
- ***cultural services [see Annex 1, p. 27]*** such as recreational, aesthetic, and spiritual benefits;
- ***supporting services [see Annex 1, p. 27]*** such as soil formation, pollination, and nutrient cycling. Supporting services are not developed further in this question because they are not used directly by humans, even if they are critical to the maintenance of the other types of services.

2.2 What have been the changes in specific ecosystem services?

Human use of all ecosystem services is growing rapidly. Humans have increased the amount or supply of only a small number of ecosystem services, specifically: crops, livestock, aquaculture, and recently, carbon sequestration. Approximately two thirds of the assessed services have been degraded over the past century, for example, freshwater supply and capture fisheries.

2.2.1 **Provisioning services** are the products obtained from ecosystems, such as food, water, and timber. Their use by humans increased rapidly during the second half of the 20th century and continues to grow. The capacity of ecosystems to provide services in the future is jeopardized when services are used more quickly than they can be renewed. The sustainability of the use of provisioning services differs in different locations, but for several of them overall use is unsustainable. For example:

- The current level of fishing has led to the collapse of many fisheries. One quarter of marine fish stocks is currently overexploited or significantly depleted.
- Overall, a significant part of local freshwater use exceeds the renewable supplies, requiring engineered water transfers or overuse of groundwater.
- In some regions, agricultural practices are not sustainable due to the use of unsustainable sources of water, excessive fertilizer or pesticide use, and soil degradation.

See also: Table on Trends in human use of provisioning services [see Annex 40, p. 62] and their enhancement or degradation

2.2.2 **Regulating services** are the results of the functioning of ecosystem processes, and include, for example, climate and disease patterns and waste processing. Humans have substantially modified regulating services by modifying the ecosystem providing the service or, in the case of waste processing, by exceeding the capabilities of ecosystems to provide the service.

Changes to ecosystems have led to:

- modified climate regulation through changing levels of carbon dioxide,
- altered patterns of disease due to habitat change, for example because human populations have been brought into closer contact with diseases,
- a significant rise in the number of floods and major wildfires on all continents since the 1940s, and
- reaching limits of the capabilities of ecosystems to eliminate toxins and excess nutrients

See also: Table on Trends in human use of regulating services [see Annex 41, p. 64] and their enhancement or degradation

2.2.3 **Cultural Services** are the non-material benefits people obtain from ecosystems such as spiritual enrichment, recreation, and aesthetic experiences. Whereas the use of these services has continued to grow, the capability of ecosystems to provide them has been significantly diminished in the past century. Ecosystem change can have a significant impact on cultural identity and social stability. Rapid loss of culturally valued ecosystems and landscapes can contribute to social disruption.

See also: Table on Trends in human use of cultural services [see Annex 42, p. 66] and their enhancement or degradation

2.3 What are the effects of developing substitutes for ecosystem services?

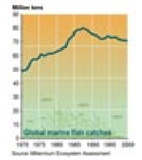


Figure 2.1 Global fish catch [see Annex 17, p. 41]

In the last hundred years, global gains in the supply of food, water, timber, and other provisioning services have often been achieved despite local resource limitations by shifting production and harvest to new less exploited regions. These options are diminishing. Although human demand for ecosystem services continues to grow, the development of substitutes lowers the demand for certain services in particular regions. However, the overall impact of such substitutions may not always be positive. Using fossil fuels instead of fuelwood, for example, reduces indoor air pollution and pressures on forests but increases net greenhouse gas emissions. Substitutes are also often far more expensive to provide than the original ecosystem services.

2.4 What is the link between biodiversity and ecosystem services?

Changes in biodiversity affect the ability of ecosystems to supply services and to recover from disturbances. When a species is added or lost at a particular location, the various ecosystem services specifically associated with that species are changed.

Similarly, when a particular habitat is converted for human use, the ecosystem services associated with the species that live there are changed. This often has direct and immediate impacts on people as well as long-term consequences.

2.5 What are trade-offs or synergies between ecosystem services?

When humans modify an ecosystem to improve a service it provides, this generally results in changes to other ecosystem services.

Trade-offs: When the improvement of one ecosystem service results in negative effects on other services, the net benefits are often smaller than initially believed. For example, actions to increase food production often involve some of the following: reduced water availability for other uses, degraded water quality, reduced biodiversity, reduced forest cover, loss of forest products, and release of greenhouse gases. Such trade-offs are rarely fully considered in decision-making.

Synergies: Actions to conserve or enhance a particular component of an ecosystem or its services can also produce positive synergies which benefit other services or other stakeholders. For example, urban green spaces fulfill spiritual, aesthetic, educational, and recreational needs, while generating other services such as water purification, wildlife habitat, and carbon sequestration. Positive synergies often occur between regulating, cultural and supporting services and with biodiversity conservation.

3. How have ecosystem changes affected human well-being and poverty alleviation?

3.1 How is human well-being linked to ecosystem services?

Human well-being depends notably on material welfare, health, good social relations, security, and freedom. All of these are affected by changes in ecosystem services (see **Box 3.1 [see Annex 3, p. 29]**), but also by the supply and quality of, for example, social capital and technology. When the supply of ecosystem services exceeds the demand, an increase in supply tends to enhance human well-being only marginally. In contrast, when the service is in short supply, a small decrease can substantially reduce well-being.

Specific components of human well-being are linked to ecosystem services (***see figure on linkages in Box 3.1 [see Annex 3, p. 29]***). Further information for each main component is provided in Box 3.1 in the links below:

Basic material for a good life [see Annex 5, p. 30]
Health [see Annex 8, p. 33]
Good social relations [see Annex 7, p. 32]
Security [see Annex 9, p. 34]
Freedom of choice and action [see Annex 6, p. 31]

3.2 How is the economy linked to ecosystem services?

Ecosystem services, particularly food production, timber, and marine fisheries, contribute significantly to global employment and economic activity.

In 2000, the total value of food production was less than 3% of gross world product, but it is a much higher share of GDP within developing countries. Close to half of the total global labor force worked in agriculture, but in industrial countries the share of agricultural employment is much lower (for example, 2.4% in the United States).

The depletion and degradation of many ecosystem services represents a loss of a capital asset that is poorly reflected in conventional economic indicators of well-being such as GDP. For example, a country could cut its forests and deplete its fisheries, and this would show only as a positive gain to GDP, despite the loss of capital assets.

The degradation of ecosystem services often causes significant harm to human well-being.

- Resource management decisions are influenced by markets, and as a result, non-marketed benefits are often lost or degraded.
- The overall benefit of sustainable ecosystem management may often exceed that of converting the ecosystem through farming, clear-cut logging, or other intensive uses (see Figure 3.3 [see Annex 18, p. 42]). However, because of the immediate financial benefit, the conversion of ecosystems is often favored.
- Economic and public health costs associated with damage to ecosystem services can be substantial. For example, the collapse of the Newfoundland cod fishery due to overfishing cost tens of thousands of jobs and at least 2 billion dollars in income support and re-training, (see Figure 3.4 [see Annex 19, p. 44])
- Significant investments are often needed to restore or maintain non-marketed ecosystem services.

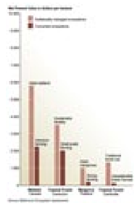


Figure 3.3 Alternate Management Practices [see Annex 18, p. 42]

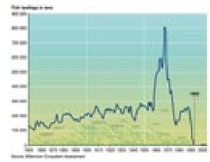


Figure 3.4 Collapse of the Newfoundland cod fishery [see Annex 19, p. 44]

Degradation of ecosystem services could be significantly slowed or reversed if the full economic value of the services were taken into account in decision-making. However, some ecosystem services, like agriculture, often 'compete' with the benefits of maintaining greater biological diversity, and many of the steps taken to increase the production require the simplification of natural systems. The level of biodiversity that survives on Earth will be determined not just by considerations of usefulness but also by ethical concerns like the intrinsic value of species.

Wealthy populations are often buffered from the degradation of ecosystem services through institutions and financial resources. Nevertheless, physical or social impacts of ecosystem service degradation may cross boundaries. It worsens poverty in developing countries, which in turn can affect neighboring industrial countries by slowing regional economic growth and contributing to the outbreak of conflicts or to migration of refugees. Moreover, many industries such as fisheries are still directly dependent on ecosystem services. Wealth can insulate populations from some of the effects of ecosystem degradation, but not from all. For example, substitutes for lost cultural benefits are often not available.

The relative contribution of ecosystem services to gross world product is declining along with the relative importance of traditional natural resource sectors based on ecosystem services. However, economic and employment contributions from ecotourism, recreational hunting, and fishing have all grown. Many of the benefits provided by increasingly important ecosystem services, such as water, are not traded in markets and thus not captured in conventional economic statistics.

Increased trade has often helped to meet growing demand for ecosystem services such as grains, fish, and timber in regions where the supply of those services is limited. While this lessens pressures on ecosystem services within the importing region, it increases pressures in the exporting region. Fish, for example, is heavily traded, and approximately 50% of exports are from developing countries. This trade means that the increasing demand in industrial countries can be met despite reductions in marine fish catch.

Almost half of the world's population now lives in urban areas, and this proportion is growing. Urban developments have strong impacts on both local and distant ecosystem services, for instance by generating waste and affecting air or water quality.

Spiritual and cultural aspects of ecosystems are as important as other services for many local communities. People benefit in many ways from cultural ecosystem services including aesthetic enjoyment, recreation, artistic and spiritual fulfillment, and intellectual development.

3.3 What is the current situation of poverty in the world?

The degradation of ecosystem services poses a significant barrier to the achievement of the Millennium Development Goals (MDGs).

See: Box on Ecosystems and the Millennium Development Goals [see Annex 10, p. 34]

Many of the regions facing the greatest challenges in achieving the MDGs overlap with the regions facing the greatest problems related to the sustainable supply of ecosystem services. Among others, these include sub-Saharan Africa, Central Asia, parts of South and South-East Asia, as well as some regions in Latin America. In the past 20 years, these same regions have experienced some of the highest rates of forest and land degradation in the world.

Despite the increases in the production and use of some ecosystem services, levels of poverty remain high, social differences are growing, and many people still do not have a sufficient supply of, or access to, ecosystem services.

- Over one billion people survive on less than $1 per day of income, most of them in rural areas where they are highly dependent on agriculture, grazing, and hunting for subsistence.
- Inequality has increased over the past decade. A child born in sub-Saharan Africa is 20 times more likely to die before age 5 than a child born in an OECD country, and this ratio is higher than it was a decade ago.
- Despite the growth in per capita food production in the past four decades, an estimated 852 million people were undernourished in 2000-2003. Of these, nearly 95% live in developing countries. The regions with the largest numbers of undernourished people are also the regions where growth in per capita food production has been the slowest.
- 1.1 billion people still lack access to improved water supply and more than 2.6 billion lack access to improved sanitation.

3.4 How is poverty linked to ecosystem services?

The degradation of ecosystem services is harming many of the world's poorest people, and is sometimes the principal factor causing poverty. Some ecosystem changes such as increased food production have helped to lift hundreds of millions of people out of poverty, but these changes have harmed many other communities and their problems have been largely overlooked.

- Half of the urban population in Africa, Asia, Latin America and the Caribbean suffers from one or more diseases associated with inadequate water and sanitation. Approximately 1.8 million people die annually as a result of inadequate water, sanitation, and hygiene.
- The declining state of capture fisheries is reducing a cheap source of protein in developing countries.
- Desertification affects the livelihoods of millions of people.

Changes in ecosystems typically yield benefits for some people and inflict costs on others who may lose either access to resources or livelihoods. The question of who ‘wins’ and who ‘loses’ as a result of ecosystem change has not been adequately taken into account in management decisions.

- People who were dependent on common pool resources such as forests have lost their rights to these resources because of privatization.

- Certain people and places are highly vulnerable and poorly equipped to cope with the major changes in ecosystems that may occur.
- Significant differences between the roles and rights of men and women in many societies make women more vulnerable to changes in ecosystem services. In developing countries, rural women are the main producers of basic crops, and are often also responsible for routine care of the household. Therefore, degradation of ecosystem services can result in increased labor demands on women, diverting time from other activities such as food preparation and child care.
- The reliance of the rural poor on ecosystem services is rarely measured and thus typically overlooked in national statistics and in poverty assessments. This results in inappropriate strategies that do not take into account the role of the environment in poverty reduction.

As demand for ecosystem services has grown, it is particularly poor people that have lost access to them. For example, significant quantities of fish are caught by large foreign fleets in the waters of western Africa, without substantial local benefits.

Diminished human well-being tends to increase immediate dependence on ecosystem services, and the resultant additional pressure can damage the capacity of those ecosystems to deliver services. This can create a downward spiral of increasing poverty and further degradation of ecosystem services.

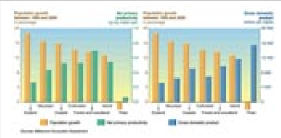


Figure 3.7 Population growth and GDP [see Annex 20, p. 45]

Nearly 500 million people live in rural areas in dryland ecosystems, which have the lowest per capita GDP and the highest Infant Mortality Rate of all of the ecosystem categories assessed in this study (see *comparative table 1.1* *[see Annex 39, p. 61]*).

In the past, population growth was high in high-productivity ecosystems and urban areas. However, since the 1990s growth has been highest in less productive ecosystems such as drylands and mountains (*see Figure 3.7* *[see Annex 20, p. 45]*). Migration from these areas to cities or agriculturally productive regions has helped balance relative population growth, but opportunities for this are now limited.

4. What are the most critical factors causing ecosystem changes?

4.1 What is a "driver" and how does it affect ecosystems?

Natural or human-induced factors that directly or indirectly cause a change in an ecosystem are referred to as drivers.

- A **direct driver**, such as habitat change, explicitly influences ecosystem processes.
- An **indirect driver**, such as human population change, operates more diffusely, by altering one or more direct drivers.

Drivers affecting ecosystem services and human well-being range from local to global and from immediate to long-term, which makes both their assessment and management complex. Climate change may operate on a global or large regional scale; political change may operate at the scale of a nation or a municipal district. Socio-cultural change typically occurs slowly, on a time scale of decades, while economic changes tend to occur more rapidly. As a result of this spatial and temporal dependence of drivers, the forces that appear to be most significant at a particular location and time may not be the most significant over larger, or smaller, regions or time scales.

4.2 What are the indirect drivers and how are they changing?

4.2.1 Driving forces are almost always multiple and interactive, so that a one-to-one linkage between particular driving forces and particular changes in ecosystems rarely exists. Five major indirect drivers that influence ecosystems and ecosystem services are:

- **Population change:** This includes population growth and migration. World population has doubled in the past forty years, reaching 6 billion in 2000, with most of the growth taking place in developing countries. However, at present some developing countries have very low rates of population growth, whereas some high income countries have high rates because of immigration.
- **Change in Economic activity:** Global economic activity has increased nearly seven-fold in the last 50 years. As per capita income grows, demand for many ecosystem services increases and the structure of consumption also changes. The share of income devoted to food, for example, decreases in favor of industrial goods and services.
- **Socio-Political factors:** These factors include decision-making processes and the extent of public participation in them. The trend toward democratic institutions over the past 50 years has helped empower local communities. There has also been an increase in multilateral environmental agreements.
- **Cultural and Religious factors:** In this context, culture can be defined as the values, beliefs, and norms that a group of people share. It conditions individuals' perceptions of the world, and suggests courses of action which can have important impacts on other drivers such as consumption behavior.
- **Science and Technology:** The 20th century saw tremendous advances in the understanding of how the world works and in the technical applications of that knowledge. Much of the increase in agricultural output over the past 40 years has come from an increase in yields per hectare rather than an expansion of area. At the same time, technological advances can also lead to degradation of ecosystem services. Advances in fishing technologies, for example, have contributed significantly to the depletion of marine fish stocks.

4.2.2 Economic growth and consumption of ecosystem services are no longer as closely linked as they were in the past. Generally, the use of ecosystem services has grown much less over the past five decades than GDP. This reflects a change in economic structures but also an increase in the efficient use of services and in the availability of substitutes. However, the consumption of energy and materials continues to grow in absolute terms, since the growth in demand is faster than the increase in efficiency.

Trade of ecosystem services magnifies the effect of governance, regulations, and management practices, both good and bad. Increased trade can accelerate degradation of ecosystem services in exporting countries if their policy, regulatory, and management systems are inadequate. International trade is an important source of economic gains, as it enables comparative advantages to be exploited and accelerates the diffusion of more efficient technologies and practices.

Population and economic growth in urban centers has been increasing pressures on ecosystems. However, dense urban settlement is considered to be a lesser burden on the environment than urban and suburban sprawl. Moreover, pressures on some ecosystems have been significantly lowered by the movement of people to urban areas, leading to the reforestation of some parts of industrial countries.

4.3 What are the direct drivers of changes in ecosystem services?

Figure 4.3 Main Direct Drivers [see Annex 21, p. 46]

Important direct drivers include habitat change, climate change, invasive species, overexploitation, and pollution. Most of the direct drivers of degradation in ecosystems and biodiversity currently remain constant or are growing in intensity in most ecosystems (see Figure 4.3 [see Annex 21, p. 46]).

4.3.1 Over the past 50 years, the most important direct drivers of change have been:

- **In terrestrial ecosystems:** land cover change, mainly by conversion to cropland, and the application of new technologies contributing to the increased supply of food, timber, and fiber. Only areas unsuited to crop plants, such as deserts, boreal forests, and tundra, remain largely untransformed by human action.
- **In marine ecosystems [see Annex 36, p. 59] :** fishing. About half of the commercially exploited wild marine fish stocks for which information is available are fully exploited and without scope for increased catches. The impact of fishing has been particularly significant in coastal areas but is now also affecting the open oceans.
- **In freshwater ecosystems:** water regime changes, such as those following the construction of large dams; invasive species, which can lead to species extinction; and pollution, such as high levels of nutrient loading.

Coastal ecosystems [see Annex 36, p. 59] are affected by multiple direct drivers. Worldwide, nearly 40% of people live on the thin fringe of land within 50 km of the ocean. Fishing pressures in those systems are linked to a wide array of other drivers including land-, river-, and ocean-based pollution, habitat loss, invasive species, and nutrient loading. The greatest threat to **coastal systems [see Annex 36, p. 59]** is the conversion of coastal habitats through coastal urban sprawl, resort and port development, aquaculture, and industrialization.

4.3.2 Over the past four decades, excessive levels of nutrients in soil and water have emerged as one of the most important direct drivers of ecosystem change in terrestrial, freshwater, and **marine ecosystems [see Annex 36, p. 59]** (see table 4.1 [see Annex 45, p. 69]). The use of fertilizers can increase crop productivity, but there are important adverse effects to other ecosystems. Excessive additions of nutrients to freshwater or **coastal marine systems [see Annex 36, p. 59]** can lead to excessive plant and algae growth (a process referred to as eutrophication) and to further undesirable changes in ecosystems. This can in turn reduce or eliminate fish populations, increase outbreaks of microbes, increase the cost of water purification, and degrade cultural services by keeping people from swimming, boating, and otherwise enjoying lakes. Other effects of nutrient loading include air pollution, emission of greenhouse gases, and depletion of the ozone layer.

The climate has changed in the past century: global temperature has increased by about 0.6°C, precipitation patterns have been altered, and the average sea level has risen by 10 to 20 centimeters. Those changes have already had a measurable impact on ecosystems and are projected to continue throughout the 21st century. The effects of climate change on ecosystems include modifications in species distributions, population sizes, and the timing of reproduction or migrations, as well as an increase in pest and disease outbreaks.

5. How might ecosystems and their services change in the future under various plausible scenarios?

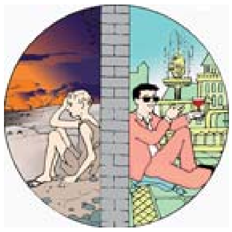
5.1 Which scenarios have been explored in this assessment?

Four plausible scenarios explore the future of ecosystems and human well-being for the next 50 years and beyond. The scenarios consider two possible paths of world development: increasing globalization or increasing regionalization. They also consider two different approaches to ecosystem management: in one approach, actions are reactive and address problems only after they become obvious, in the other approach, ecosystem management is proactive and deliberately aims for long-term maintenance of ecosystem services.

5.1.1 The four scenarios are:

- **Global Orchestration** **[see Annex 32, p. 55]** - This scenario depicts a globally-connected society that focuses on global trade and economic liberalization and takes a reactive approach to ecosystem problems. However, it also takes strong steps to reduce poverty and inequality and to invest in public goods such as infrastructure and education. In comparison to the other scenarios, this scenario has the highest economic growth while it assumes the smallest population in 2050.
- **Order from Strength** **[see Annex 33, p. 56]** - This scenario represents a regionalized and fragmented world, concerned with security and protection, emphasizing primarily regional markets, paying little attention to public goods, and taking a reactive approach to ecosystem problems. In comparison to the other scenarios, economic growth rates are the lowest (particularly low in developing countries) and decrease with time, while population growth is the highest.
- **Adapting Mosaic** **[see Annex 31, p. 54]** - In this scenario, regional watershed-scale ecosystems are the focus of political and economic activity. Local institutions are strengthened and local ecosystem management strategies are common, and societies develop a strongly proactive approach to the management of ecosystems. Economic growth rates are somewhat low initially but increase with time, and the population in 2050 is nearly as high as in the **Order from Strength** **[see Annex 33, p. 56]** scenario.
- **TechnoGarden** **[see Annex 34, p. 57]** - This scenario depicts a globally connected world relying strongly on environmentally sound technology, using highly managed, often engineered, ecosystems to deliver ecosystem services, and taking a proactive approach to the management of ecosystems in an effort to avoid problems. Economic growth is relatively high and accelerates, while population in 2050 is in the mid-range of the scenarios.

Further information about each scenario is provided in the links below:

Ecosystem Management	World Development	
	Globalization	**Regionalization**
Reactive	 **Global Orchestration [see Annex 32, p. 55]**	 **Order from Strength [see Annex 33, p. 56]**
Proactive	 **TechnoGarden [see Annex 34, p. 57]**	 **Adapting Mosaic [see Annex 31, p. 54]**

5.1.2 The scenarios are not predictions, but explore possible future changes in ecosystem services and socio-economic factors. No scenario represents business-as-usual, though all begin from current conditions and trends. The actual future is likely to consist of a mix of approaches and consequences described in the scenarios, as well as events and innovations that have not yet been imagined. No scenario will match the future as it actually occurs. Other scenarios could be developed with either more optimistic or more pessimistic outcomes for ecosystems, their services, and human well-being.

5.2 How might the indirect and direct drivers change over time?

5.2.1 In the four scenarios, ecosystems are affected by the same set of indirect and direct drivers as today, but the relative importance of different drivers is projected to change over the next 50 years. Factors such as global population growth will become relatively less important and other factors (for instance the distribution of people, climate change, and changes to nutrient cycles) will grow in importance.

See: Table 5.1 on the main assumptions of the different scenarios [see Annex 46, p. 70] on future changes in different indirect and direct drivers

Projections from 2000 to 2050 under all the four scenarios:

- **World population** is projected to reach between approximately 8.1 and 9.6 billion people in 2050 (and between 6.8 and 10.5 billion in 2100), depending on the scenario (see figure 5.1 [see Annex 22, p. 47]).
- **Per capita income** is projected to increase two- to four-fold, depending on the scenario, leading to increased consumption.
- **Land use change**, particularly the expansion of agriculture, is projected to stay a major direct driver of change both on land and in rivers and lakes.
- **High nutrient levels** in water (nutrient loading) is projected to become an increasing problem, particularly in developing countries. At present, major impacts include growth of toxic algae, health problems, fish kills, and damage to coral reefs.

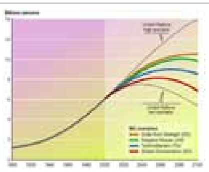


Figure 5.1 Population Growth in the scenarios [see Annex 22, p. 47]

- **Climate change effects** on biodiversity and ecosystem services are projected to increase. Changes are expected at least in temperature, precipitation, vegetation, sea level, and the frequency of extreme weather events.

5.2.2 scenarios

Compared to other estimates of climate change (see, for example, the estimates of the IPCC 3rd Assessment report [see https://www.greenfacts.org/en/climate-change-ar3/index.htm]) these estimates are in the low to middle range, partly because the four scenarios assume that significant action will be taken against climate change by the middle of the 21st century. An increase in global average precipitation is predicted, but some areas will become drier, others wetter.

Ecosystem services will be directly altered by climate change through changes in productivity and growing zones of vegetation, and through changes in the frequency of extreme weather events. Moreover, climate change is predicted to affect ecosystems indirectly, for example through sea level rise affecting shoreline vegetation.

A series of ecosystem services identified as key development challenges are expected to be adversely affected by climate change. These include providing clean water, energy services, and food, maintaining a healthy environment, as well as conserving ecological systems, their biodiversity, and associated ecological goods and services.

By 2100, climate change and its impacts may become the dominant direct drivers of biodiversity loss and change of ecosystem services globally. Though some ecosystem services in some regions may initially benefit from predicted increases in temperature or precipitation, a significant net harmful impact on ecosystem services worldwide is expected once the temperature reaches 2°C above pre-industrial levels or warming increases by more than 0.2°C per decade.

5.3 How might ecosystems change until 2050?

5.3.1 Rapid conversion of ecosystems is projected to continue under all four scenarios. Roughly 10 to 20% of current grassland and forest areas are expected to be converted for the expansion of agriculture, cities, and infrastructure. How quickly ecosystems will be converted is highly dependent on future changes in population, wealth, trade, and technology. Habitat loss on land will lead to a sharp decline in local diversity of native species and related services in all four scenarios by 2050.

The habitat losses projected in the four scenarios will lead to global extinctions as populations adjust to the remaining habitat. The number of plant species, for example, could drop by 10-15% as a result of habitat lost between 1970 and 2050. Some species will be lost immediately when their habitat is modified but others may persist for decades or centuries. Time lags between habitat reduction and extinction provide an opportunity for humans to restore habitats and rescue species from extinction.

See: Table 5.2 on the outcomes of scenarios for ecosystem services [see Annex 47, p. 72] in 2050 Compared with 2000

5.4 How might human well-being change due to changing ecosystems?


Figure 5.3 Services in MA scenarios
[see Annex 23, p. 48]

When comparing provisioning, regulating, and cultural services available to humans today and in 2050, all the scenarios except the **"Order from Strength" scenario [see Annex 33, p. 56]** lead to net improvements in at least one of the service categories. However, even in scenarios showing improvements, biodiversity loss continues rapidly (see figure 5.3 [see Annex 23, p. 48]).

5.4.1 The following changes to ecosystem services and human well-being were common to all the four scenarios:

- Human use of ecosystem services increases substantially. In many cases, this leads to a deterioration in the quality of services, and even a reduction in quantity if the use is unsustainable. Growing population and per capita consumption increase the demand for services, even though resource use is increasingly efficient.
- Food security is likely to remain out of reach for many people, despite increasing food supply and more varied diets in poor countries.
- World freshwater resources are projected to go through vast and complex changes, with great geographic variability. Increased precipitation due to climate change will make more water available in some areas, but will also increase the frequency of flooding. In other areas decreases in precipitation will make less water available. In addition, water withdrawals and wastewater discharges are expected to increase substantially in some developing regions.
- Growing demand for fish leads to an increasing risk of collapse of regional marine fisheries. Aquaculture may relieve some of this pressure, but would have to stop relying on marine fish as a feed source.

5.4.2 The future contribution of terrestrial ecosystems to the regulation of climate is uncertain. Carbon release or uptake by ecosystems affects the amount of certain greenhouse gases in the atmosphere and thus regulates world climate. Currently, ecosystems are a net sink of carbon, absorbing about 20% of fossil fuel emissions. This climate regulating service is very likely to be affected by changes in land use, although predictions are difficult to make because of our limited understanding of soil respiration processes.

5.4.3 Dryland ecosystem services are especially vulnerable to changes, particularly those due to climate change, water stress, and intensive use.

5.4.4 Human health improves in the future under most of the scenarios. The number of children affected by undernourishment is reduced, and so are rates of HIV/AIDS, malaria, and tuberculosis. Improved public health measures limit the impact of new diseases such as SARS. However, under the **"Order from Strength" scenario [see Annex 33, p. 56]** , health and social conditions for the North and South could diverge, causing a negative spiral of poverty, declining health, and degraded ecosystems in developing countries.

5.4.5 Each scenario yields a different package of gains, losses, and vulnerabilities to human well-being in different regions and populations. For example, globally-integrated approaches that focus on technology and property rights for ecosystem services generally improve human well-being in terms of health, security, social relations, and material needs. However, if the same technologies are used globally, local culture can be lost or undervalued.

See: Table 5.3 on the outcomes of scenarios for human well-being [see Annex 48, p. 73] in 2050 compared with 2000

5.5 What are the benefits of proactive management of ecosystems?

The scenarios suggest that proactive management of ecosystems is generally advantageous and particularly so under changing or novel conditions. Ecological surprises are inevitable because the interactions involved are complex and because the dynamic properties of ecosystems are currently not well understood. Surprising phenomena of the past century that are now well understood include the ability of pests to become resistant to biocides and the contribution of certain land uses to desertification.

A proactive approach is more beneficial than a reactive approach, because restoring degraded or collapsed ecosystem services is, if at all possible, more costly and time consuming than preventing degradation. Nevertheless, there are costs and benefits to both proactive and reactive approaches (*as shown in Table 5.4 [see Annex 49, p. 73]*).

See: Table 5.4 on the costs and benefits [see Annex 49, p. 73] of proactive versus reactive ecosystem management

6. Why are both global and sub-global assessments of ecosystem change useful?

The Millennium Ecosystem Assessment (MA) included sub-global assessments. These were designed to address differences in the importance of ecosystem services for human well-being around the world at local, national, and regional scales. The sites of the sub-global assessments are indicated on the map [see Annex 24, p. 49] on the right.

Figure 6.1 MA Sub-Global Assessments [see Annex 24, p. 49]

The assessments conducted at different scales tended to focus on drivers of change and impacts most relevant at each scale, yielding different but complementary findings. Each separate assessment provides a different perspective on the issues addressed.

Overall, the global and sub-global assessments gave similar results on the present state of ecosystem services. However, there are examples such as water resources or biodiversity, where local assessments showed that local conditions were either better or worse than expected from the global assessment.

Similar drivers might be present in different assessments, but their interactions and the conditions leading to ecosystem change differed significantly. The assessments identified an imbalance in the distribution of the benefits and costs of ecosystem change, as these are often displaced or postponed.

Some ecosystem problems have been reduced by innovative local responses. However, the “threats” observed at a global level may be difficult to assess from a more local perspective, and the consequences of actions that go beyond the actor’s immediate perspective are often overlooked. Therefore, institutions are needed at multiple levels to enhance the adaptive capacity and effectiveness of sub-national and local responses.

Stakeholders at different scales perceive different values in various ecosystem services. Ignoring this can undermine the effectiveness of assessments and lead to unworkable and inequitable policies or programs at all scales. Ecosystem services that are of considerable importance at global scales, such as carbon sequestration or waste regulation, are not necessarily seen to be of value locally. Similarly, services of local importance are often not seen as important globally.

Results of sub-assessments which included not only scientific but also local non-scientific knowledge appeared more relevant, credible, and legitimate to some local users. Integrated assessments of ecosystems and human well-being must adapt to the specific needs and characteristics of the different groups undertaking the assessment and should also consider the needs of decision-makers.

Several community-based assessments adapted the Millennium Ecosystem Assessment (MA) framework in order to gain more dynamic interplay between variables, capture finer patterns and processes in complex systems, and leave room for a more spiritual worldview. These modifications and adaptations of the framework are an important outcome of this assessment.

7. How do ecosystems change over time?

7.1 What is known about ecosystem inertia and time scales of change?

This question addresses:

- Time scales of change: how long it takes for the effects of change in an ecosystem to become apparent (also referred to as lag time).
- Inertia: the delay or slowness in the response of an ecosystem to certain factors of change.

Many impacts of humans on ecosystems (both harmful and beneficial) are slow to become apparent. This may transfer the costs associated with current ecosystem changes to future generations. For example, the use of groundwater supplies can exceed the recharge capacity for some time before costs of extraction begin to increase significantly. In general, people manage ecosystems in such ways that short-term benefits are increased, while long-term costs go unnoticed or are ignored.

Different ecosystem services tend to change over different time scales, making it difficult for managers to fully evaluate trade-offs. For example, supporting services (such as soil formation and plant growth) and regulating services (such as water and disease regulation) tend to change over much longer time scales than provisioning services do. As a consequence, impacts on more slowly changing services are often overlooked.

The degree of inertia of different drivers of ecosystem change differs considerably. The speed at which a driver reacts strongly influences how quickly related ecosystem problems can be solved once they are identified. For some drivers, such as the overharvest of particular species, lag times are rather short and the impact of the driver can quickly be reduced or stopped. Nutrient loading and, especially, climate change have much longer lag times and the effects of these drivers cannot be reduced for years or decades. The extinction of species due to habitat loss also has a significant lag time. Even if habitat loss were to end today, it would take hundreds of years for species numbers to reach a new, lower, equilibrium in response to the habitat change that took place in the last centuries.

For some species this process can be rapid, but for others, like trees, it may take centuries. Consequently, reducing the rate of habitat loss might only have a small impact on extinction rates over the next half century, but lead to significant benefits in the long term. Time lags between habitat reduction and extinction provide an opportunity for humans to restore habitats and rescue species from extinction.

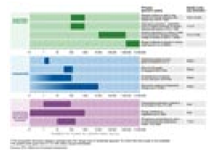


Figure 7.1 Temporal and spatial scales
[see Annex 25, p. 50]

7.2 When do non-linear or abrupt changes occur in ecosystems?

Most changes in ecosystems and their services are gradual and incremental, making them, at least in principle, detectable and predictable. However, many examples exist of non-linear and sometimes abrupt changes in ecosystems. A change may be gradual until a particular pressure on the ecosystem reaches a threshold, at which point rapid shifts to a new state occur. Some non-linear changes can be very large and have substantial impacts on human well-being. Capabilities for predicting non-linear changes are improving, but in most cases science can not yet predict the exact thresholds.

- **Emergence of infectious diseases:** An epidemic spreads if a certain transmission threshold is crossed, that is if, on average, each infected person infects at least one other person. The epidemic dies out if the infection rate is lower. When humans live closely together and in contact with infected animals, epidemics can potentially spread quickly through the well connected and mobile world population. The almost instantaneous outbreak of SARS in different parts of the world is an example of such potential, although rapid and effective action contained its spread.
- **Algal blooms and fish kills:** Excessive nutrient loading causes eutrophication of freshwater and coastal ecosystems. While small increases in nutrient loading often cause little change in ecosystems, once a threshold is reached the changes can be abrupt and extensive, causing bursts of algae growth. Severe eutrophication can kill animal life in the water by causing oxygen-depleted zones.
- **Collapse of fisheries:** Collapses of fish populations have been common in both freshwater and marine fisheries. A moderate level of catch often has a relatively small impact, but with increasing catches a threshold is reached where too few adult fish remain to produce enough offspring to support this level of harvest. For example, the Atlantic cod stocks of the east coast of Newfoundland collapsed in 1992, forcing the closure of the fishery (*see Figure 3.4 [see Annex 19, p. 44]*).
- **Species introductions and losses** can also cause non-linear changes in ecosystems and their services. For example, the loss of the sea otters from many coastal ecosystems on the Pacific Coast of North America due to hunting led to a boom of sea urchin populations (a prey species for otters) which in turn led to the loss of kelp forests (which are eaten by urchins).
- **Changes in dominant species in coral ecosystems:** Some coral reef ecosystems have undergone sudden shifts from coral-dominated to algae-dominated reefs. Such abrupt shifts are essentially irreversible, and once a threshold is reached the change takes place within months. In Jamaican reef systems, centuries of overfishing of algae-grazing species contributed to a sudden switch leading to low diversity, algae-dominated reefs with very limited capacity to support fisheries.
- **Regional climate change:** The vegetation in a region influences climate through affecting the amount of sunlight which is reflected, the amount of water released by plants to the atmosphere, and the amount of wind and erosion. In the Sahel region, vegetation cover is closely linked to rainfall. When vegetation is present, rainfall is quickly recycled, generally increasing precipitation and, in turn, leading to denser vegetation. Land degradation reduces water recycling and may have contributed to the rainfall reduction in the Sahel region during the last 30 years.

7.3 How are humans increasing the risk of non-linear ecosystem changes?

Ecosystem are resilient to disturbances until a certain threshold, meaning that they are able to withstand them or to recover from them. Changes in ecosystems caused by humans may reduce this resilience and increase the likelihood of abrupt changes in the system, with important consequences for human well-being.

The species of an ecosystem belong to different functional groups. Within each group, species may contribute in similar ways to ecosystem processes and services but respond differently to environmental fluctuations. This diversity in responding enables ecosystems to adjust to changing environments and to maintain processes and services. The loss of biodiversity that is now taking place thus tends to reduce the resilience of ecosystems.

Threshold changes in ecosystems are not uncommon, but are becoming much more likely as human-induced pressures on ecosystems are growing. For example, as human populations become more mobile, more and more species are being introduced into new habitats. This increases the likelihood of harmful pests to emerge.

Once an ecosystem has undergone a non-linear change, recovery to the original state is generally slow, costly, and sometimes even impossible. For example, the recovery of over-exploited fisheries after collapse and closure is quite variable. The cod fishery in Newfoundland has been closed for nearly 13 years, but there have been few signs of a recovery (*see Figure 3.4 [see Annex 19, p. 44]*). However, the North Sea herring fishery recovered after a four-year closure after a collapse due to overharvest in the late 1970s.

8. What options exist to manage ecosystems sustainably?

8.1 How can degradation of ecosystem services be reversed?

It is a major challenge to reverse the degradation of ecosystems while meeting increasing demands for their services, but this challenge can be met. Three of the four scenarios show that changes in policies, institutions, and practices can mitigate some of the negative consequences of growing pressures on ecosystems. However, the actions that would be required to reverse degradation are much larger than those currently under way.

Required actions include

- major investments in environmentally sound technology,
- active adaptive management,
- proactive action to address environmental problems before their full consequences are experienced,
- major investments in public goods (for example, education and health), and
- strong action to reduce economic disparities and eliminate poverty.

Examples of specific actions taken under different Millennium Ecosystem Assessment scenarios

- in **Global Orchestration [see Annex 32, p. 55]** trade barriers are eliminated, distorting subsidies are removed, and a major emphasis is placed on eliminating poverty and hunger;
- in **Adapting Mosaic [see Annex 31, p. 54]** , by 2010 most countries are spending close to 13% of their GDP on education (compared with an average of 3.5% in 2000), and many institutional arrangements are made to transfer skills and knowledge among regional groups;
- In **TechnoGarden [see Annex 34, p. 57]** , individuals and companies are paid to provide or maintain ecosystem services and significant advances occur in the development of environmental technologies.

Past actions to slow or reverse the degradation of ecosystems have been beneficial. However, these improvements have generally not kept pace with growing pressures and demands. Although most ecosystem services have been degraded, the extent of that degradation would have been much greater without actions implemented in past decades.

8.2 What types of actions would most benefit ecosystems?

The present assessment examined a wide range of possible actions to benefit ecosystems. The following general categories of actions emerged as particularly promising as they lead to the greatest long-term benefits for ecosystems and human well-being.

8.2.1 **Institutions and governance:** Many institutions at both the global and the national level have the mandate to address the degradation of ecosystem services but face a variety of challenges in doing so. Today's institutions were not designed to take into account the threats associated with this degradation, nor to deal adequately with the management of open access resources, a characteristic of many ecosystem services. Changes in institutional and environmental governance frameworks are sometimes required to enable effective management of ecosystems. Promising actions include, amongst others, integration of ecosystem management goals within other sectors, and an increased coordination among international environmental agreements.

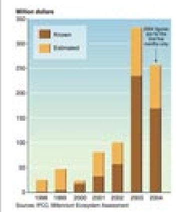


Figure 8.1 Carbon market
[see Annex 26, p. 50]

8.2.2 **Economics and incentives:** Economic and financial interventions are powerful instruments that can regulate the use of goods and services. However, since many ecosystem services are not traded in markets, there are no appropriate market signals (such as price) that contribute to their efficient distribution and sustainable use. In addition, the people harmed by the degradation of ecosystem services are often not the ones who benefit from the actions leading to their degradation. Hence those costs are not taken into account in management decisions. Promising actions include, amongst others, the elimination of subsidies that promote excessive and unsustainable fishing or agriculture, and the greater use of market instruments such as taxes and user fees.

8.2.3 **Social and behavioral actions** generally involve participation of stakeholders in efforts to improve ecosystems and human well-being. Promising actions include improved communication, as well as education and empowerment of groups particularly dependent on ecosystem services or affected by their degradation, including women, indigenous people, and youth.

8.2.4 **Technological actions:** Given the increased pressures on ecosystems, the development and diffusion of technologies that can increase the efficiency of resource use or reduce impacts on ecosystems are essential. However, technological changes can also have unknown negative consequences on ecosystems and human well-being. It is thus important to make careful assessments before the introduction of new technologies, as the cost of later adjustments may be extremely high. Promising actions target, for instance, agricultural practices, ecosystem restoration, and energy efficiency.

8.2.5 **Information based actions:** The lack or inadequate use of information on different aspects of ecosystems can limit the efficiency of ecosystem management. Although enough information exists to take many actions that could help to conserve ecosystems and enhance human well-being, major gaps remain. For example, in most regions, relatively limited information exists about the status and economic value of most ecosystem services, and their degradation is rarely tracked in national economic accounts (e.g., GDP). Moreover, decision-makers do not use all of the relevant information that is available, such as scientific information or traditional knowledge. Promising actions include basing management and investment decisions on both market and non-market values of ecosystems, improving the use of relevant information, and enhancing and sustaining the capacity to assess the consequences of ecosystem change.

8.3 How can decision-making processes be improved?

Decision-making processes vary across jurisdictions, institutions, and cultures. A series of elements tend to improve the decisions reached and their outcomes for ecosystems and human well-being:

- Use the best available information.
- Ensure transparency and the effective participation of important stakeholders.
- Recognize that not all important values at stake can be quantified.
- Strive for efficiency.
- Consider equity and vulnerability.
- Ensure accountability, monitoring, and evaluation.
- Consider cumulative effects and effects that occur on different scales.

Decision-making can be improved through tools for stakeholder participation, information gathering, and planning.

A variety of frameworks and methods can be used to make better decisions in the face of uncertainties in data, prediction, context, and scale, but few of them address equity.

Scenarios can be used to address many uncertainties, but they also create uncertainties of their own due to our limited understanding of ecological and human responses.

Historically, most actions addressing ecosystem services have concentrated on increasing short-term productivity of provisioning services such as food production.

Effective management of the ecosystems in any particular region requires coordinated actions at multiple scales. Stakeholder at different scales perceive different values in various ecosystem services. Ignoring this can undermine the effectiveness of assessments and lead to unworkable and inequitable policies or programs at all scales. Ecosystem services that are of considerable importance at global scales, such as carbon sequestration or waste regulation, are not necessarily seen to be of value locally. Similarly, services of local importance are often not seen as important globally. Active adaptive management can be particularly valuable as a tool for reducing uncertainty about ecosystem management decisions.

9. What are the most important uncertainties hindering decision-making concerning ecosystems?

Adequate scientific information related to a number of important policy questions on ecosystem services and human well-being could not be provided by this assessment.

The following key uncertainties were identified. Reducing these could significantly enhance the ability of a process like the present assessment to answer those policy questions.

9.1 What remains unknown about conditions and trends in ecosystems?

Conditions and trends in ecosystems are difficult to assess because of gaps in, or lack of:

- global and national **monitoring systems** and analysis of the data gathered;
- information on **non-marketed ecosystem services**, particularly regulating, cultural, and supporting services;
- a complete **inventory** of services;

- information on the **economic consequences** of changes in ecosystem services at any scale;
- **models** of the relationship between ecosystem services and human well-being.

More information is needed about:

- interactions among drivers in particular regions and across scales;
- responses of ecosystems to changes in nutrient and carbon dioxide availability;
- non-linear changes and thresholds in ecosystems;
- specific relationships between biodiversity and ecosystem services.

9.2 What are the problems linked to the use of scenarios?

There is a need for analytical and methodological approaches to explicitly link scenarios developed at different geographic scales. Such approaches would provide decision-makers with detailed information that directly links the local, national, regional, and global scales of the future of ecosystem services.

Significant advances are needed in models that link ecological and social processes. Models do not yet exist for many cultural, and supporting ecosystem services. There is also a lack of theories and models that anticipate thresholds at which an ecosystem suffers fundamental changes or even a collapse.

Communicating the complexity associated with comprehensive models and scenarios involving ecosystem services to non-specialists is difficult, in particular due to non-linear changes, feedbacks, and time lags in most global ecosystems.

9.3 What are the uncertainties in the response options?

There is limited information on the costs and benefits of alternative policy options in terms of total economic value (including non-marketed ecosystem services).

There has been little social science analysis of the effectiveness of actions on biodiversity conservation.

Not enough is known about the importance placed by different cultures on cultural services, how this changes over time, and how it influences the net costs and benefits of trade-offs and decisions.

10. Conclusions: main findings

The Millennium Assessment was carried out in order to better understand the link between ecosystems and human well-being. This process led to four main findings:

10.1 Finding 1: Ecosystem change in last 50 years

Over the past 50 years, humans have changed the structure and functioning of the world's ecosystems more rapidly and extensively than in any period in human history. For instance, more land has been converted to cropland since 1945 than in the 18th and 19th centuries combined. These changes have been made largely to meet rapidly growing demands for food, freshwater, timber, fiber, and fuel. Between 1960 and 2000, the demand for ecosystem services grew significantly as the world's population doubled and global economic activity increased more than six-fold. The demands have been met by both consuming an increasing fraction of the available supply (for example, diverting more water for irrigation or catching more fish) and by raising the production of services such as crops and livestock. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth.

More information on:

- Changes to the structure and functioning of ecosystems [see https://www.greenfacts.org/en/ecosystems/millennium-assessment-3/99-main-findings-0.htm#1p0]
- Loss of biodiversity [see https://www.greenfacts.org/en/ecosystems/millennium-assessment-3/99-main-findings-0.htm#1p2]
- Growth in demand for resource [see https://www.greenfacts.org/en/ecosystems/millennium-assessment-3/99-main-findings-0.htm#1p2]

10.2 Finding 2: Gains and losses from ecosystem change

The changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development in most countries. The use of ecosystems through agriculture, fisheries, and forestry has been the basis for development for centuries, providing revenues that have enabled investments in industrialization and poverty reduction. However, actions to increase one ecosystem service often cause degradation of other services, which in turn can cause significant harm to human well-being. Examples include increased risks of non-linear ecosystem changes, loss of natural capital assets, the exacerbation of poverty for some people, and growth in inequalities between groups of people. These problems, unless addressed, will substantially reduce the benefits that future generations obtain from ecosystems. It is difficult to assess the implications of ecosystem changes and to manage ecosystems effectively because many of the effects are slow to become apparent, because they may occur at some distance, and because different stakeholders bear the costs and reap the benefits of changes. Approximately 60% of the ecosystem services evaluated in this assessment (15 out of 24) are being degraded or used unsustainably. For example, capture fisheries and freshwater are now used at levels well beyond what can be sustained even at current demands, let alone at future ones.

More information on:

- Gains for human well-being [see https://www.greenfacts.org/en/ecosystems/millennium-assessment-3/99-main-findings-0.htm#2p0]
- Degradation and unsustainable use of ecosystem services [see https://www.greenfacts.org/en/ecosystems/millennium-assessment-3/99-main-findings-0.htm#2p2]
- Increased likelihood of nonlinear changes [see https://www.greenfacts.org/en/ecosystems/millennium-assessment-3/99-main-findings-0.htm#2p3]
- Disparities across groups of people [see https://www.greenfacts.org/en/ecosystems/millennium-assessment-3/99-main-findings-0.htm#2p4]

10.3 Finding 3: Ecosystem prospects for next 50 years

The Millennium Ecosystem Assessment (MA) developed four scenarios to explore plausible futures for ecosystems and human well-being. In the scenarios, growing pressures on ecosystems during the first half of this century could result in significant growth in consumption, continued loss of biodiversity, and further degradation of some ecosystem services. Most direct drivers of change in ecosystems, such as climate change, overexploitation, and pollution, are likely to remain constant or increase in intensity in most ecosystems. In all four scenarios, these pressures on ecosystems are projected to continue to grow during the first half of the century. The degradation of ecosystem services already poses a significant barrier to the achievement of the Millennium Development Goals.

More information on:

- Direct drivers in the scenarios [see https://www.greenfacts.org/en/ecosystems/millennium-assessment-3/99-main-findings-0.htm#3p0]
- Changes in consumption [see https://www.greenfacts.org/en/ecosystems/millennium-assessment-3/99-main-findings-0.htm#3p2]
- Ecosystem change & Millennium Development Goals [see https://www.greenfacts.org/en/ecosystems/millennium-assessment-3/99-main-findings-0.htm#3p3]

10.4 Finding 4: Reversing ecosystem degradation

The challenge of reversing the degradation of ecosystems while meeting increasing demands for their services can be partially met under some scenarios involving significant changes in policies and institutions, substantial technological innovations, and increases in the capacity of people to manage local ecosystems and adapt to ecosystem change. However, the actions that would be required to reverse degradation are much larger than those currently taken. Past actions to slow down or reverse the degradation of ecosystems have yielded significant benefits, but these improvements have generally not kept pace with growing pressures and demands. Substitutes can be developed for some ecosystem services, but not for all. However, they are generally expensive and may also have negative environmental consequences.

Ecosystem degradation can rarely be reversed without addressing the five indirect drivers of change: population change (including growth and migration), change in economic activity (including economic growth, disparities in wealth, and trade patterns), socio-political factors (ranging from the presence of conflict to public participation in decision-making), cultural factors, and technological change. Many options exist to conserve or enhance specific ecosystem services in ways that reduce negative trade-offs or that provide positive synergies with other ecosystem services.

More information on:

- The possiblity to reverse ecosystem degradation [see https://www.greenfacts.org/en/ecosystems/millennium-assessment-3/99-main-findings-0.htm#0p0]
- Response options [see https://www.greenfacts.org/en/ecosystems/millennium-assessment-3/99-main-findings-0.htm#4p2]

Annex

Annex 1:
Box 2.1: Ecosystem Services

"Ecosystem Services are the benefits people obtain from ecosystems. These include provisioning, regulating, and cultural services that directly affect people and supporting services needed to maintain other services (CF-2). Many of the services listed here are highly interlinked (Primary production, photosynthesis, nutrient cycling, and water cycling, for example, all involve different aspects of the same biological processes.)

Provisioning Services. These are the products obtained from ecosystems, including:

- *Food.* This includes the vast range of food products derived from plants, animals, and microbes.
- *Fiber.* Materials such as wood, jute, cotton, hemp, silk, and wool.
- *Fuel.* Wood, dung, and other biological materials serve as sources of energy.
- *Genetic resources.* This includes the genes and genetic information used for animal and plant breeding and biotechnology.
- *Biochemicals, natural medicines, and pharmaceuticals.* Many medicines, biocides, food additives such as alginates, and biological materials are derived from ecosystems.
- *Ornamental resources.* Animal and plant products, such as skins, shells and flowers are used as ornaments and whole plants are used for landscaping and ornaments.
- *Freshwater.* People obtain freshwater from ecosystems and thus the supply of freshwater can be considered a provisioning service. Freshwater in rivers is also a source of energy. Because water is required for other life to exist, however, it could also be considered a supporting service.

Regulating Services. These are the benefits obtained from the regulation of ecosystem processes, including:

- *Air quality regulation.* Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality;
- *Climate regulation.* Ecosystems influence climate both locally and globally. For example, at a local scale, changes in *land cover* can affect both temperature and precipitation. At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases.
- *Water regulation.* The timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in *land cover*, including, in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.
- *Erosion regulation.* Vegetative cover plays an important role in soil retention and the prevention of landslides.
- *Water purification and waste treatment.* Ecosystems can be a source of impurities (e.g., in fresh water) but also can help to filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems and assimilate and detoxify compounds through soil and sub-soil processes.
- *Disease regulation.* Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes.
- *Pest regulation.* Ecosystem changes affect the prevalence of crop and livestock pests and diseases.
- *Pollination.* Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators.
- *Natural hazard regulation.* The presence of coastal ecosystems such as *mangroves* and coral reefs can reduce the damage caused by hurricanes or large waves.

Cultural Services. These are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, including:

- *Cultural diversity.* The diversity of ecosystems is one factor influencing the diversity of cultures.
- *Spiritual and religious values.* Many religions attach spiritual and religious values to ecosystems or their components.
- *Knowledge systems (traditional and formal).* Ecosystems influence the types of knowledge systems developed by different cultures.
- *Educational values.* Ecosystems and their components and processes provide the basis for both formal and informal education in many societies.
- *Inspiration.*. Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.
- *Aesthetic values.* Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, scenic drives, and the selection of housing locations.
- *Social relations.* Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies.

- *Sense of place.* Many people value the "sense of place" that is associated with recognized features of their environment, including aspects of the ecosystem.
- *Cultural heritage values.* Many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species.
- *Recreation and ecotourism.* People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.

Supporting Services. Supporting services are those that are necessary for the production of all other ecosystem services. They differ from provisioning, regulating, and cultural services in that their impacts on people are often indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people. (Some services, like erosion regulation, can be categorized as both a supporting and a regulating service, depending on the time scale and immediacy of their impact on people).

- *Soil Formation.* Because many provisioning services depend on soil fertility, the rate of soil formation influences human well-being in many ways.
- *Photosynthesis.* Photosynthesis produces oxygen necessary for most living organisms.
- *Primary Production.* The assimilation or accumulation of energy and nutrients by organisms.
- *Nutrient cycling.* Approximately 20 nutrients essential for life, including nitrogen and phosphorus, cycle through ecosystems and are maintained at different concentrations in different parts of ecosystems.
- *Water cycling.* Water cycles through ecosystems and is essential for living organisms."

Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 2, p.40
(Responses Working Group Report, R9 Nutrient Management, Fig 9.2)

Annex 2:

Box 3.1 Table. Selected Water-related Diseases.

"Approximate yearly number of cases, mortality, and disability-adjusted life years. The DALY is a summary measure of population health, calculated on a population scale as the sum of years lost due to premature mortality and the healthy years lost due to disability for incident cases of the ill-health condition."

Disease	Number Of Cases	Disability Adjusted Life Years (1000 Dalys)	Estimated Mortality (1000s)	Relationship To Freshwater Services
Diarrhea	4 billion	62,000 (54 000[b])	1,800 (1700[b])	Water contaminated by human faeces
Malaria	300-500 million	46,000	1,300	Transmitted by Anopheles mosquitoes
Schistosomiasis	200 million	1,700	15	Transmitted by aquatic mollusks
Dengue and dengue hemorrhagic fever	50 to 100 million dengue & 500,000 DHF	616	19	Transmitted by Aedes mosquitoes
Onchocerciasis (River Blindness)	18 million	484	0	Transmitted by black fly
Typhoid and paratyphoid fevers	17 million			Contaminated water, food, flooding
Trachoma	150 million with 6 million blind	2,300	0	Lack of basic hygiene
Cholera	140,000 to 184,000 [a]		5 to 28[a]	Water and food contaminated by human faeces
Dracunculiasis (Guinea Worm Disease)	96,000			Contaminated water

[a] The upper part of the range refers specifically to 2001.
[b] Diarrhea is a water-related disease, but not all diarrhea is associated with contaminated water. The number in parentheses refers to the diarrhea specifically associated with contaminated water.

Annex 3:
Box 3.1. Linkages between Ecosystem Services and Human Well-being

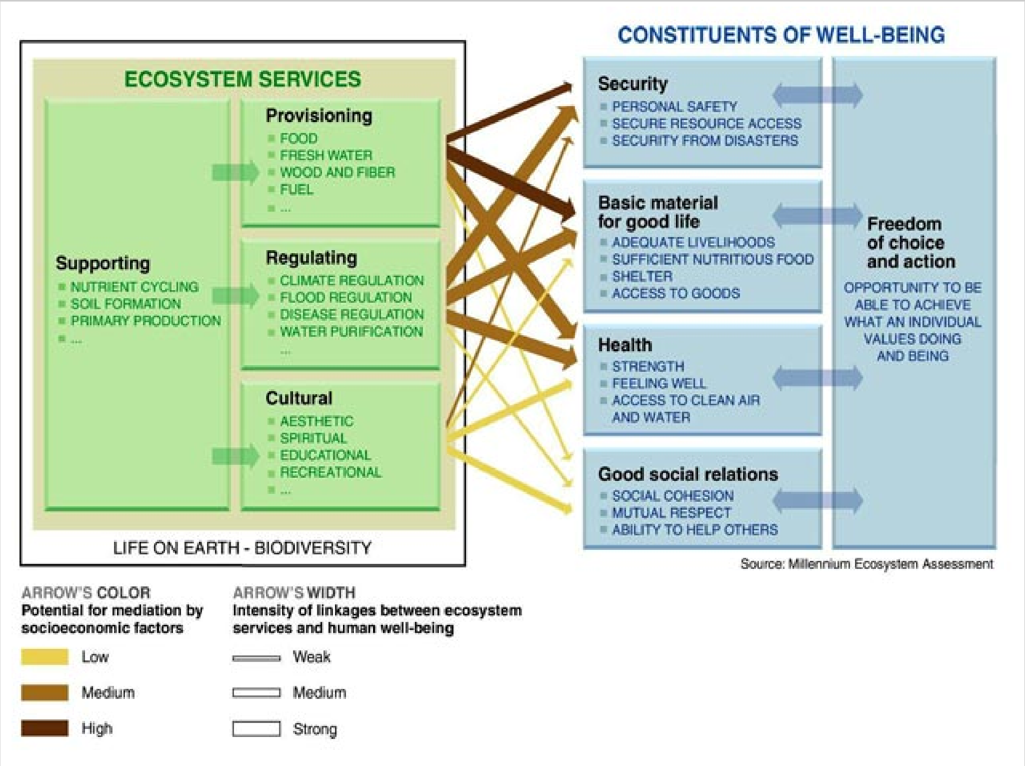
"Human well-being has five main components: the basic material needs for a good life, health, good social relations, security, and freedom of choice and action. (See Figure A, below) This last component is influenced by other constituents of well-being (as well as by other factors including, notably, education) and is also a precondition for achieving other components of well-being, particularly with respect to equity and fairness. Human well-being is a continuum-from extreme deprivation, or poverty, to a high attainment or experience of well-being. Ecosystems underpin human well-being through supporting, provisioning, regulating, and cultural services. Well-being also depends on the supply and quality of human services, technology, and institutions.

See also specific information for each main component:

- Basic material for a good life [see Annex 5, p. 30]
- Health [see Annex 8, p. 33]
- Good social relations [see Annex 7, p. 32]
- Security [see Annex 9, p. 34]
- Freedom of choice and action [see Annex 6, p. 31]

Figure A. Linkages between Ecosystem Services and Human Well-being.

This figure depicts the strength of linkages between categories of ecosystem services and components of human well-being that are commonly encountered, and includes indications of the extent to which it is possible for socioeconomic factors to mediate the linkage. (For example, if it is possible to purchase a substitute for a degraded ecosystem service, then there is a high potential for mediation.) The strength of the linkages and the potential for mediation differ in different ecosystems and regions. In addition to the influence of ecosystem services on human well-being depicted here, other factors-including other environmental factors as well as economic, social, technological, and cultural factors-influence human well-being, and ecosystems are in turn affected by changes in human well-being. (See Figure B [see Annex 4, p. 30]) "

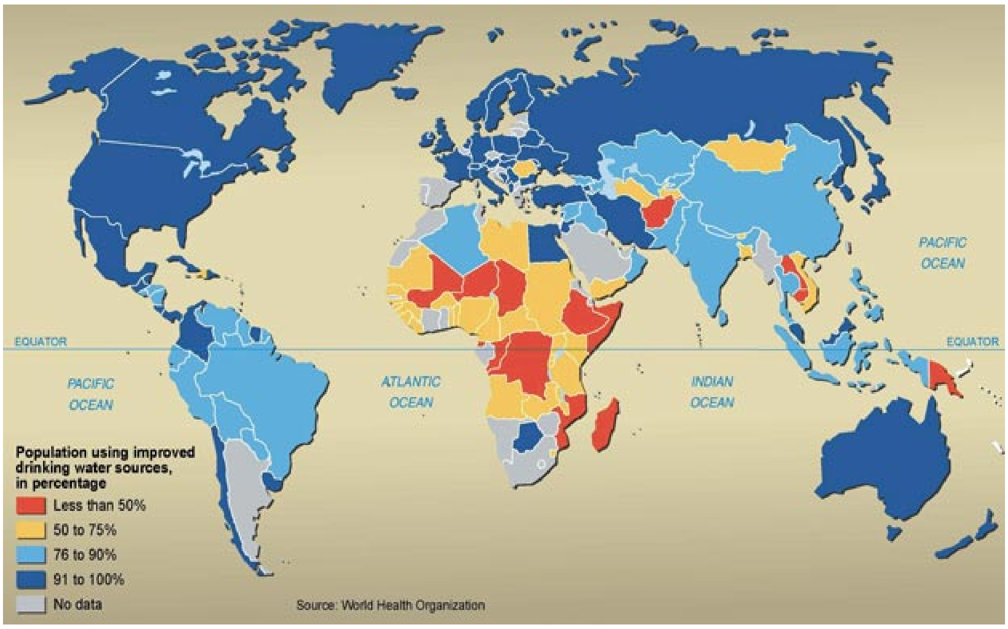


Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 3, p.50

Annex 4:

Box Figure B. Proportion of Population with Improved Drinking Water Supply in 2002

"Access to improved drinking water is estimated by the percentage of the population using the following drinking water sources: household connection, public standpipe, borehole, protected dug well, protected spring, or rainwater collection."



Source: Millennium Ecosystem Assessment Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 3, Box 3.1, p.52

Annex 5:

Box 3.1. Linkages between Ecosystem Services and Human Well-being: Basic Materials for a Good Life

(see figure on linkages in Box 3.1 [see Annex 3, p. 29]).

See also specific information for each main component:

- Health [see Annex 8, p. 33]
- Good social relations [see Annex 7, p. 32]
- Security [see Annex 9, p. 34]
- Freedom of choice and action [see Annex 6, p. 31]

"This refers to the ability to have a secure and adequate livelihood, including income and assets, enough food and water at all times, shelter, ability to have energy to keep warm and cool, and access to goods. Changes in provisioning services such as food, water, and fuelwood have very strong impacts on the adequacy of material for a good life. Access to these materials is heavily mediated by socioeconomic circumstances. For the wealthy, local changes in ecosystems may not cause a significant change in their access to necessary material goods, which can be purchased from other locations, sometimes at artificially low prices if governments provide subsidies (for example, water delivery systems). Changes in regulating services influencing water supply, pollination and food production, and climate have very strong impacts on this element of human well-being. These, too, can be mediated by socioeconomic circumstances, but to a smaller extent. Changes in cultural services have relatively weak linkages to material elements of well-being. Changes in supporting services have a strong influence by virtue of their influence on provisioning and regulating services. The following are some examples of material components of well-being affected by ecosystem change.

Income and Employment: Increased production of crops, fisheries, and forest products has been associated with significant growth in local and national economies. Changes in the use and management of these services can either increase employment (as, for example, when agriculture spreads to new regions) or decrease it through gains in productivity of labor. In regions where productivity has declined due to land degradation or overharvesting of fisheries, the impacts on local economies and employment can be devastating to the poor or to those who rely on these services for income.

Food: The growth in food production and farm productivity has more than kept pace with global population growth, resulting in significant downward pressure on the price of foodstuffs. Following significant spikes in the 1970s caused primarily by oil crises, there have been persistent and profound reductions in the price of foodstuffs globally (C8.1). Over the last 40 years, food prices have dropped by around 40% in real terms due to increases in productivity (C26.2.3). It is well established that past increases in food production, at progressively lower unit cost, have improved the health and well-being of billions, particularly the most needy, who spend the largest share of their incomes on food (C8.1). Increased production of food and lower prices for food have not been entirely positive. Among industrial countries, and increasingly among developing ones, diet-related risks, mainly associated with overnutrition, in combination with physical inactivity now account for one third of the burden of disease (R16.1.2). At present, over 1 billion adults are overweight, with at least 300 million considered clinically obese, up from 200 million in 1995 (C8.5.1).

Water Availability: The modification of rivers and lakes through the construction of dams and diversions has increased the water available for human use in many regions of the world. However, the declining per capita availability of water is having negative impacts on human well-being. Water scarcity is a globally significant and accelerating condition for roughly 1-2 billion people worldwide, leading to problems with food production, human health, and economic development. Rates of increase in a key water scarcity measure (water use relative to accessible supply) from 1960 to the present averaged nearly 20% per decade globally, with values of 15% to more than 30% per decade for individual continents (C7.ES). "

Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 3, pp.50-51

Annex 6:

Box 3.1. Linkages between Ecosystem Services and Human Well-being: Freedom of Choice and Action

(see figure on linkages in Box 3.1 [see Annex 3, p. 29]).

See also specific information for each main component:

- Basic material for a good life [see Annex 5, p. 30]
- Health [see Annex 8, p. 33]
- Good social relations [see Annex 7, p. 32]
- Security [see Annex 9, p. 34]

"Freedom and choice refer to the ability of individuals to control what happens to them and to be able to achieve what they value doing or being. Freedom and choice cannot exist without the presence of the other elements of well-being, so there is an indirect influence of changes in all categories of ecosystem services on the attainment of this constituent of well-being. The influence of ecosystem change on freedom and choice is heavily mediated by socioeconomic circumstances. The wealthy and people living in countries with efficient governments and strong civil society can maintain freedom and choice even in the face of significant ecosystem change, while this would be impossible for the poor if, for example, the ecosystem change resulted in a loss of livelihood.

In the aggregate, the state of our knowledge about the impact that changing ecosystem conditions have on freedom and choice is severely limited. Declining provision of fuelwood and drinking water have been shown to increase the amount of time needed to collect such basic necessities, which in turn reduces the amount of time available for education, employment, and care of family members. Such impacts are typically thought to be disproportionately experienced by women (although the empirical foundation for this view is relatively limited) (C5.4.2)."

Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 3, p.54

Annex 7:

Box 3.1. Linkages between Ecosystem Services and Human Well-being: Good Social Relations

(see figure on linkages in Box 3.1 [see Annex 3, p. 29]).

See also specific information for each main component:

- Basic material for a good life [see Annex 5, p. 30]
- Health [see Annex 8, p. 33]
- Security [see Annex 9, p. 34]
- Freedom of choice and action [see Annex 6, p. 31]

"Good social relations refer to the presence of social cohesion, mutual respect, and the ability to help others and provide for children. Changes in provisioning and regulating ecosystem services can affect social relations, principally through their more direct impacts on material well-being. These, too, can be mediated by socioeconomic circumstances, but to a smaller extent. Changes in cultural services have relatively weak linkages to material elements of well-being, health, and security. Changes in cultural services can have a strong influence on social relations, particularly in cultures that have retained strong connections to local environments. Changes in provisioning and regulating services can be mediated by socioeconomic factors, but those in cultural services cannot. Even a wealthy country like Sweden or the United Kingdom cannot readily purchase a substitute to a cultural landscape that is valued by the people in the community.

Changes in ecosystems have tended to increase the accessibility that people have to ecosystems for recreation and ecotourism. There are clear examples of declining ecosystem services disrupting social relations or resulting in conflicts. Indigenous societies whose cultural identities are tied closely to particular habitats or wildlife suffer if habitats are destroyed or wildlife populations decline. Such impacts have been observed in coastal fishing communities, Arctic populations, traditional forest societies, and pastoral nomadic societies (C5.4.4)."

Source & © Millennium Ecosystem Assessment

Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 3, pp.53-54

Annex 8:

Box 3.1. Linkages between Ecosystem Services and Human Well-being: Health

(see figure on linkages in Box 3.1 [see Annex 3, p. 29]).

See also specific information for each main component:

- Basic material for a good life [see Annex 5, p. 30]
- Good social relations [see Annex 7, p. 32]
- Security [see Annex 9, p. 34]
- Freedom of choice and action [see Annex 6, p. 31]

"By health, we refer to the ability of an individual to feel well and be strong, or in other words to be adequately nourished and free from disease, to have access to adequate and clean drinking water and clean air, and to have the ability to have energy to keep warm and cool. Human health is both a product and a determinant of well-being. Changes in provisioning services such as food, water, medicinal plants, and access to new medicines and changes in regulating services that influence air quality, water quality, disease regulation, and waste treatment also have very strong impacts on health. Changes in cultural services can have strong influences on health, since they affect spiritual, inspirational, aesthetic, and recreational opportunities, and these in turn affect both physical and emotional states. Changes in supporting services have a strong influence on all of the other categories of services. These benefits are moderately mediated by socioeconomic circumstances. The wealthy can purchase substitutes for some health benefits of ecosystems (such as medicinal plants or water quality), but they are more susceptible to changes affecting air quality. The following are some examples of health components of well-being affected by ecosystem change.

Nutrition: In 2000, about a quarter of the burden of disease among the poorest countries was attributable to childhood and maternal undernutrition. Worldwide, undernutrition accounted for nearly 10% of the global burden of disease (R16.1.2).

Water and Sanitation: The burden of disease from inadequate water, sanitation, and hygiene totals 1.7 million deaths and results in the loss of at least 54 million healthy life years annually. Along with sanitation, water availability and quality are well recognized as important risk factors for infectious diarrhea and other major diseases. (See Box Table [see Annex 2, p. 28] .) Some 1.1 billion people lack access to clean drinking water, and more than 2.6 billion lack access to sanitation (C7.ES). (See Box Figure B [see Annex 4, p. 30] and Figure C [see Annex 11, p. 36]). Globally, the economic cost of pollution of coastal waters is estimated to be $16 billion annually, mainly due to human health impacts (C19.3.1)."

Figure B. Water
[see Annex 4, p. 30]

Figure C. Sanitation
[see Annex 11, p. 36]

Vector-borne Disease: Actions to reduce vector-borne diseases have resulted in major health gains and helped to relieve important constraints on development in poor regions. Vector-borne diseases cause approximately 1.4 million deaths a year, mainly due to malaria in Africa. These infections are both an effect and a cause of poverty (R12-ES). Prevalence of a number of infectious diseases appears to be growing, and environmental changes such as deforestation, dam construction, road building, agricultural conversion, and urbanization are contributing factors in many cases (C14.2).

Medicines: The use of natural products in the pharmaceutical industry has tended to fluctuate widely, with a general decline in pharmaceutical bioprospecting by major companies. Historically, most drugs were obtained from natural products. Even near the end of the twentieth century, approximately 50% of prescription medicines were originally discovered in plants (C10.2). Natural products still are actively used in drug exploration. Medicinal plants continue to play an important role in health care systems in many parts of the world. One MA sub-global assessment in the Mekong wetlands identified more than 280 medically important plant species, of which 150 are still in regular use (C10.2.2). Medicinal plants have generally declined in availability due to overharvesting and loss of habitats (C10.5.4).

Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 3, pp.52-53

Annex 9:

Box 3.1. Linkages between Ecosystem Services and Human Well-being: Security

(see figure on linkages in Box 3.1 [see Annex 3, p. 29]).

See also specific information for each main component:

- Basic material for a good life [see Annex 5, p. 30]
- Health [see Annex 8, p. 33]
- Good social relations [see Annex 7, p. 32]
- Freedom of choice and action [see Annex 6, p. 31]

"By security, we refer to safety of person and possessions, secure access to necessary resources, and security from natural and human-made disasters. Changes in regulating services such as disease regulation, climate regulation, and flood regulation have very strong influences on security. Changes in provisioning services such as food and water have strong impacts on security, since degradation of these can lead to loss of access to these essential resources. Changes in cultural services can influence security since they can contribute to the breakdown or strengthening of social networks within society. Changes in supporting services have a strong influence by virtue of their influence on all the other categories of services. These benefits are moderately mediated by socioeconomic circumstances. The wealthy have access to some safety nets that can minimize the impacts of some ecosystem changes (such as flood or drought insurance). Nevertheless, the wealthy cannot entirely escape exposure to some of these changes in areas where they live.

One example of an aspect of security affected by ecosystem change involves influences on the severity and magnitude of floods and major fires. The incidence of these has increased significantly over the past 50 years. Changes in ecosystems and in the management of ecosystems have contributed to these trends. The canalization of rivers, for example, tends to decrease the incidence and impact of small flood events and increase the incidence and severity of large ones. On average, 140 million people are affected by floods each year-more than all other natural or technological disasters put together. Between 1990 and 1999, more than 100,000 people were killed in floods, which caused a total of $243 billion in damages (C7.4.4)."

Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 3, p.54

Annex 10:

Box 3.2. Ecosystems and the Millennium Development Goals

"The eight Millennium Development Goals were endorsed by governments at the United Nations in September 2000. The MDGs aim to improve human well-being by reducing poverty, hunger, and child and maternal mortality; ensuring education for all; controlling and managing diseases; tackling gender disparity; ensuring sustainable development; and pursuing global partnerships. For each MDG, governments have agreed to between 1 and 8 targets (a total of 15 targets) that are to be achieved by 2015. Slowing or reversing the degradation of ecosystem services will contribute significantly to the achievement of many of the MDGs.

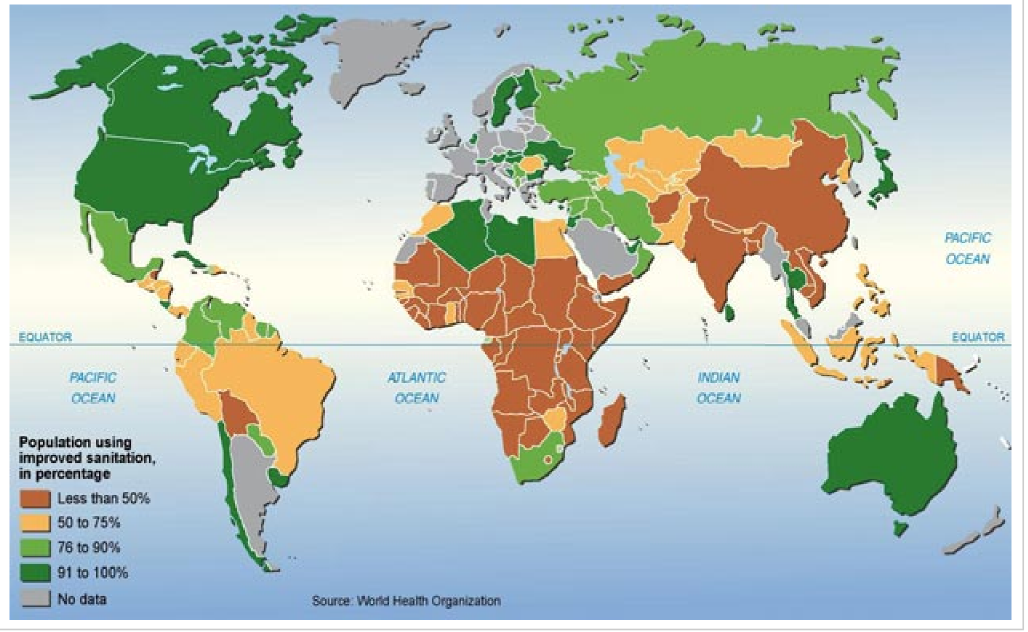
- **Poverty Eradication**: ecosystem services are a dominant influence on livelihoods of most poor people. Most of the world's poorest people live in rural areas and are thus highly dependent, directly or indirectly, on the ecosystem service of food production, including agriculture, livestock, and hunting (R19.2.1). Mismanagement of ecosystems threatens the livelihood of poor people and may threaten their survival (C5.ES). Poor people are highly vulnerable to changes in watershed services that affect the quality or availability of water, loss of ecosystems such as wetlands, *mangroves*, or coral reefs that affect the likelihood of flood or storm damage, or changes in climate regulating services that might alter regional climate. Ecosystem degradation is often one of the factors trapping people in cycles of poverty.
- **Hunger Eradication** (R19.2.2). Although economic and social factors are often the primary determinants of hunger, food production remains an important factor, particularly among the rural poor. Food production is an ecosystem service in its own right, and it also depends on watershed services, pollination, pest regulation, and soil formation. Food production needs to increase to meet the needs of the growing human population, and at the same time the efficiency of food production (the amount produced per unit of land, water, and other inputs) needs to increase in order to reduce harm to other key ecosystem services. Ecosystem conditions, in particular climate, soil degradation, and water availability, influences progress toward this goal through its influence on crop yields as well as through impacts on the availability of wild sources of food.
- **Reducing Child Mortality**. Undernutrition is the underlying cause of a substantial proportion of all child deaths. Child mortality is also strongly influenced by diseases associated with water quality. Diarrhea is one of the predominant causes of infant deaths worldwide. In sub-Saharan Africa, malaria additionally plays an important part in child mortality in many countries of the region.
- **Combating Disease** (R19.2.7). Human health is strongly influenced by ecosystem services related to food production, water quality, water quantity, and natural hazard regulation, and the role of ecosystem management is central to addressing some of the most pressing global diseases such as malaria. Changes in ecosystems influence the abundance of human pathogens such as malaria and cholera as well as the risk of emergence of new diseases. Malaria is responsible for 11% of the disease burden in Africa, and it is estimated that Africa's GDP could have been $100 billion larger (roughly a 25% increase) in 2000 if malaria had been eliminated 35 years ago (R16.1).
- **Environmental Sustainability**. Achievement of this goal will require, at a minimum, an end to the current unsustainable uses of ecosystem services such as fisheries and fresh water and an end to the degradation of other services such as water purification, natural hazard regulation, disease regulation, climate regulation, and cultural amenities."

Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 3, p.60

Annex 11:

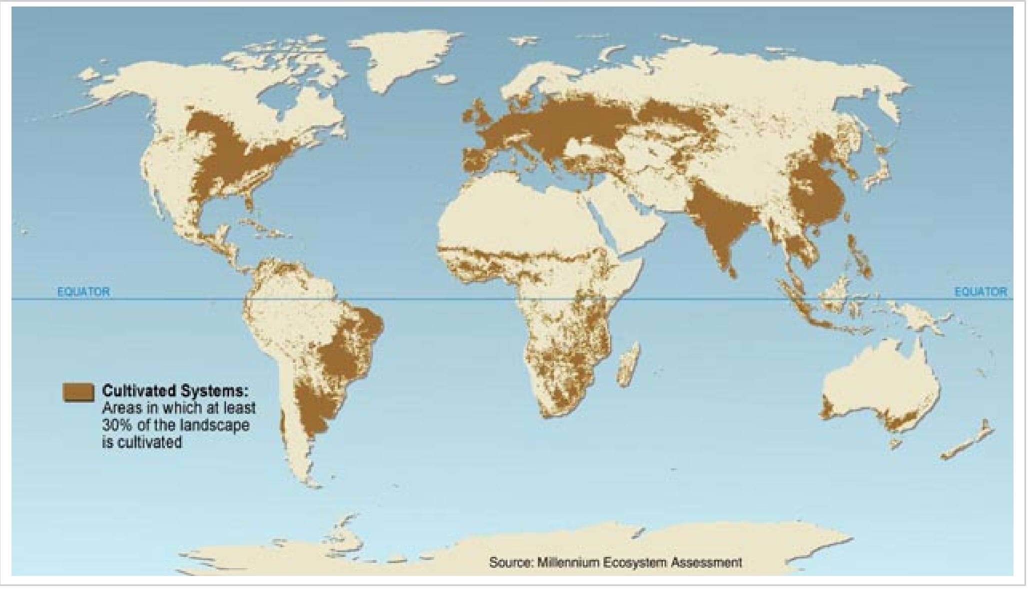
Box Figure C. Proportion of population with improved sanitation coverage in 2002

"Access to improved sanitation is estimated by the percentage of the population using the following sanitation facilities: connection to a public sewer, connection to a septic system, pour-flush latrine, simple pit latrine (a portion of pit latrines are also considered unimproved sanitation), and ventilated improved pit latrine."



Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 3, Box 3.1, p.53

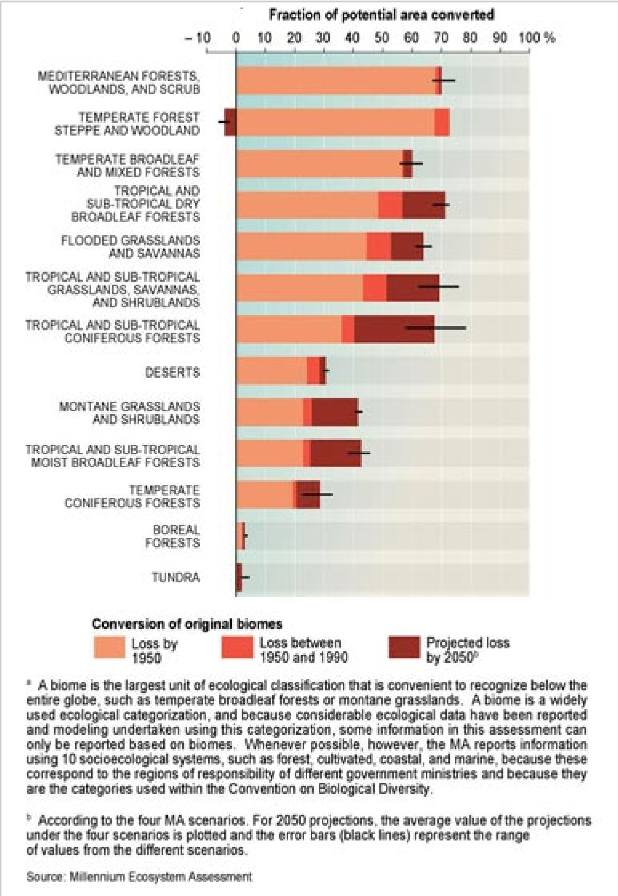
Annex 12:
Cultivated systems



Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 1, p.29

Annex 13:
Figure 1.2. Conversion of Terrestrial Biomes

"It is not possible to estimate accurately the extent of different biomes prior to significant human impact, but it is possible to determine the "potential" area of biomes based on soil and climatic conditions. This figure shows how much of that potential area is estimated to have been converted by 1950 (medium certainty), how much was converted between 1950 and 1990 (medium certainty), and how much would be converted under the four MA scenarios [see Annex 36, p. 59] (low certainty) between 1990 and 2050. Mangroves are not included here because the area was too small to be accurately assessed. Most of the conversion of these biomes is to cultivated systems [see Annex 27, p. 51] ."

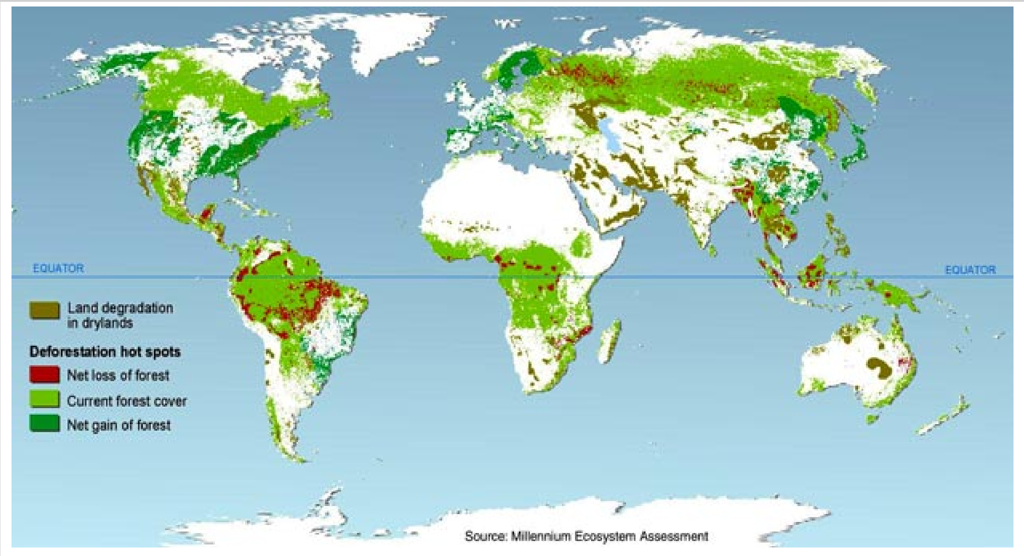


Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 1, p.32
(Adapted from Conditions and Trends Working Group Report, C4 Biodiversity;
Scenarios Working Group Report, S10 Novel Products and Industries from Biodiversity)

Annex 14:

Figure 1.4. Locations reported by various studies as undergoing high rates of land cover change in the past few decades.

"In the case of forest cover change, the studies refer to the period 1980-2000, and are based on national statistics, remote sensing, and to a limited degree expert opinion. In the case of *land cover* change resulting from degradation in drylands [see Annex 51, p. 74] (desertification), the period is unspecified but inferred to be within the last half-century, and the major study was entirely based on expert opinion, with associated low certainty. Change in cultivated area is not shown."



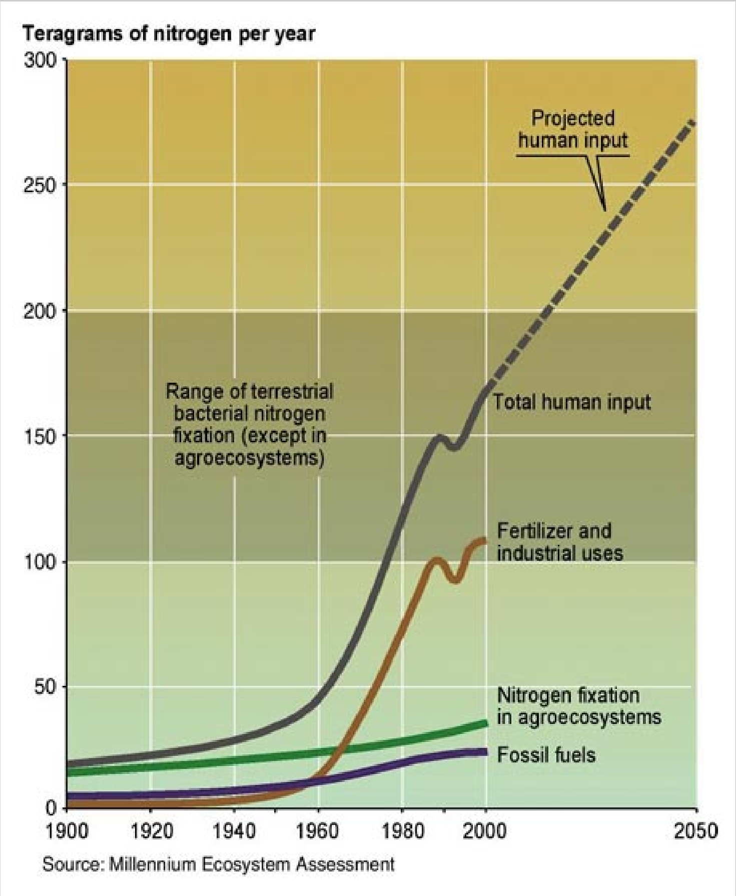
Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 1, p.33

Annex 15:

Figure 1.5. Global Trends in the Creation of Reactive Nitrogen on Earth by Human Activity, with Projection to 2050

(teragrams nitrogen per year)

"Most of the reactive nitrogen produced by humans comes from manufacturing nitrogen for synthetic fertilizer and industrial use. Reactive nitrogen is also created as a by-product of fossil fuel combustion and by some (nitrogen-fixing) crops and trees in agroecosystems. The range of the natural rate of bacterial nitrogen fixation in natural terrestrial ecosystems (excluding fixation in agroecosystems) is shown for comparison. Human activity now produces approximately as much reactive nitrogen as natural processes do on the continents (R9 Fig 9.1).
(Note: the 2050 projection is included in the original study and is not based on MA scenarios [see Annex 38, p. 60]). "

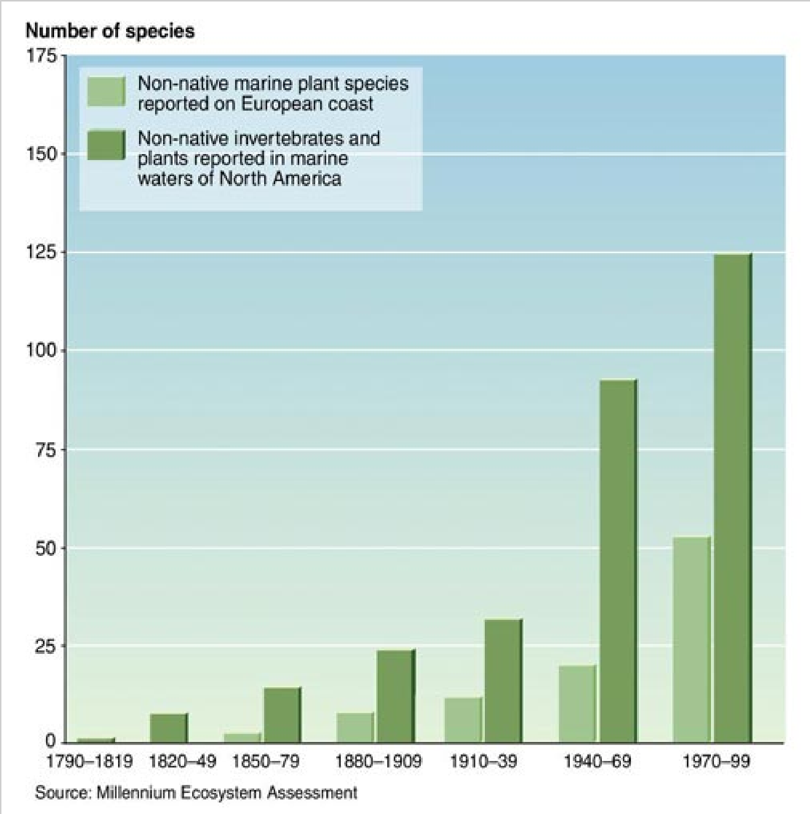


Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 1, p.35

Annex 16:

Figure 1.7. Growth in Number of Marine Species Introductions.

"Number of new records of established non-native invertebrate and algae species reported in marine waters of North America shown by date of first record and number of new records of non-native marine plant species reported on the European coast by date of first record."

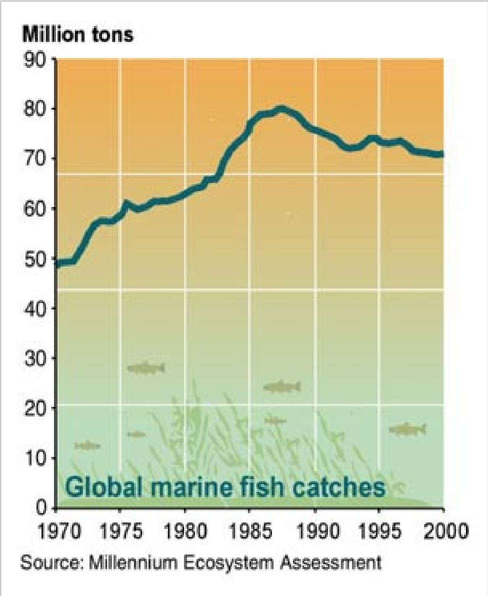


Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 1, p.37

Annex 17:

Figure 2.1. Estimated Global Marine Fish Catch, 1950-2001.

"In this figure, the catch reported by governments is in some cases adjusted to correct for likely errors in data."

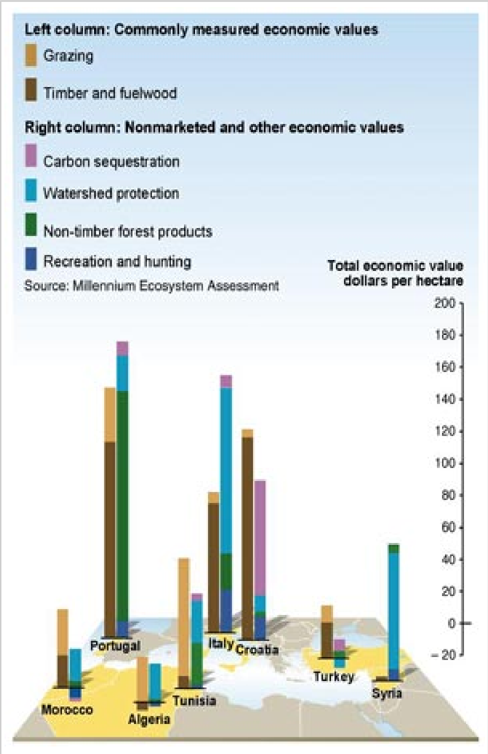


Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 2, p.39
(Conditions and Trends Working Group Report, C18 Marine Systems, Fig C18.3)

Annex 18:
Figure 3.3. Economic Benefits Under Alternate Management Practices

(expressed as net present value in dollars per hectare)

"In each case, the net benefits from the more sustainably managed ecosystem are greater than those from the converted ecosystem even though the private (market) benefits would be greater from the converted ecosystem. (Where ranges of values are given in the original source, lower estimates are plotted here.)"

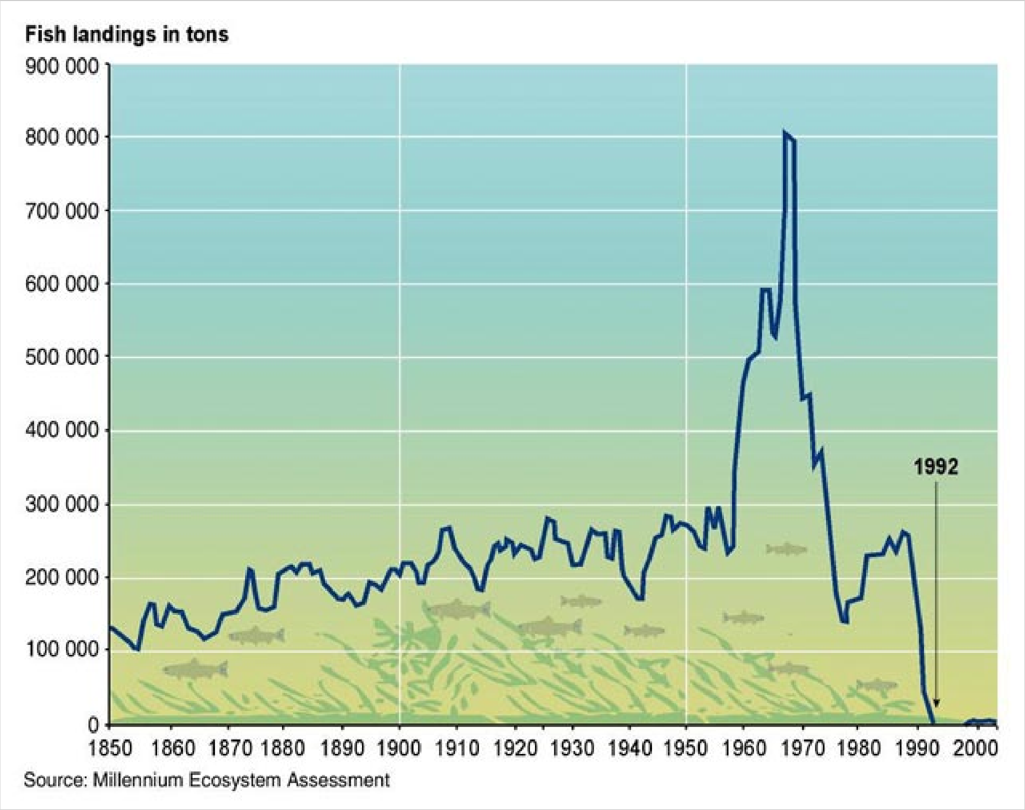


Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 3, p.57
(Conditions and Trends Working Group Report, C5 Ecosystem Change and Human Well-being, Box 5.1)

Annex 19:

Figure 3.4. Collapse of Atlantic Cod Stocks Off the East Coast of Newfoundland in 1992

"This collapse forced the closure of the fishery after hundreds of years of exploitation. Until the late 1950s, the fishery was exploited by migratory seasonal fleets and resident inshore small-scale fishers. From the late 1950s, offshore bottom trawlers began exploiting the deeper part of the stock, leading to a large catch increase and a strong decline in the underlying biomass. Internationally agreed quotas in the early 1970s and, following the declaration by Canada of an Exclusive Fishing Zone in 1977, national quota systems ultimately failed to arrest and reverse the decline. The stock collapsed to extremely low levels in the late 1980s and early 1990s, and a moratorium on commercial fishing was declared in June 1992. A small commercial inshore fishery was reintroduced in 1998, but catch rates declined and the fishery was closed indefinitely in 2003."

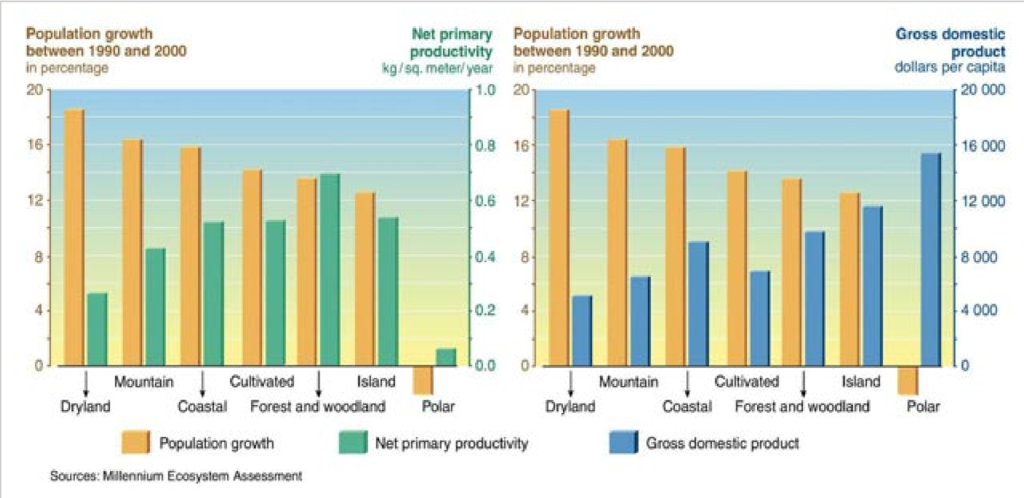


Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 3, p.58
(Conceptual Framework, Box 2.4)

Annex 20:

Figure 3.7. Human Population Growth Rates, 1990-2000, and Per Capita GDP and Biological Productivity in 2000 in MA Ecological Systems

"MA systems [see Annex 35, p. 58] with the lowest net primary productivity and lowest GDP tended to have the highest population growth rate between 1990 and 2000. Urban [see Annex 51, p. 74] , inland water and marine systems are not included in this figure due to the somewhat arbitrary nature of determining net primary productivity of the system (urban) or population growth and GDP (freshwater and marine) for these systems."

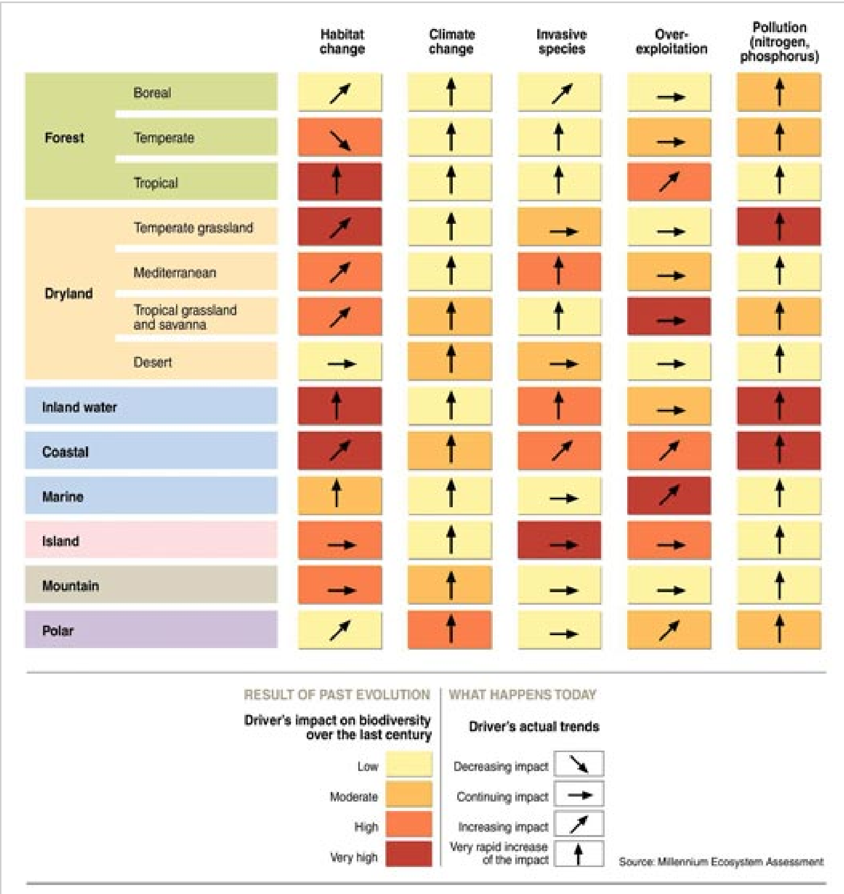


Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 3, p.63
Descriptive text from Summary for Decision Makers, Figure 12

Annex 21:

Figure 4.3. Main Direct Drivers of Change in Biodiversity and Ecosystems

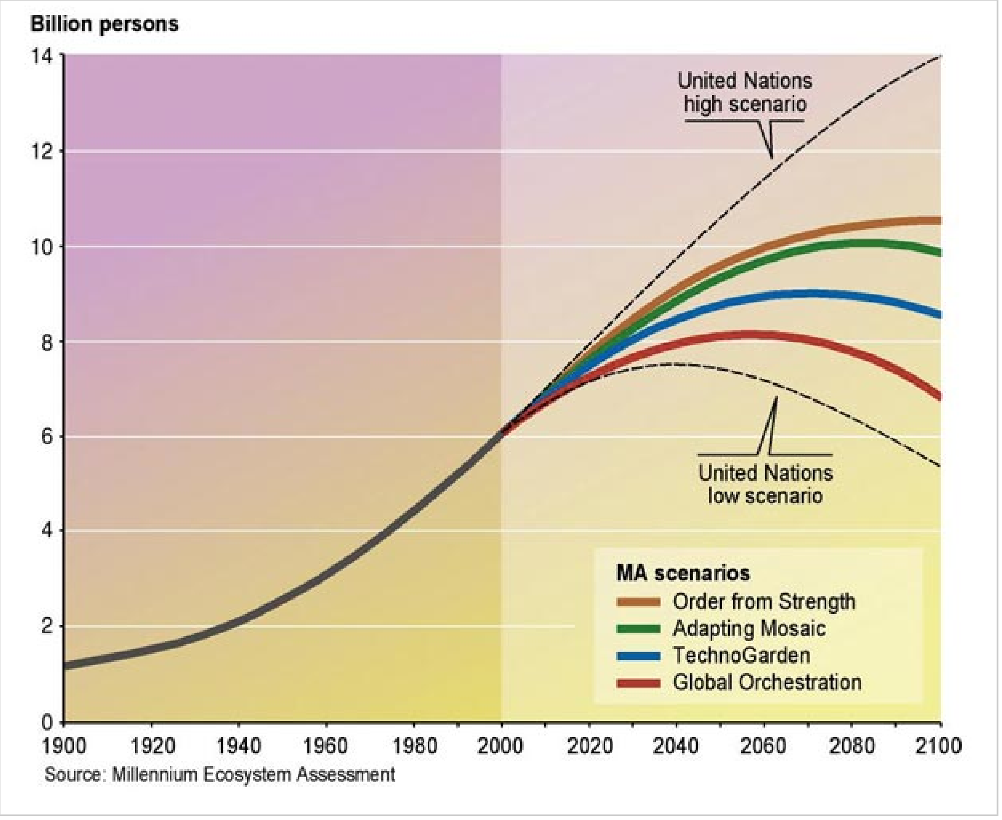
"The cell color indicates impact of each driver on biodiversity in each type of ecosystem over the past 50-100 years. High impact means that over the last century the particular driver has significantly altered biodiversity in that biome; low impact indicates that it has had little influence on biodiversity in the biome. The arrows indicate the trend in the driver. Horizontal arrows indicate a continuation of the current level of impact; diagonal and vertical arrows indicate progressively stronger increasing trends in impact. Thus, for example, if an ecosystem had experienced a very high impact of a particular driver in the past century (such as the impact of invasive species on islands), a horizontal arrow indicates that this very high impact is likely to continue. This figure is based on expert opinion consistent with and based on the analaysis of drivers of change in the various chapters of the assessment report of the MA Condition and Trends Working Group. The figure presents global impacts and trends which may be different from those in specific regions."



Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 4, p.68
(Condition and Trends Working Group Report)

Annex 22:

Figure 5.1. MA World Population Scenarios

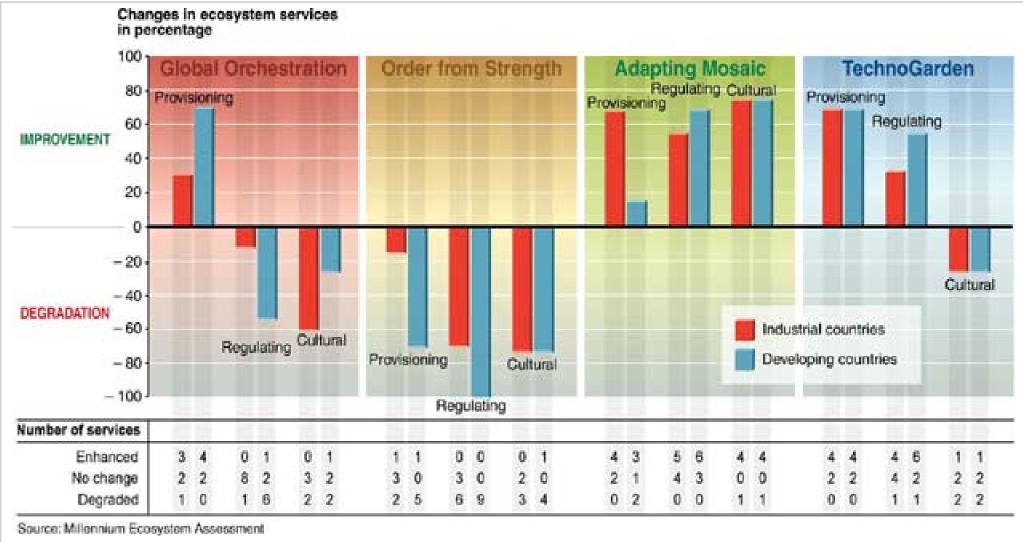


Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 5, p.74
(Sub-Global Working Group Report, S7 Drivers of Ecosystem Change, Fig 7.2)

Annex 23:

Figure 5.3. Number of Ecosystem Services Enhanced or Degraded by 2050 in the Four MA Scenarios

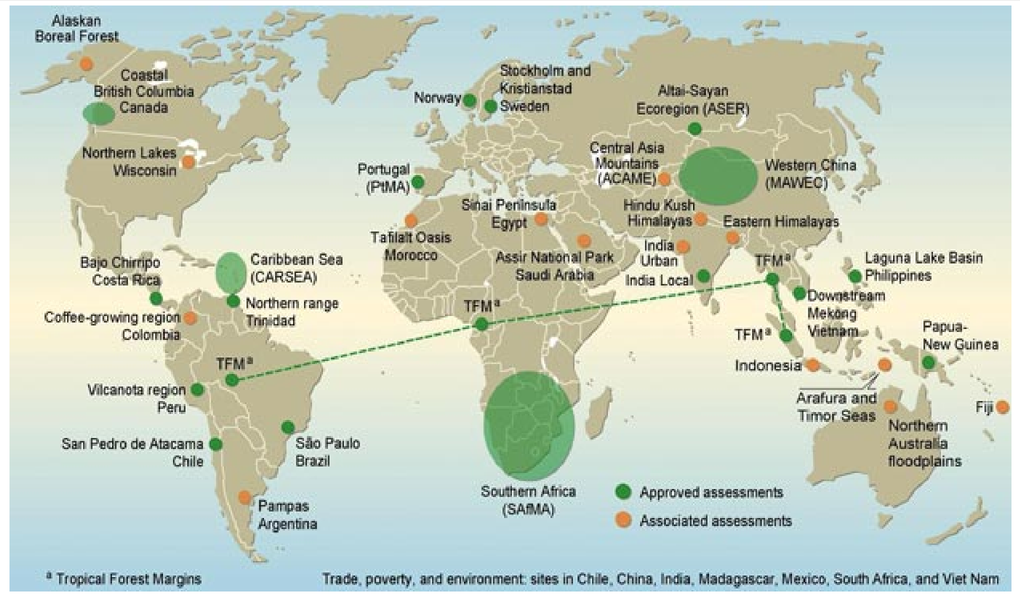
"The Figure shows the net change in the number of ecosystem services enhanced or degraded in the MA scenarios [see Annex 38, p. 60] in each category of services for industrial and developing countries expressed as a percentage of the total number of services evaluated in that category. Thus, 100% degradation means that all the services in the category were degraded in 2050 compared with 2000, while 50% improvement could mean that three out of six services were enhanced and the rest were unchanged or that four out of six were enhanced and one was degraded. The total number of services evaluated for each category was six provisioning services, nine regulating services, and five cultural services."



Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 5, p.80

Annex 24:
Figure 6.1. MA Sub-Global Assessments

"Eighteen assessments were approved as components of the MA. Any institution or country was able to undertake an assessment as part of the MA if it agreed to use the MA Conceptual Framework, to centrally involve the intended users as stakeholders and partners, and to meet a set of procedural requirements related to peer review, metadata, transparency, and intellectual property rights. The MA assessments were largely self-funded, although planning grants and some core grants were provided to support some assessments. The MA also drew on information from 15 other sub-global assessments affiliated with the MA that met a subset of these criteria or were at earlier stages in development."



Source: Millennium Ecosystem Assessment Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 6, p.85

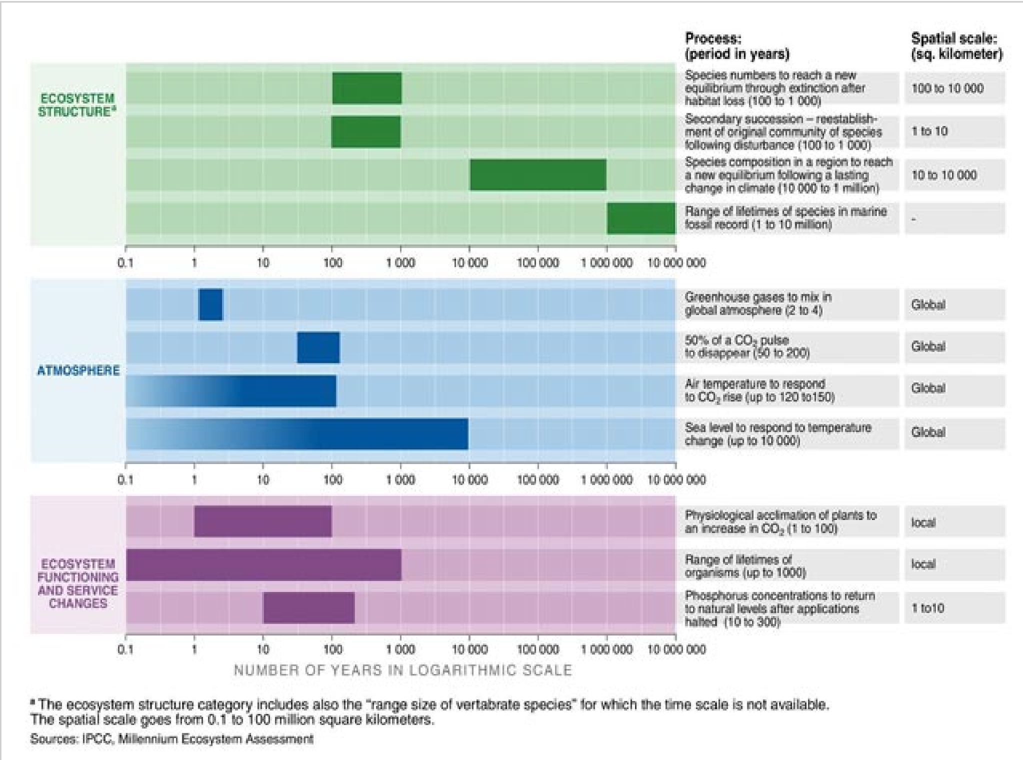
More information on the sub-global assessments
can be found on Millennium Ecosystem Assessment website at:
[see http://www.millenniumassessment.org/en/subglobal.overview.aspx?]

Annex 25:

Figure 7.1. Characteristic Time and Space Scales Related to Ecosystems and Their Services

"Time scale is defined here as the time needed for at least half the process to be expressed. The characteristic spatial scale is the spatial area over which the process takes place.

(Note: For comparison, this table includes references to time and space scales cited in the Synthesis Report of the IPCC Third Assessment Report.)"

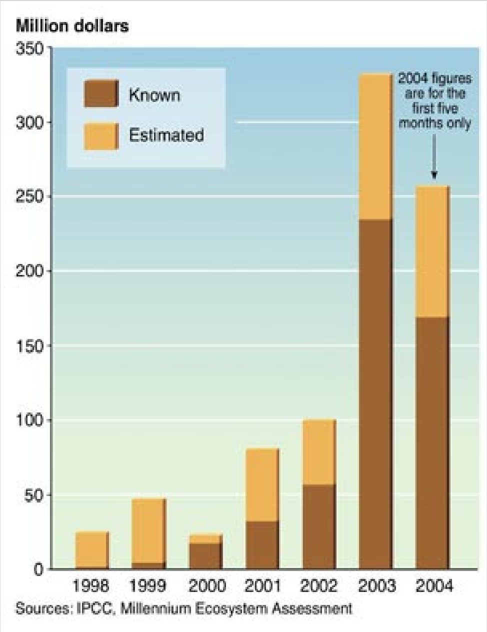


Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 7, p.89
(IPCC, Third Assessment Report; Condition and Trends Working Group, C4 Biodiversity, Fig 4.15, C4.4.2; Conceptual Framework, CF7 Analytical Approaches; Sub-Global Working Group Report, S7)

GreenFacts note: A GreenFacts digest of the IPCC Third Assessment Report on Climate Change is available [see https://www.greenfacts.org/en/climate-change-ar3/index.htm]

Annex 26:

Figure 8.1. Total Carbon Market Value per Year (in million dollars nominal)

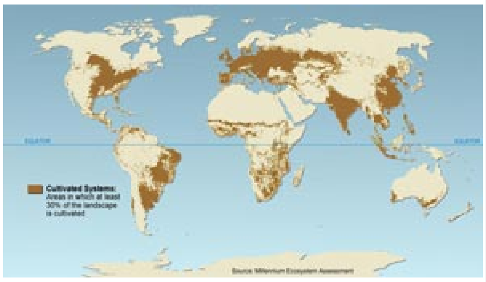


Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 8, p.96
(Condition and Trends Working Group Report, C5 Ecosystem Change and human Well-beiing, Box 5.1)

Annex 27:
Forest and Cultivated systems

(click image for a larger map of **Forest systems**)
[see Annex 28, p. 53]

"**Forest systems** are lands dominated by trees; they are often used for timber, fuelwood, and non-timber forest products. The map shows areas with a canopy cover of at least 40% by woody plants taller than 5 meters. Forests include temporarily cut-over forests and plantations but exclude orchards and agroforests where the main products are food crops. The global area of forest systems has been reduced by one half over the past three centuries. Forests have effectively disappeared in 25 countries, and another 29 have lost more than 90% of their forest cover. Forest systems are associated with the regulation of 57% of total water runoff. About 4.6 billion people depend for all or some of their water on supplies from forest systems. From 1990 to 2000, the global area of temperate forest increased by almost 3 million hectares per year, while deforestation in the tropics occurred at an average rate exceeding 12 million hectares per year over the past two decades.

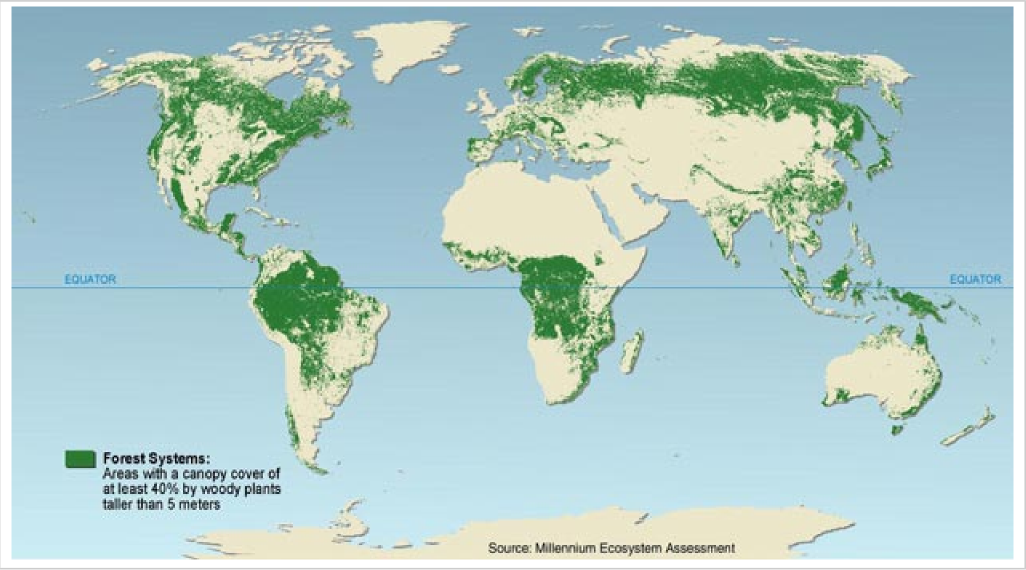


(click image for a larger map of **Cultivated systems**)
[see Annex 12, p. 37]

Cultivated systems are lands dominated by domesticated species and used for and substantially changed by crop, agroforestry, or aquaculture production. The map shows areas in which at least 30% by area of the landscape comes under cultivation in any particular year. Cultivated systems, including croplands, shifting cultivation, confined livestock production, and freshwater aquaculture, cover approximately 24% of total land area. In the last two decades, the major areas of cropland expansion were located in Southeast Asia, parts of South Asia, the Great Lakes region of eastern Africa, the Amazon Basin, and the U.S. Great Plains. The major decreases of cropland occurred in the southeastern United States, eastern China, and parts of Brazil and Argentina. Most of the increase in food demand of the past 50 years has been met by intensification of crop, livestock, and aquaculture systems rather than expansion of production area. In developing countries, over the period 1961–99 expansion of harvested land contributed only 29% to growth in crop production, although in sub-Saharan Africa expansion accounted for two thirds of growth in production. Increased yields of crop production systems have reduced the pressure to convert natural ecosystems into cropland, but intensification has increased pressure on inland water ecosystems, generally reduced biodiversity within agricultural landscapes, and it requires higher energy inputs in the form of mechanization and the production of chemical fertilizers. Cultivated systems provide only 16% of global runoff, although their close proximity to humans means that about 5 billion people depend for all or some of their water on supplies from cultivated systems. Such proximity is associated with nutrient and industrial water pollution."

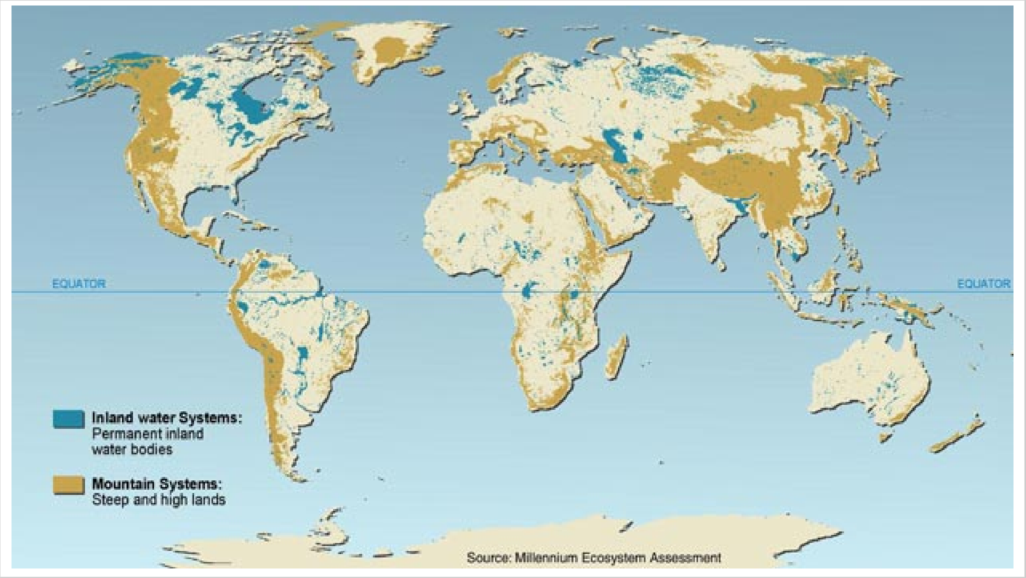
Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 1, pp.29-30

Annex 28:
Forest systems



Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 1, p.28

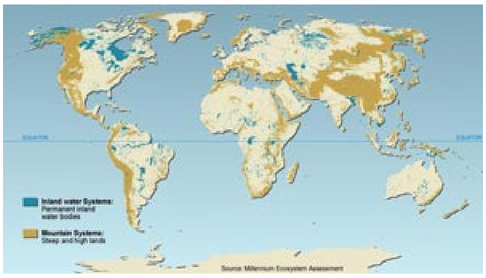
Annex 29:
Inland water and Mountain systems



Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 1, p.30

Annex 30:

Inland waters and Mountain systems



(click image for a larger map) [see Annex 29, p. 53]

"**Inland water systems** are permanent water bodies inland from the coastal zone and areas whose properties and use are dominated by the permanent, seasonal, or intermittent occurrence of flooded conditions. Inland waters include rivers, lakes, floodplains, reservoirs, wetlands, and inland saline systems. (Note that the wetlands definition used by the Ramsar Convention includes the MA inland water and coastal system categories.) The biodiversity of inland waters appears to be in a worse condition than that of any other system, driven by declines in both the area of wetlands and the water quality in inland waters. It is speculated that 50% of inland water area (excluding large lakes) has been lost globally. Dams and other infrastructure fragment 60% of the large river systems in the world.

Mountain systems are steep and high lands. The map is based on elevation and, at lower elevations, a combination of elevation, slope, and local topography. Some 20% (or 1.2 billion) of the world's people live in mountains or at their edges, and half of humankind depends, directly or indirectly, on mountain resources (largely water). Nearly all—90%—of the 1.2 billion people in mountains live in countries with developing or transition economies. In these countries, 7% of the total mountain area is currently classified as cropland, and people are often highly dependent on local agriculture or livestock production. About 4 billion people depend for all or some of their water on supplies from mountain systems. Some 90 million mountain people—almost all those living above 2,500 meters—live in poverty and are considered especially vulnerable to food insecurity."

Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 1, p.30

Annex 31:
MA Scenarios - Adapting Mosaic

The MA developed four global scenarios exploring plausible future changes in drivers, ecosystems, ecosystem services, and human well-being. These scenarios are :

Ecosystem Management	**World Development**	
	Globalization	**Regionalization**
Reactive	Global Orchestration [see Annex 32, p. 55]	Order from Strength [see Annex 33, p. 56]
Proactive	TechnoGarden [see Annex 34, p. 57]	**Adapting Mosaic**

"The **Adapting Mosaic** scenario, regional watershed-scale ecosystems are the focus of political and economic activity. This scenario sees the rise of local ecosystem management strategies, and the strengthening of local institutions. Investments in human and social capital are geared towards improving knowledge about ecosystem functioning and management, which results in a better understanding of resilience, fragility, and local flexibility of ecosystems. There is optimism that we can learn, but humility about preparing for surprises and about our ability to know everything about managing ecosystems.

There is also great variation among nations and regions in styles of governance, including management of ecosystem services. Some regions explore actively adaptive management, investigating alternatives through experimentation. Others employ bureaucratically rigid methods to optimize ecosystem performance. Great diversity exists in the outcome of these approaches: some areas thrive, while others develop severe inequality or experience ecological degradation. Initially, trade barriers for goods and products are increased, but barriers for information nearly disappear (for those who are motivated to use them) due to improving communication technologies and rapidly decreasing costs of access to information.

Eventually, the focus on local governance leads to failures in managing the global commons. Problems like climate change, marine fisheries, and pollution grow worse and global environmental problems intensify. Communities slowly realize that they cannot manage their local areas because global and regional problems are infringing, and they begin to develop networks among communities, regions, and even nations, to better manage the global commons. Solutions that were effective locally are adopted among networks. These networks of regional successes are especially common in situations where there are mutually beneficial opportunities for coordination, such as along river valleys. Sharing good solutions and discarding poor ones eventually improves approaches to a variety of social and environmental problems, ranging from urban poverty to agricultural water pollution. As more knowledge is collected from successes and failures, provision of many services improves. "

Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 5, Box 5.1, pp.72-73

Annex 32:
MA Scenarios - Global Orchestration

The MA developed four global scenarios exploring plausible future changes in drivers, ecosystems, ecosystem services, and human well-being. These scenarios are :

Ecosystem Management	World Development	
	Globalization	Regionalization
Reactive	**Global Orchestration**	Order from Strength [see Annex 33, p. 56]
Proactive	TechnoGarden [see Annex 34, p. 57]	Adapting Mosaic [see Annex 31, p. 54]

"The **Global Orchestration** scenario depicts a globally-connected society in which policy reforms that focus on global trade and economic liberalization are used to reshape economies and governance, emphasizing the creation of markets that allow equal participation and provide equal access to goods and services. These policies, in combination with large investments in global public health and the improvement of education worldwide, generally succeed in promoting economic expansion and lifting many people out of poverty into an expanding global middle class. Supra national institutions in this globalized scenario are well-placed to deal with global environmental problems such as climate change and fisheries. However, the reactive approach to ecosystem management favored in this scenario makes people vulnerable to surprises arising from delayed action. While the focus is on improving human well-being of all people, environmental problems that threaten human well-being are only considered after they become apparent.

Growing economies, expansion of education, and growth of the middle class leads to demand for cleaner cities, less pollution, and a more beautiful environment. Rising income levels bring about changes in global consumption patterns, boosting demand for ecosystem services, including agricultural products such as meat, fish, and vegetables. Growing demand for these services leads to declines in other services, as forests are converted into cropped area and pasture, and the services formerly provided by forests decline. The problems related to increasing food production, such as loss of wildlands, are not apparent to most people who live in urban areas. These problems therefore receive only limited attention.

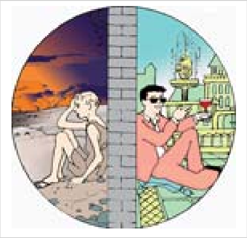
Global economic expansion expropriates or degrades many of the ecosystem services poor people once depended upon for their survival. While economic growth more than compensates for these losses in some regions by increasing our ability to find substitutes for particular ecosystem services, in many other places, it does not. An increasing number of people are impacted by the loss of basic ecosystem services essential for human life. While risks seem manageable in some places, in other places there are sudden, unexpected losses as ecosystems cross thresholds and degrade irreversibly. Loss of potable water supplies, crop failures, floods, species invasions, and outbreaks of environmental pathogens increase in frequency. The expansion of abrupt, unpredictable changes in ecosystems, many with harmful effects on increasingly large numbers of people, is the key challenge facing managers of ecosystem services. "

Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 5, Box 5.1, pp.72-73

Annex 33:
MA Scenarios - Order from Strength

The MA developed four global scenarios exploring plausible future changes in drivers, ecosystems, ecosystem services, and human well-being. These scenarios are :

Ecosystem Management	World Development	
	Globalization	**Regionalization**
Reactive	Global Orchestration [see Annex 32, p. 55]	**Order from Strength**
Proactive	TechnoGarden [see Annex 34, p. 57]	Adapting Mosaic [see Annex 31, p. 54]



"The **Order from Strength** scenario represrnts a regionalized and fragmented world, concerned with security and protection, emphasizing primarily regional markets, and paying little attention to common goods. Nations see looking after their own interests as the best defense against economic insecurity, and the movement of goods, people, and information is strongly regulated and policed. The role of government expands as oil companies, water systems, and other strategic businesses are either nationalized or subjected to more state oversight. Trade is restricted, large amounts of money are invested in security systems, and technological change slows due to restrictions on the flow of goods and information. Regionalization exacerbates global inequality.

Treaties on global climate change, international fisheries, and the trade in endangered species are only weakly and haphazardly implemented, resulting in degradation of the global commons. Local problems often go unresolved, but major problems are sometimes handled by rapid disaster relief to at least temporarily resolve the immediate crisis. Many powerful countries cope with local problems by shifting burdens to other, less powerful countries, increasing the gap between rich and poor. In particular, natural resource-intensive industries are moved from wealthier nations to poorer and less powerful ones. Inequality increases considerably within countries as well.

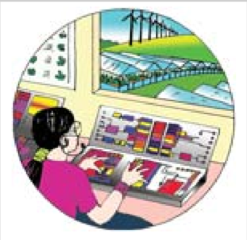
Ecosystem services become more vulnerable, fragile, and variable in Order from Strength. For example, parks and reserves exist within fixed boundaries, but climate changes around them, leading to the unintended extirpation of many species. Conditions for crops are often suboptimal, and the ability of societies to import alternative foods is diminished by trade barriers. As a result, there are frequent shortages of food and water, particularly in poor regions. Low levels of trade tend to restrict the number of invasions by exotic species; however, ecosystems are less resilient and invaders are therefore more often successful when they arrive."

Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Cahpter 5, Box 5.1, pp.72-73

Annex 34:
MA Scenarios - TechnoGarden

The MA developed four global scenarios exploring plausible future changes in drivers, ecosystems, ecosystem services, and human well-being. These scenarios are :

Ecosystem Management	World Development	
	Globalization	**Regionalization**
Reactive	Global Orchestration [see Annex 32, p. 55]	Order from Strength [see Annex 33, p. 56]
Proactive	**TechnoGarden**	Adapting Mosaic [see Annex 31, p. 54]



"The **TechnoGarden** scenario depicts a globally connected world relying strongly on technology and highly managed, often engineered ecosystems, to deliver ecosystem services. Overall efficiency of ecosystem service provision improves, but is shadowed by the risks inherent in large-scale human-made solutions and rigid control of ecosystems. Technology and market-oriented institutional reform are used to achieve solutions to environmental problems. These solutions are designed to benefit both the economy and the environment. These changes co-develop with the expansion of property rights to ecosystem services, such as requiring people to pay for pollution they create or paying people for providing key ecosystem services through actions such as preservation of key watersheds.

Interest in maintaining, and even increasing, the economic value of these property rights, combined with an interest in learning and information, leads to a flowering of ecological engineering approaches for managing ecosystem services. Investment in green technology is accompanied by a significant focus on economic development and education, improving people's lives and helping them understand how ecosystems make their livelihoods possible.

A variety of problems in global agriculture are addressed by focusing on the multifunctional aspects of agriculture and a global reduction of agricultural subsidies and trade barriers. Recognition of the role of agricultural diversification encourages farms to produce a variety of ecological services, rather than simply maximizing food production. The combination of these movements stimulates the growth of new markets for ecosystem services, such as tradable nutrient runoff permits, and the development of technology for increasingly sophisticated ecosystem management. Gradually, environmental entrepreneurship expands as new property rights and technologies co-evolve to stimulate the growth of companies and cooperatives providing reliable ecosystem services to cities, towns, and individual property owners.

Innovative capacity expands quickly in developing nations. The reliable provision of ecosystem services, as a component of economic growth, together with enhanced uptake of technology due to rising income levels, lifts many of the world's poor into a global middle class. Elements of human well-being associated with social relations decline in this scenario due to great loss of local culture, customs, and traditional knowledge that occurs and due to the weakening of civil society institutions as an increasing share of interactions take place over the Internet. While the provision of basic ecosystem services improves the well-being of the world's poor, the reliability of the services, especially in urban areas, is increasingly critical and increasingly difficult to ensure. Not every problem has succumbed to technological innovation. Reliance on technological solutions sometimes creates new problems and vulnerabilities. In some cases, we seem to be barely ahead of the next threat to ecosystem services. In such cases new problems often seem to emerge from the last solution, and the costs of managing the environment are continually rising. Environmental breakdowns that impact large numbers of people become more common. Sometimes new problems seem to emerge faster than solutions. The challenge for the future will be to learn how to organize social-ecological systems so that ecosystem services are maintained without taxing society's ability to implement solutions to novel, emergent problems. "

Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 5, Box 5.1, pp.72-73

Annex 35:
MA Systems

Findings of the Millennium Ecosystem Assessment (MA) reports findings for 10 categories of the land and marine surface, which are refered to as “systems”:

- forest systems [see Annex 27, p. 51] ,
- cultivated systems [see Annex 27, p. 51] ,
- dryland systems [see Annex 51, p. 74] ,
- coastland systems [see Annex 36, p. 59] ,
- marine systems [see Annex 36, p. 59] ,
- urban systems [see Annex 51, p. 74] ,
- polar systems [see Annex 51, p. 74] ,
- inland water systems [see Annex 30, p. 53] (which include freshwater systems),
- island systems [see Annex 36, p. 59] and
- mountain systems [see Annex 30, p. 53] .

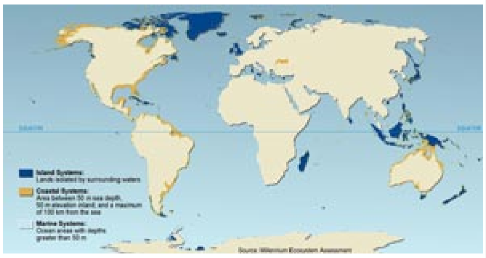
"Each category contains a number of ecosystems. However, ecosystems within each category share a suite of biological, climatic, and social factors that tend to be similar within categories and differ across categories.

The MA reporting categories are not spatially exclusive; their areas often overlap. For example, transition zones between forest and cultivated lands are included in both the forest system and cultivated system reporting categories.

These reporting categories were selected because they correspond to the regions of responsibility of different government ministries (such as agriculture, water, forestry, and so forth) and because they are the categories used within the Convention on Biological Diversity."

Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 5, Box 1.1, pp.27-30

Annex 36:
Marine, Coastal and Island systems



(click image for a larger map) [see Annex 37, p. 60]

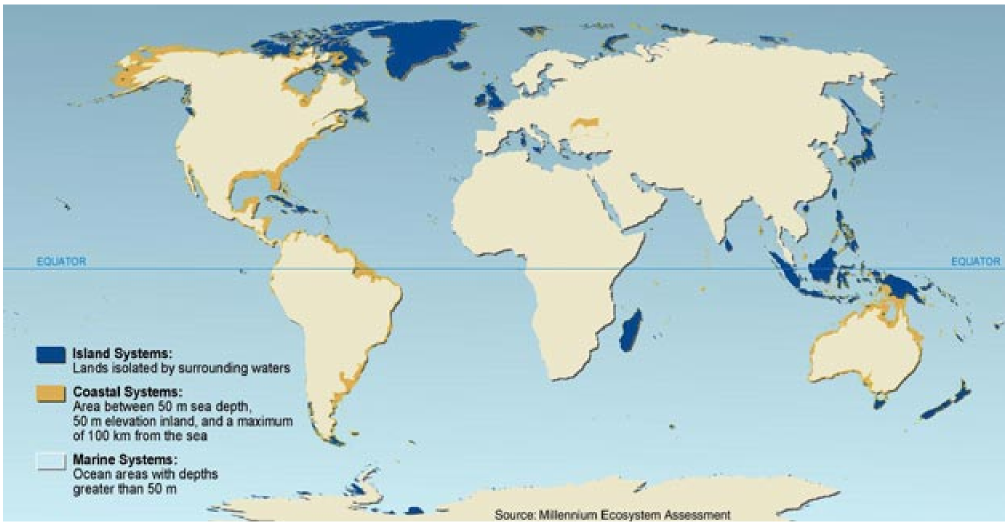
"**Marine systems** are the world's oceans. For mapping purposes, the map shows ocean areas where the depth is greater than 50 meters. Global fishery catches from marine systems peaked in the late 1980s and are now declining despite increasing fishing effort.

Coastal systems refer to the interface between ocean and land, extending seawards to about the middle of the continental shelf and inland to include all areas strongly influenced by proximity to the ocean. The map shows the area between 50 meters below mean sea level and 50 meters above the high tide level or extending landward to a distance 100 kilometers from shore. Coastal systems include coral reefs, intertidal zones, estuaries, coastal aquaculture and sea grass communities Nearly half of the world's major cities (having more than 500,000 people) are located within 50 kilometers of the coast, and coastal population densities are 2.6 times larger than the density of inland areas. By all commonly used measures, the human well-being of coastal inhabitants is on average much higher than that of inland communities.

Islands are lands (both continental and oceanic) isolated by surrounding water and with a high proportion of coast to hinterland. For mapping purposes, the MA uses the ESRI ArcWorld Country Boundary dataset, which contains nearly 12,000 islands. Islands smaller than 1.5 hectares are not mapped or included in the statistics. The largest island included is Greenland. The map above includes islands within 2km of the mainland (e.g., Long Island in the United States) but the statistics provided for island systems in this report exclude these islands. Island states together with their exclusive economic zones cover 40% of the world's oceans. Island systems are especially sensitive to disturbances, and the majority of recorded extinctions have occurred on island systems, although this pattern is changing, and over the past 20 years as many extinctions have occurred on continents as on islands."

Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 1, p.27

Annex 37:
Marine, Coastal, and Island Systems



Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 1, p.27

Annex 38:
Scenarios of the Millennium Ecosystem Assessment

Four plausible scenarios explore the future of ecosystems and human well-being for the next 50 years and beyond.

The scenarios consider two possible paths of world development:
- increasing globalization or
- increasing regionalization.

They also consider two different approaches to ecosystem management:
- in one approach, actions are reactive and address problems only after they become obvious,
- in the other approach, ecosystem management is proactive and deliberately aims for long-term maintenance of ecosystem services.

These scenarios are:

Ecosystem Management	World Development	
	Globalization	Regionalization
Reactive	Global Orchestration [see Annex 32, p. 55]	Order from Strength [see Annex 33, p. 56]
Proactive	TechnoGarden [see Annex 34, p. 57]	Adapting Mosaic [see Annex 31, p. 54]

Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 5, Box 5.1, pp.72-73

Annex 39:

Table 1.1. Comparative table of reporting systems as defined by the Millennium Assessment

"Note that these systems often overlap. Statistics for different systems can therefore be compared, but cannot be totaled across systems as this will result in partial double-counting."

System and subsystem	Area (million km^2)	% of terrestrial surface of the globe	Population			GDP per capita[1]	Infant Mortality Rate[2]	Mean NPP ($KgC/m^2/yr$)[3]	% System covered by PA's[4]	% Area trans-formed[5]
			Density (people per square km)		Growth rate (% 1990-2000)					
			Urban [see Annex 51, p. 74]	Rural						
Marine	**349.3**	**68.6**[6]	-	-	-	-	-	**0.15**	**0.3**	-
Coastal	**17.9**	**4.5**	**1105**	**70**	**15.9**	**8960**	**41.5**		**7**	
Terrestrial	6.7	4.5	1105	70	15.9	8960	41.5	0.52	4	11
Marine	11.2	2.26	-	-	-	-	-	0.14	9	-
Inland water[7]	**10.3**	**7.0**	**817**	**26**	**17**	**7300**	**57.6**	**0.36**	**12**	**11**
Forest/ woodlands	**42.2**	**28.6**	**472**	**18**	**13.5**	**9580**	**57.7**	**0.68**	**10**	**42**
Tropical/ subtropical	23.5	15.9	565	14	17	6854	58.3	0.95	11	34
Temperate	6.3	4.3	320	7	4.4	17109	12.5	0.45	16	67
Boreal	12.4	8.4	114	0.1	-3.7	13142	16.5	0.29	4	25
Dryland [see Annex 51, p. 74]	**60.9**	**41.3**	**750**	**20**	**18.5**	**4930**	**66.6**	**0.26**	**7**	**18**
Hyperarid	9.8	6.6	1061	1	26.2	5930	41.3	0.01	11	1
Arid	15.7	10.6	568	3	28.1	4680	74.2	0.12	6	5
Semiarid	22.3	15.3	643	10	20.6	5580	72.4	0.34	6	25
Dry sub-humid	12.9	8.7	711	25	13.6	4270	60.7	0.49	7	35
Island	**9.9**	**6.7**	**1020**	**37**	**12.3**	**11570**	**30.4**	**0.54**	**17**	**17**
Island states	7.0	4.8	918	14	12.5	11148	30.6	0.45	18	21
Mountain	**33.2**	**22.2**	**63**	**3**	**16.3**	**6470**	**57.9**	**0.42**	**14**	**12**
300-1000m	15.1	10.2	58	3	12.7	7815	48.2	0.47	11	13
1000-2500m	11.9	8.1	69	3	20.0	5080	67.0	0.45	14	13
2500-4500m	3.9	2.7	90	2	24.2	4144	65.0	0.28	18	6
> 4500m	1.8	1.2	104	0	25.3	3663	39.4	0.06	22	0.3
Polar	**23.0**	**15.6**	**161**	**0.06**	**-6.5**	**15401**	**12.8**	**0.06**	**42**[8]	**0.3**[8]
Cultivated	**35.6**	**24.1**	**786**	**70**	**14.1**	**6810**	**54.3**	**0.52**	**6**	**47**
Pasture	0.1	0.1	419	10	28.8	15790	32.8	0.64	4	11
Cropland	8.3	5.7	1014	118	15.6	4430	55.3	0.49	4	62
Mixed (crop & other)	27.1	18.4	575	22	11.8	11060	46.5	0.6	6	43
Gobal	**510**	-	**681**	**13**	**16.7**	**7309**	**57.4**	-	**4**	**38**

[1] Gross Domestic Product.
[2] Infant Mortality Rate (deaths of <1yr old children per thousand live births).
[3] Mean Net Primary Productivity.
[4] Includes only natural or mixed classes of Protected Areas in IUCN categories I to VI.
[5] Area Transformed - For all systems except forest/woodland, area transformed is calculated from land depicted as cultivated or urban [see Annex 51, p. 74] areas by GLC2000 land cover data set. The area transformed for forest/woodland systems is calculated as the % change in area between potential vegetation (forest biomes of the WWF Ecoregions) and current forest/woodland areas in GLC2000. Note: 22% of the forest/woodland system falls outside forest biomes and is therefore not included in this analysis.
[6] % total surface of the globe.
[7] Population density, growth rate, GDP per capita and growth rate for the Inland Water system have been calculated with an area buffer of 10km
[8] Excluding Antarctica

Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 1, p.31
(Conditions and Trends Working Group Report, C.SDM Summary)

Annex 40:

Table 2.1. Trends in the Human Use of Ecosystem Services and Enhancement or Degradation of the Service Around the Year 2000 - Provisioning services

Legend

↑	= Increasing (for Human Use column) or enhanced (for Enhanced or Degraded column)
↓	= Decreasing (for Human Use column) or degraded (for Enhanced or Degraded column)
+/-	= Mixed (trend increases and decreases over past 50 years or some components/regions increase while others decrease

Click on the links below for similar tables on:

Regulating services [see Annex 41, p. 64]

Cultural services [see Annex 42, p. 66]

Supporting services [see Annex 43, p. 68]

Service	Sub-category	Human Use (a)	Enhanced or Degraded (b)	Notes
Provisioning Services				
Food	Crops	↑	↑	Food provision has grown faster than overall population growth. Primary source of growth from increase in production per unit area but also significant expansion in cropland. Still persistent areas of low productivity and more rapid area expansion, e.g., sub-Saharan Africa and parts of Latin America.
	Livestock	↑	↑	Significant increase in area devoted to livestock in some regions, but major source of growth has been more-intensive, confined production of chicken, pigs, and cattle.
	Capture Fisheries	↓	↓	Marine fish harvest increased until the late 1980s and has been declining since then. Currently, one quarter of marine fish stocks are overexploited or significantly depleted. Freshwater capture fisheries have also declined. Human use of capture fisheries has declined because of the reduced supply, not because of reduced demand.
	Aquaculture	↑	↑	Aquaculture has become a globally significant source of food in the last 50 years and, in 2000, contributed 27% of total fish production. Use of fish feed for carnivorous aquaculture species places an additional burden on capture fisheries.
	Wild plants and animal food products	**NA**	↓	Provision of these food sources is generally declining as natural habitats worldwide are under increasing pressure and as wild populations are exploited for food, particularly by the poor, at unsustainable levels.
Fiber	Timber	↑	+/-	Global timber production has increased by 60% in the last four decades. Plantations provide an increasing volume of harvested roundwood, amounting to 35% of the global harvest in 2000. Roughly 40% of forest area has been lost during the industrial era, and forests continue to be lost in many regions (thus the service is degraded in those regions), although forest is now recovering in some temperate countries and thus this service has been enhanced (from this lower baseline) in these regions in recent decades.
	Cotton, hemp, silk	+/-	+/-	Cotton and silk production have doubled and tripled respectively in the last four decades. Production of other agricultural fibers has declined.
	Wood fuel	+/-	↓	Global consumption of fuelwood appears to have peaked in the 1990s and is now believed to be slowly declining but remains the dominant source of domestic fuel in some regions.
Genetic resources		↑	↓	Traditional crop breeding has relied on a relatively narrow range of germplasm for the major crop species, although molecular genetics and biotechnology provide new tools to quantify and expand genetic diversity in these crops. Use of genetic resources also is growing in connection with new industries based on biotechnology. Genetic resources have been lost through the loss of traditional cultivars of crop species (due in part to the adoption of modern farming practices and varieties) and through species extinctions.
Biochemicals, natural medicines, and pharmaceuticals		↑	↓	Demand for biochemicals and new pharmaceuticals is growing, but new synthetic technologies compete with natural products to meet the demand. For many other natural products (cosmetics, personal care, bioremediation, biomonitoring, ecological restoration), use is growing. Species extinction and overharvesting of medicinal plants is diminishing the availability of these resources.
Ornamental resources		**NA**	**NA**	

Service	Sub-category	Human Use (a)	Enhanced or Degraded (b)	Notes
Freshwater		↑	↓	Human modification to ecosystems (e.g., reservoir creation) has stabilized a substantial fraction of continental river flow, making more fresh water available to people but in dry regions reducing river flows through open water evaporation and support to irrigation that also loses substantial quantities of water. Watershed management and vegetation changes have also had an impact on seasonal river flows. From 5% to possibly 25% of global freshwater use exceeds long-term accessible supplies and requires supplies either through engineered water transfers or overdraft of groundwater supplies. Between 15% and 35% of irrigation withdrawals exceed supply rates. Freshwater flowing in rivers also provides a service in the form of energy that is exploited through hydropower. The construction of dams has not changed the amount of energy, but it has made the energy more available to people. The installed hydroelectric capacity doubled between 1960 and 2000. Pollution and biodiversity loss are defining features of modern inland water systems in many populated parts of the world.

* = Low to medium certainty. All other trends are medium to high certainty.

NA = Not assessed within the MA. In some cases, the service was not addressed at all in the MA (such as ornamental resources), while in other cases the service was included but the information and data available did not allow an assessment of the pattern of human use of the service or the status of the service.

† = The categories of "Human Benefit" and "Enhanced or Degraded" do not apply for supporting services since, by definition, these services are not directly used by people. (Their costs or benefits would be double-counted if the indirect effects were included). Changes in supporting services influence the supply of provisioning, cultural, or regulating services that are then used by people and may be enhanced or degraded.

a For provisioning services, human use increases if the human consumption of the service increases (e.g., greater food consumption); for regulating and cultural services, human use increases if the number of people affected by the service increases. The time frame is in general the past 50 years, although if the trend has changed within that time frame the indicator shows the most recent trend.

b For provisioning services, we define enhancement to mean increased production of the service through changes in area over which the service is provided (e.g., spread of agriculture) or increased production per unit area. We judge the production to be degraded if the current use exceeds sustainable levels. For regulating and supporting services, enhancement refers to a change in the service that leads to greater benefits for people (e.g., the service of disease regulation could be improved by eradication of a vector known to transmit a disease to people). Degradation of a regulating and supporting services means a reduction in the benefits obtained from the service, either through a change in the service (e.g., *mangroves* loss reducing the storm protection benefits of an ecosystem) or through human pressures on the service exceeding its limits (e.g., excessive pollution exceeding the capability of ecosystems to maintain water quality). For cultural services, enhancement refers to a change in the ecosystem features that increase the cultural (recreational, aesthetic, spiritual, etc.) benefits provided by the ecosystem. The time frame is in general the past 50 years, although if the trend has changed within that time frame the indicator shows the most recent trend.

Source: MA Millennium Ecosystem Assessment
Ecosystems and Human Well-being: Biodiversity Synthesis [see http://www.millenniumassessment.org/documents/document.354.aspx.pdf] (2005), p.33-37

Annex 41:

Table 2.1. Trends in the Human Use of Ecosystem Services and Enhancement or Degradation of the Service Around the Year 2000 - Regulating services

Legend

↑	= Increasing (for Human Use column) or enhanced (for Enhanced or Degraded column)
↓	= Decreasing (for Human Use column) or degraded (for Enhanced or Degraded column)
+/-	= Mixed (trend increases and decreases over past 50 years or some components/regions increase while others decrease

Click on the links below for similar tables on:

Provisioning services [see Annex 40, p. 62]

Cultural services [see Annex 42, p. 66]

Supporting services [see Annex 43, p. 68]

Service	Sub-category	Human Use (a)	Enhanced or Degraded (b)	Notes
Regulating Services				
Air quality regulation		↑	↓	The ability of the atmosphere to cleanse itself of pollutants has declined slightly since pre-industrial times but likely not by more than 10%. The net contribution of ecosystems to this change is not known. Ecosystems are also a sink for tropospheric ozone, ammonia, NO_x, SO_2, particulates, and CH_4, but changes in these sinks were not assessed. (C13.ES)
Climate regulation	Global	↑	↑	Terrestrial ecosystems were on average a net source of CO_2 during the nineteenth and early twentieth century, and became a net sink sometime around the middle of the last century. The biophysical effect of historical *land cover* changes (1750 to present) is net cooling on a global scale due to increased albedo, partially offsetting the warming effect of associated CO_2 emissions from land cover change over much of that period. (C13.ES)
	Regional and Local	↑	↓	Changes in land cover have affected regional and local climates both positively and negatively, but there is a preponderance of negative impacts. For example, tropical deforestation and desertification have tended to reduce local rainfall. (C13.3, C11.3)
Water regulation		↑	+/-	The effect of ecosystem change on the timing and magnitude of runoff, flooding, and aquifer recharge depends on the specific change and the specific ecosystem. (C7.4.4)
Erosion regulation		↑	↓	Land use and crop/soil management practices have exacerbated soil degradation and erosion, although appropriate soil conservation practices that reduce erosion, such as minimum tillage, are increasingly being adopted by farmers in North America and Latin America. (C26)
Water purification and waste treatment		↑	↓	Globally, water quality is declining, although in most industrial countries pathogen and organic pollution of surface waters has decreased over the last 20 years. Nitrate concentration has grown rapidly in the last 30 years. The capacity of ecosystems to purify such wastes is limited, as evidenced by widespread reports of inland waterway pollution. Loss of wetlands has further decreased the ability of ecosystems to filter and decompose wastes. (C7.2.5, C19)
Disease regulation		↑	+/-	Ecosystem modifications associated with development have often increased the local incidence of infectious diseases, although major changes in habitats can both increase or decrease the risk of particular infectious diseases. (C14)
Pest regulation		↑	↓	In many agricultural areas, pest control provided by natural enemies has been replaced by the use of pesticides. Such pesticide use has itself degraded the capacity of agroecosystems to provide pest control. In other systems, pest control provided by natural enemies is being used and enhanced through integrated pest management. Crops containing pest-resistant genes can also reduce the need for application of toxic synthetic pesticides. (C11.3)
Pollination		↑	↓	There is established but incomplete evidence of a global decline in the abundance of pollinators. Pollinator declines have been reported in at least one region or country on every continent except for Antarctica, which has no pollinators. Declines in abundance of pollinators have rarely resulted in complete failure to produce seed or fruit, but more frequently resulted in fewer seeds or in fruit of reduced viability or quantity. Losses in populations of specialized pollinators have directly affected the reproductive ability of some rare plants. (C11 Box 11.2)
Natural hazard regulation		↑	↓	People are increasingly occupying regions and localities that are exposed to extreme events, thereby exacerbating human vulnerability to natural hazards. This trend, along with the decline in the capacity of ecosystems to buffer from extreme events, has led to continuing high loss of life globally and rapidly rising economic losses from natural disasters. (C16,C19)

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† = The categories of "Human Benefit" and "Enhanced or Degraded" do not apply for supporting services since, by definition, these services are not directly used by people. (Their costs or benefits would be double-counted if the indirect effects were included). Changes in supporting services influence the supply of provisioning, cultural, or regulating services that are then used by people and may be enhanced or degraded.

a For provisioning services, human use increases if the human consumption of the service increases (e.g., greater food consumption); for regulating and cultural services, human use increases if the number of people affected by the service increases. The time frame is in general the past 50 years, although if the trend has changed within that time frame the indicator shows the most recent trend.

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Source: MA Millennium Ecosystem Assessment
Ecosystems and Human Well-being: Biodiversity Synthesis [see http://www.millenniumassessment.org/documents/document.354.aspx.pdf] (2005), p.33-37

Annex 42:

Table 2.1. Trends in the Human Use of Ecosystem Services and Enhancement or Degradation of the Service Around the Year 2000 - Cultural services

Legend

↑	= Increasing (for Human Use column) or enhanced (for Enhanced or Degraded column)
↓	= Decreasing (for Human Use column) or degraded (for Enhanced or Degraded column)
+/-	= Mixed (trend increases and decreases over past 50 years or some components/regions increase while others decrease

Click on the links below for similar tables on:

Provisioning services [see Annex 40, p. 62]

Regulating services [see Annex 41, p. 64]

Supporting services [see Annex 43, p. 68]

Service	Human Use (a)	Enhanced or Degraded (b)	Notes
Cultural services			
Cultural diversity	**NA**	**NA**	
Spiritual and religious values	↑	↓	There has been a decline in the numbers of sacred groves and other such protected areas. The loss of particular ecosystem attributes (sacred species or sacred forests), combined with social and economic changes, can sometimes weaken the spiritual benefits people obtain from ecosystems. On the other hand, under some circumstances (e.g., where ecosystem attributes are causing significant threats to people), the loss of some attributes may enhance spiritual appreciation for what remains. (C17.2.3)
Knowledge systems	**NA**	**NA**	
Educational values	**NA**	**NA**	
Inspiration	**NA**	**NA**	
Aesthetic values	↑	↓	The demand for aesthetically pleasing natural landscapes has increased in accordance with increased urbanization. There has been a decline in quantity and quality of areas to meet this demand. A reduction in the availability of and access to natural areas for urban residents may have important detrimental effects on public health and economies. (C17.2.5)
Social relations	**NA**	**NA**	
Sense of place	**NA**	**NA**	
Cultural heritage values	**NA**	**NA**	
Recreation and ecotourism	↑	+/-	The demand for recreational use of landscapes is increasing, and areas are increasingly being managed to cater for this use, to reflect changing cultural values and perceptions. However, many naturally occurring features of the landscape (e.g., coral reefs) have been degraded as resources for recreation. (C17.2.6, C19.??)

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Annex 43:

Table 2.1. Trends in the Human Use of Ecosystem Services and Enhancement or Degradation of the Service Around the Year 2000 - Supporting services

Legend

	= Increasing (for Human Use column) or enhanced (for Enhanced or Degraded column)
	= Decreasing (for Human Use column) or degraded (for Enhanced or Degraded column)
+/-	= Mixed (trend increases and decreases over past 50 years or some components/regions increase while others decrease

Click on the links below for similar tables on:

Provisioning services [see Annex 40, p. 62]

Regulating services [see Annex 41, p. 64]

Cultural services [see Annex 42, p. 66]

Service	Human Use (a)	Enhanced or Degraded (b)	Notes
Supporting services			
Soil formation	†	†	
Photosynthesis	†	†	
Primary production	†	†	Several global MA systems [see Annex 35, p. 58] , including drylands [see Annex 51, p. 74] , forest, and cultivated systems [see Annex 27, p. 51] , show a trend of NPP increase for the period 1981 to 2000. However, high seasonal and inter-annual variations associated with climate variability occur within this trend on the global scale (C22.2.1)
Nutrient cycling	†	†	There have been large-scale changes in nutrient cycles in recent decades, mainly due to additional inputs from fertilizers, livestock waste, human wastes, and biomass burning. Inland water and coastal systems have been increasingly affected by eutrophication due to transfer of nutrients from terrestrial to aquatic systems as biological buffers that limit these transfers have been significantly impaired. (C12, S7)
Water cycling	†	†	Humans have made major changes to water cycles through structural changes to rivers, extraction of water from rivers, and, more recently, climate change. (C7)

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† = The categories of “Human Benefit” and “Enhanced or Degraded” do not apply for supporting services since, by definition, these services are not directly used by people. (Their costs or benefits would be double-counted if the indirect effects were included). Changes in supporting services influence the supply of provisioning, cultural, or regulating services that are then used by people and may be enhanced or degraded.

a For provisioning services, human use increases if the human consumption of the service increases (e.g., greater food consumption); for regulating and cultural services, human use increases if the number of people affected by the service increases. The time frame is in general the past 50 years, although if the trend has changed within that time frame the indicator shows the most recent trend.

b For provisioning services, we define enhancement to mean increased production of the service through changes in area over which the service is provided (e.g., spread of agriculture) or increased production per unit area. We judge the production to be degraded if the current use exceeds sustainable levels. For regulating and supporting services, enhancement refers to a change in the service that leads to greater benefits for people (e.g., the service of disease regulation could be improved by eradication of a vector known to transmit a disease to people). Degradation of a regulating and supporting services means a reduction in the benefits obtained from the service, either through a change in the service (e.g., *mangroves* loss reducing the storm protection benefits of an ecosystem) or through human pressures on the service exceeding its limits (e.g., excessive pollution exceeding the capability of ecosystems to maintain water quality). For cultural services, enhancement refers to a change in the ecosystem features that increase the cultural (recreational, aesthetic, spiritual, etc.) benefits provided by the ecosystem. The time frame is in general the past 50 years, although if the trend has changed within that time frame the indicator shows the most recent trend.

Source: MA Millennium Ecosystem Assessment

Ecosystems and Human Well-being: Biodiversity Synthesis [see http://www.millenniumassessment.org/documents/document.354.aspx.pdf] (2005), p.33-37

Annex 44:

Annex 45:

Table 4.1. Increase in Nitrogen Fluxes in Rivers to Coastal Oceans

due to Human Activities Relative to Fluxes Prior to the Industrial and Agricultural Revolutions

Labrador & Hudson's Bay	no change
Southwestern Europe	3.7-fold
Great Lakes/St. Lawrence basin	4.1-fold
Mississippi River basin	5.7-fold
Yellow River basin	10-fold
Northeastern US	11-fold
North Sea watersheds	15-fold
Republic of Korea	17-fold

Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 4, p.69
(Responses Working Group Report, R9, Table 9.1)

Annex 46:

Table 5.1. Main Assumptions Concerning Indirect and Direct Driving Forces Used in the MA Scenarios

("Industrialized" and "developing" nations refer to the countries at the beginning of the scenario; some may change by 2050.)

	Global Orchestration	Order from Strength		Adapting Mosaic	TechnoGarden
		Industrialized Countries	Developing Countries		
Indirect drivers					
Demographics	high migration; low fertility and mortality levels 2050 population: 8.1 billion	high fertility and mortality levels (esp. in developing countries); low migration 2050 population: 9.6 billion		high fertility level;high mortality levels until 2010 then to medium by 2050; low migration 2050 population: 9.5 billion	medium fertility and mortality levels; medium migration 2050 population: 8.8 billion
Average income growth	high	medium	low	similar to Order from Strength but with increasing growth rates toward 2050	lower than Global Orchestration, but catching up toward 2050
GDP growth rates/capita per year until 2050	Global: 1995-2020: 2.4% per year 2020-2050: 3.0% per year	1995-2020: 1.4% per year 2020-2050: 1.0% per year		1995-2020: 1.5% per year 2020-2050: 1.9% per year	1995-2020: 1.9% per year 2020-2050: 2.5% per year
	industrialized c.:1995-2020: 3.2% per year 2020-2050: 2.1% per year developing c.:1995-2020: 4.8% per year 2020-2050: 4.8% per year	1995-2020: 2.6% per year 2020-2050: 1.4% per year	1995-2020: 3.0% per year 2020-2050: 2.3% per year	industrialized c.: 1995-2020: 2.6% per year 2020-2050: 1.7% per year developing c: c.:1995-2020: 3.5% per year 2020-2050: 3.5% per year	industrialized c.: 1995-2020: 2.9% per year 2020-2050: 1.9% per year developing c.:1995-2020: 4.0% per year 2020-2050: 4.3% per year
Income distribution	becomes more equal	similar to today		similar to today, then becomes more equal	becomes more equal
Investments into new produced assets	high	medium	low	begins like Order from strength, then increases in tempo	high
Investments into human capital	high	medium	low	begins like Order from strength, then increases in tempo	medium
Overall trend in technology advances	high	low		medium-low	medium in general; high for environmental technology
International cooperation	strong	weak - international competition		weak - focus on local environment	strong
Attitude toward environmental policy	reactive	reactive		proactive - learning	proactive
Energy demand and lifestyle	energy-intensive	regionalized assumptions		regionalized assumptions	high level of energy resources and rapid technology change
Energy supply	market liberalization; selects least-cost options; rapid technology change	focus on domestic energy resources		some preference for clean energy resources	preference for renewable energy resources and rapid technology change
Climate policy	no	no		no	yes, aims at stabilization of CO_2-equivalent concentration at 550 ppmv
Approach to achieving sustainability	economic growth leads to sustainable development	national-level policies; conservation; reserves, parks		local-regional co-management; common-property institutions	green-technology; eco-efficiency; tradable ecological property rights
Direct drivers					
Land use change	global forest loss until 2025 slightly below historic rate, stabilizes after 2025; ~10% increase in arable land	global forest loss faster than historic rate until 2025; near current rate after 2025; ~20% increase in arable land compared with 2000		global forest loss until 2025 slightly below historic rate; stabilizes after 2025; ~10% increase in arable land	net increase in forest cover globally until 2025; slow loss after 2025; ~9% increase in arable land
Greenhouse gas emissions by 2050	CO^2: 20.1 GtC-eq CH_4: 3.7 GtC-eq N_2O: 1.1 GtC-eq Other GHG: 0.7 GtC-eq	CO_2: 15.4 GtC-eq CH_4: 3.3GtC-eq N_2O: 1.1 GtC-eq GHG: 0.5 GtC-eq		CO_2: 13.3 GtC-eq CH_4: 3.2 GtC-eq N_2O: 0.9 GtC-eq Other GHG: 0.6 GtC-eq	CO_2: 4.7 bfGtC-eq CH_4: 1.6 GtC-eq N_2O: 0.6 GtC-eq Other GHG: 0.2 GtC-eq
Air pollution emissions	SO_2 emissions stabilize; NO_x emissions increase from 2000 to 2050	both SO_2 and NO_x emissions increase globally		SO_2 emissions decline; NO_x emissions increase slowly	strong reductions in SO_2 and NO_x emissions

	Global Orchestration	Order from Strength		Adapting Mosaic	TechnoGarden
		Industrialized Countries	Developing Countries		
Climate change	2.0oC in 2050 and 3.5oC in 2100 above pre-industrial	1.7oC in 2050 and 3.3oC in 2100 above pre-industria		1.9oC in 2050 and 2.8oC in 2100 above pre-industrial	1.5oC in 2050 and 1.9oC in 2100 above pre-industrial
Nutrient loading	increase in N transport in rivers	increase in N transport in rivers		increase in N transport in rivers	decrease in N transport in rivers

Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 5, pp.75-76
(Scenarios Working Group Report, S.SDM Summary)

Annex 47:

Table 5.2. Outcomes of Scenarios for Ecosystem Services in 2050 Compared with 2000

Legend	
↑	increase,
⇔	remains the same as in 2000
↓	decrease

	Global Orchestration		Order from Strength		Adapting Mosaic		TechnoGarden	
	Indus- trialized	Devel- oping	Indus- trialized	Devel- oping	Indus- trialized	Devel- oping	Indus- trialized	Devel- oping
Provisioning Services								
Food (extent to which demand is met)	↑	↑	⇔	↓	⇔	↓	↑	↑
Fuel	↑	↑	↑	↑	↑	↑	↑	↑
Genetic resources	⇔	⇔	↓	↓	↑	↑	⇔	↑
Biochemicals/ Pharmaceuticals discoveries	↓	↑	↓	↓	⇔	⇔	↑	↑
Ornamental resources	⇔	⇔	⇔	↓	↑	↑	⇔	⇔
Freshwater	↑	↑	⇔	↓	↑	↓	↑	⇔
Regulating Services								
Air quality regulation	⇔	⇔	⇔	↓	⇔	⇔	↑	↑
Climate regulation	⇔	⇔	↓	↓	⇔	⇔	↑	↑
Water regulation	⇔	↓	↓	↓	↑	↑	⇔	↑
Erosion control	⇔	↓	↓	↓	↑	↑	⇔	↑
Water purification	⇔	↓	↓	↓	↑	↑	⇔	↑
Disease control: human	⇔	↑	⇔	↓	⇔	↑	↑	↑
Disease control: pests	⇔	↓	↓	↓	↑	↑	⇔	⇔
Pollination	↓	↓	↓	↓	⇔	⇔	↓	↓
Storm protection	⇔	↓	⇔	↓	↑	↑	↑	⇔
Cultural Services								
Spiritual/ religious values	⇔	⇔	⇔	↓	↑	↑	↓	↓
Aestetic values	⇔	⇔	⇔	↓	↑	↑	⇔	⇔
Recreation and ecotourism	↓	↑	↓	↑	↓	↓	↑	↑
Cultural diversity	↓	↓	↓	↓	↑	↑	↓	↓
Knowledge systems (diversity and memory)	⇔	↓	↓	↓	↑	↑	⇔	⇔

Note: For provisioning services, we define enhancement to mean increased production of the service through changes in area over which the service is provided (e.g., spread of agriculture) or increased production per unit area. We judge the production to be degraded if the current use exceeds sustainable levels. For regulating services, enhancement refers to a change in the service that leads to greater benefits for people (e.g., the service of disease regulation could be improved by eradication of a vector known to transmit a disease to people). Degradation of regulating services means a reduction in the benefits obtained from the service, either through a change in the service (e.g., mangrove loss reducing the storm protection benefits of an ecosystem) or through human pressures on the service exceeding its limits (e.g., excessive pollution exceeding the capability of ecosystems to maintain water quality). For cultural services, degradation refers to a change in the ecosystem features that decreases the cultural (recreational, aesthetic, spiritual, etc.) benefits provided by the ecosystem, while enhancement refers to a change that increases them.

Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),

Chapter 5, p.77
(Scenarios Working Group Report, S.SDM Summary)

Annex 48:

Table 5.3. Outcomes of Scenarios for Human Well-being in 2050 Compared with 2000

Legend	
↑	increase,
⇔	remains the same as in 2000
↓	decrease

	Global Orchestration		Order from Strength		Adapting Mosaic		TechnoGarden	
	Indus-trialized	Devel-oping	Indus-trialized	Devel-oping	Indus-trialized	Devel-oping	Indus-trialized	Devel-oping
Material well-being	↑	↑	↑	↓	⇔	↑	↑	↑
Health	↑	↑	↑	↓	↑	↑	↑	↑
Security	↑	↑	↓	↓	↑	↑	↑	↑
Social relations	⇔	↑	↓	↓	↑	↑	↓	↓
Freedom of Choice	⇔	↑	↓	↓	↑	↑	↑	↑

Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 5, p.78
(Scenarios Working Group Report, S.SDM Summary)

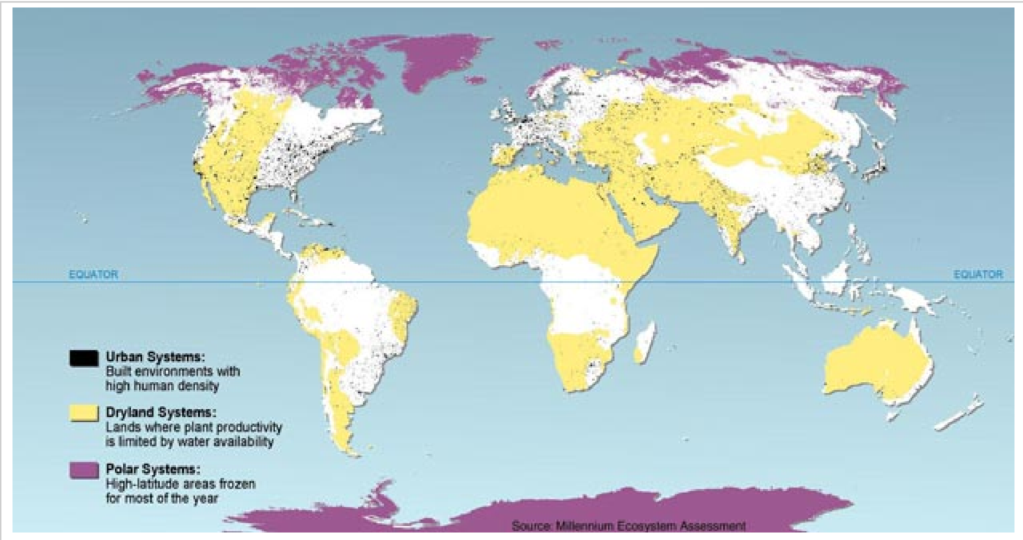
Annex 49:

Table 5.4. Costs and Benefits of Proactive as Contrasted with Reactive Ecosystem Management as Revealed in the MA Scenarios

	Proactive Ecosystem Management	Reactive Ecosystem Management
Payoffs	Benefit from lower risk of unexpected losses of ecosystem services, achieved through investment in (1) More efficient use of resources (water, energy, fertilizer etc.); (2) More innovation of green technology; (3) Capacity to absorb unexpected fluctuations in ecosystem services; (4) Adaptable management systems; (5) Ecosystems that are resilient and self-maintaining Do well under changing or novel conditions Build natural, social and human capital	Avoid paying for monitoring efforts Do well under smoothly or incrementally changing conditions Build manufactured, social and human capital
Costs	Technological solutions can create new problems Costs of unsuccessful experiments Costs of monitoring Some short-term benefits are traded for long-term benefits	Expensive unexpected events Persistent ignorance (repeating the same mistakes) Lost option values Inertia of less flexible and adaptable management of infrastructure and ecosystems Loss of natural capital

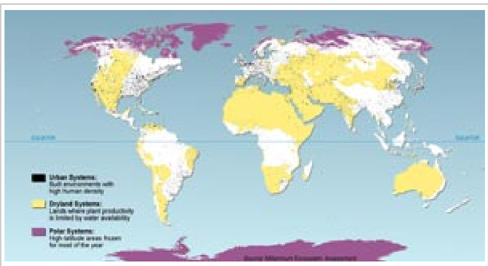
Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 5, p.83
(Scenarios Working Group Report, S.SDM Summary)

Annex 50:
Urban, Dryland and Polar systems



Source: Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005), Chapter 1, p.28

Annex 51:
Urban, Dryland and Polar systems


(click image for a larger map) [see Annex 50, p. 74]

"**Urban systems** are built environments with a high human density. For mapping purposes, the MA uses known human settlements with a population of 5,000 or more, with boundaries delineated by observing persistent night-time lights or by inferring areal extent in the cases where such observations are absent. The world's urban population increased from about 200 million in 1900 to 2.9 billion in 2000, and the number of cities with populations in excess of 1 million increased from 17 in 1900 to 388 in 2000.

Dryland systems are lands where plant production is limited by water availability; the dominant human uses are large mammal herbivory, including livestock grazing, and cultivation. The map shows drylands as defined by the U.N. Convention to Combat Desertification, namely lands where annual precipitation is less than two thirds of potential evapotranspiration—from dry subhumid areas (ratio ranges 0.50–0.65) through semiarid, arid, and hyperarid (ratio < 0.05), but excluding polar areas. Drylands include cultivated lands, scrublands, shrublands, grasslands, savannas, semi-deserts, and true deserts. Dryland systems cover about 41% of Earth's land surface and are inhabited by more than 2 billion people (about one third of the total population). Croplands cover approximately 25% of drylands, and dryland rangelands support approximately 50% of the world's livestock. The current socioeconomic condition of people in dryland systems, of which about 90% are in developing countries, is worse than in other areas. Freshwater availability in drylands is projected to be further reduced from the current average of 1,300 cubic meters per person per year in 2000, which is already below the threshold of 2,000 cubic meters required for minimum human well-being and sustainable development. Approximately 10–20% of the world's drylands are degraded (medium certainty).

Polar systems are high-latitude systems frozen for most of the year, including ice caps, areas underlain by permafrost, tundra, polar deserts, and polar coastal areas. Polar systems do not include high-altitude cold systems in low latitudes. Temperature in polar systems is on average warmer now than at any time in the last 400 years, resulting in widespread thaw of permafrost and reduction of sea ice. Most changes in feedback processes that occur in polar regions magnify trace gas–induced global warming trends and reduce the capacity of polar regions to act as a cooling system for Earth. Tundra constitutes the largest natural wetland in the world."

Source & © Millennium Ecosystem Assessment
Synthesis Report [see http://www.millenniumassessment.org/en/Products.Synthesis.aspx] (2005),
Chapter 1, pp.27-29