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Educational, Scientific and
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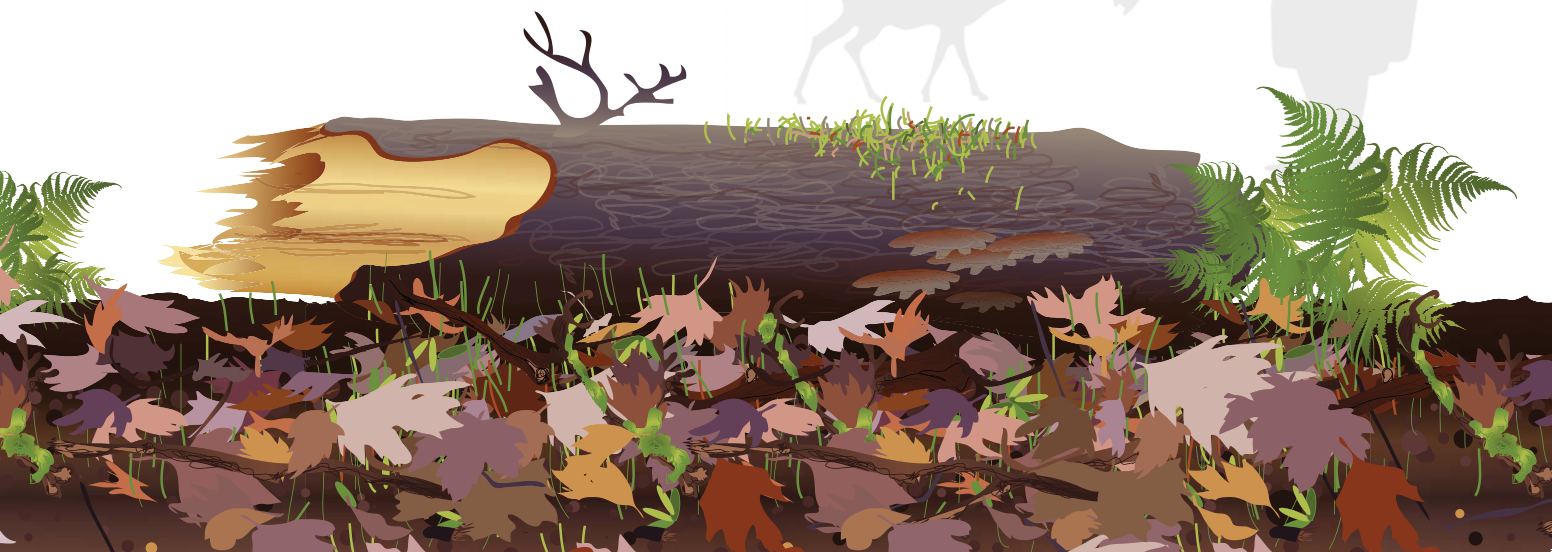
Convention on
Biological
Diversity

Biodiversity Learning Kit

Volume 1



Biodiversity Learning Kit

Volume 1

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Foreword

Biodiversity is the essence of life: it provides essential products such as food, fibres and building materials, maintains ecosystem services such as soil fertility, and underpins societies, cultures and religion.

The UNESCO/CBD Biodiversity Learning Kit uses text, illustrations and practical methods to help secondary school students and teachers understand the multiple dimensions and complex processes related to biodiversity through innovative learning pathways and hands-on activities. It also explains the status of biodiversity and how it is affected by prevailing attitudes and behaviours, and by consumption patterns.

Education is essential for the sustainable and equitable use of biodiversity and its conservation. We therefore hope that teachers and students will find the Kit to be a useful and interesting resource to deepen students' knowledge of biodiversity and thus develop an understanding that its conservation is pivotal to the future of our planet.

This Kit is a contribution to the United Nations Decade on Biodiversity (2011-2020). It supports the main objectives of the Convention on Biodiversity (CBD) Programme of Work on Communication, Education and Public Awareness, to which UNESCO has contributed actively for 15 years, and the Global Action Programme on Education for Sustainable Development coordinated by UNESCO. It was pilot tested by secondary schools of the UNESCO Associated Schools Project Network (ASPnet).

The Kit was developed as a joint initiative of the Education and Natural Sciences Sectors of the United Nations Educational, Scientific and Cultural Organization (UNESCO), in cooperation with the CBD.

We extend our warmest thanks to the CBD Secretariat, the Government of Japan, UNESCO Etxea, Beraca and the French National MAB Committee, which contributed resources to develop the kit as part of their support for UNESCO.

Flavia Schlegel
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Preface

'Go take your lessons in nature, that is where our future is.'

Leonardo da Vinci

This educational kit is the result of the joint work of experts from various disciplines including education, pedagogy, biological sciences, ecology, languages and cultural diversity. The project favours interdisciplinarity because, by definition, biodiversity – the central theme of this manual – traverses all sectors of our society. Biological diversity encompasses the past – the evolution of life on earth – the present – the contribution of biodiversity to human wellbeing – and the future – the crucial need to preserve biodiversity as it undergoes erosion and loss at local, regional and global levels.

Why produce an educational kit on biodiversity? The answer lies in the results of the Global Biodiversity Outlook *(GBO)* and the work of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), which should be brought to the attention of all, not just decision-makers. Indeed, the future of biodiversity will depend on the global collective action of an educated society, including a moral obligation to promote traditional and indigenous knowledge of biodiversity.

UNESCO has developed this kit in close collaboration with the Secretariat of the Convention on Biological Diversity (CBD) and the UNESCO Associated Schools Project Network (ASPnet). We want this kit, which will be freely available upon publication in three languages (English, French and Spanish), to serve as a reference allowing the concept of biodiversity, often seen as difficult to grasp, to be understood and applied in terms of its essence and its impact on our lives and the sustainability of our planet. Ultimately, biodiversity, beyond encapsulating the natural evolution of life on earth and in the oceans, represents the result of our interaction with nature around us. If we lead lives that reflect the objectives of sustainable development, we can continue to benefit from biodiversity and its vital ecosystem services. These services affect our food security and access to water, contribute to our health and wellbeing, offer protection against natural disasters, and provide renewable energy and key components for our habitats, as well as climate regulation.

Part 1

What is *biodiversity?*

Left:
Whiptail wallaby, Australia.
© UNESCO, Carl Moller

Right from top to bottom:
Red-eyed tree frogs.
© Brian Gratwicke CC BY 2.0
Blue macaw.
© Luc Viatour CC BY 2.0
Arctic expedition.
© Bjorn Alfthan, UNEP GRID-Arendal

Biodiversity, *a preliminary definition*

The living world is characterized by variety and a high degree of diversity. Variety, diversity … which term we use depends on whether we are referring primarily to the range of different elements that make up the whole, or to the differences between the elements themselves.

The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

Biological diversity or biodiversity covers all life forms: living organisms (animals, plants and micro-organisms), their habitats (the environments they live in), the ecosystems to which they belong and in which they play a part, and the biomes or large geographical units shaped by the climate (tropical rainforests, tropical and subtropical savannahs, hot deserts and semi-deserts, temperate deciduous forests, steppes, coral reefs and deltas).

Biological diversity is not only reflected in life forms, it is also manifested at all levels of the organization and functioning of biological life (in the systems constituted by genes, species, ecosystems and biomes).

In other words, the term does not simply stand for an inventory of the diversity of living species, visible to the naked eye or under a microscope, but also denotes the genetic diversity contained within each basic unit of life (the cell, individual, species, population and ecosystem), as well as covering all the relationships and interactions that link these units of life to one another.

These relationships also include the circulation of energy that occurs in the relationship between predator and prey in the form of cooperation between two different species. For example, the oxpecker (a bird) feeds on external parasites that live on the rhinoceros, to the mutual benefit of both. Another example is the flow of major elements through large-scale biogeochemical cycles in the biosphere, such as the carbon cycle and the storage of carbon in forests and oceans.

These are only a few examples; there are numerous instances of such relationships.

Furthermore, the variety and diversity of biological life constitutes the visible and invisible basis of human existence on the Earth.

All human beings depend on biodiversity for their wellbeing.

Biodiversity is the essential basis for the smooth functioning of ecosystems and therefore of the services these ecosystems provide for populations. The services in question can be defined as important and immediate benefits – as key factors in the wellbeing of human communities, for example, through the provision of food, clean water, medicine, energy resources or raw materials.

In addition to providing vital products and foods, biodiversity contributes to soil formation and nutrient cycling through the production and decomposition of organic matter. Greater or lesser diversity of plant cover binds the soil together. Biodiversity plays a key role in regulating the local and the global climate, thanks to the distribution and density of plant communities such as mixed and tropical forests. It also helps to regulate air and water quality.

Biological diversity is also visible within the cultural diversity of human beings on the surface of the planet. Biological life influences our thought, belief and representational systems, our views of the world, our symbols, our values, our skills, the works arising from our development of the landscape and what we build in it, and our artistic achievements.

Broadly speaking, the creation and evolution of different forms of human culture express a variety of ways of borrowing from and intervening in the biological world.

However, in recent years, we have witnessed a general erosion of biodiversity on a global scale, a level of erosion that is increasing at an unprecedented pace.

This phenomenon is caused largely by the impact of human activity on the living world, made worse by climate change and the unremitting pressure of a world population that will continue to grow.

It is now imperative that we fully identify the direct causes behind the extinction of species and the disappearance or fragmentation of habitats, so as to better counter and arrest the massive decline in biodiversity, on which our living conditions and welfare depend.

Red-eyed tree frog
© Carey James Balboa
Public domain

A brief historical survey

The word **biodiversity**, used to denote the concept of biological diversity, was first introduced into scientific analysis in 1988 by the distinguished entomologist and biologist Edward Osborne Wilson. The word is a neologism coined from the words 'biology' and 'diversity'.

The new term seemed a more effective communications tool, at a time when people were growing increasingly aware of the extent and character of the phenomenon of species extinction, which has become apparent since the end of the twentieth century.

In 1992, the term 'biodiversity' received official recognition during the Rio Conference or *Earth Summit*, held under the auspices of the United Nations (UN). Amid a context of growing preoccupation about sustainable development, and with a view to finding a viable balance between the three main aspects of human activity – economic, social and environmental – the Earth Summit drew up the *International Convention on Biological Diversity* for signature by States Parties.

The Convention gives priority to the conservation and sustainable use of biological diversity, as one of the vital resources of sustainable development. Another objective of the Convention is to promote the fair distribution of benefits deriving from biodiversity, so as to enable all populations to prosper.

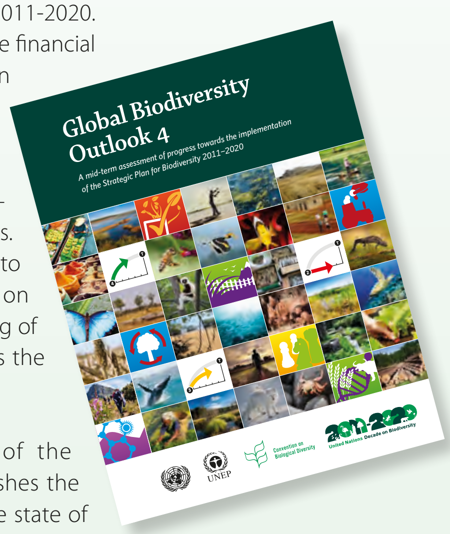
Article 2 of the Convention gives the following definition of biodiversity: 'The variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems'.

To date, 196 parties have ratified the Convention, which in 2002 set a goal of reducing significantly the rate of biodiversity loss by 2010 at the regional, national and global levels.

Following the publication of national reports, the countries that were signatories to the Convention (known as the Parties), recognized that the 2010 Target of a significant reduction in the current rate of biodiversity loss at all levels had not been achieved.

In proclaiming 2010 the *International Year of Biological Diversity*, the United Nations General Assembly once more invited State governments and the citizens of the world to make a commitment to biodiversity, and to take positive steps and initiatives to safeguard biodiversity on our planet.*

To this end, the delegates of the 196 parties met at a Conference of the Parties in Nagoya, Aichi Prefecture, Japan, in October 2010, and adopted a Strategic Plan for Biodiversity covering the period 2011-2020. The participants committed to securing the financial resources necessary for the implementation of the Plan, which is designed to halve the loss of natural habitats, to protect 17% of land and inland water areas, and restore at least 15% of degraded ecosystems by 2020 – goals known as the Aichi Biodiversity Targets. Within the summit framework, the Parties to the Convention also adopted a protocol on access to genetic resources and the sharing of benefits derived from their use, known as the 'Nagoya Protocol'.



At regular intervals, the Secretariat of the Convention on Biological Diversity publishes the *Global Biodiversity Outlook*, a report on the state of biodiversity, which has become indispensable for decision-makers. The fourth edition of *the Outlook (GBO4)*, which appeared in 2014, constitutes a source of information on current, discernible trends in the evolution of biodiversity and on future options.

The Outlook also takes stock of progress towards the 2010 Target, which prioritized the procurement of financial resources for the development of research mechanisms and structures for evaluating environmental impacts, and also allowed the implementation of important safeguards such as the creation of new protected areas and the conservation of particular species. But there still remains much work to be done. The latest edition of the *Outlook*, *GBO4*, was published almost halfway to the deadline set for achieving most of the Aichi Biodiversity Targets (2020). It reviewed progress towards achieving the goals of the Strategic Plan to which governments collectively committed in 2010.

Apatura Ilia.
© Jacob Hübner
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By bringing under one umbrella a body of precise scientific information, comprehensive and innovative analytical and assessment tools, and specific key messages, *GBO4* seeks to bring to the attention of decision-makers a powerful synthesis of present issues relating to biodiversity, which can be incorporated into the decision-making process.

In the broader informative and educational context of this *Biodiversity Learning Kit*, which is aimed at a wide readership, we shall develop these themes and focus on the main messages and some of the more relevant tools highlighted by the work of the Convention on Biological Diversity including *GBO4*.

* **For more details see**
Part 3, Greater consistency of action and jurisdiction (p. 172).

The diversity *of species*

1. All of biological life

When we talk about diversity within species and between species, we are talking about the whole of biological life: human beings, animals, plants, fungi, bacteria (single-cell organisms without a nucleus), protozoa (single-cell organisms whose cell is eukaryotic, that is to say truly nuclear) and viruses.

Among the myriad species are familiar ones such as pets, domestic animals (e.g. cows, yaks and dromedaries, depending on the part of the world); species learnt about through books, photos and documentaries; plants we like to eat, such as edible leaves like watercress (*Nasturtium officinale*); root vegetables such as carrots or manioc (*Manihot esculenta*) or pulpy fruits including berries (fruits containing seeds), such as the bilberries of the Scandinavian forests (*Vaccinium oxycoccos*) or the strawberry guavas of the Caribbean (*Psidium cattleianum*).

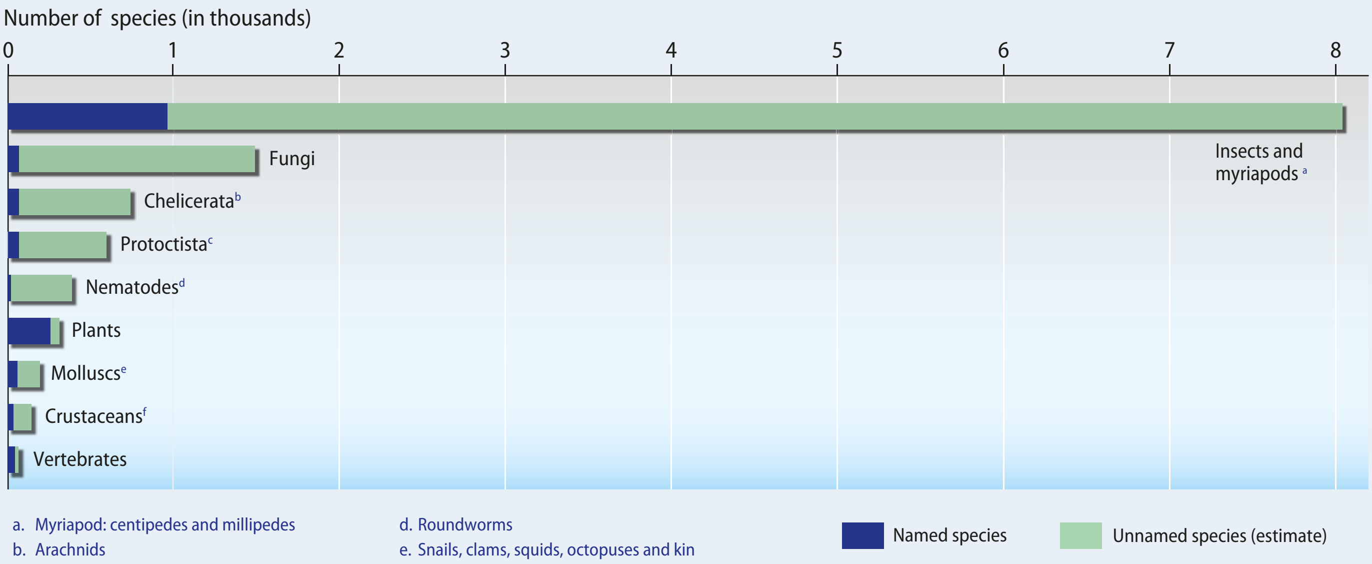
However, there are also species that we know much less about.

These include rare or endemic species found in specific geographical regions and sometimes limited to small areas, such as the alpine columbine (*Aquilegia alpina*) or the radiated tortoise of Madagascar (*Geochelone radiata*). They also include unicellular organisms that are invisible to the naked eye (bacteria, archaea and protists).

Among these are *cyanobacteria*, a subclass of bacteria found throughout the world (ubiquitous) from the polar ice to the lakes of volcanic craters that are the oldest creatures known to science. *Archaea* are another unfamiliar species, which live in hydrothermal springs on the ocean bed. These organisms do not contain chlorophyll and their biological characteristics bear witness to the environmental conditions at the time when life first appeared on Earth.

To all these unfamiliar species we might add those that have a very short lifespan such as *ephemeroptera*, insects that live only a few hours.

FIGURE 1: ESTIMATES OF THE PROPORTION OF DESCRIBED AND UNDESCRIBED SPECIES IN THE EUKARYOTIC GROUP



a. Myriapod: centipedes and millipedes
b. Arachnids
c. Algae, slime mold, amoeboids and other single-celled organisms (excluding bacteria)
d. Roundworms
e. Snails, clams, squids, octopuses and kin
f. Barnacles, copepods, crabs, lobsters, shrimps, krill and kin

Source: Millennium Ecosystem Assessment, 2005

2. Hidden biodiversity

There exist a staggering number of hidden, invisible or inaccessible species.

Their numbers push up estimates of the probable number of species still to be discovered, making it impossible to determine with certainty and accuracy the total number of species existing on the planet today.

To date, 1.8 million species have been *described*, whereas the number of living species is estimated to be anywhere between 5 million and 30 million, possibly even higher. The majority of species not yet described is made up of insects (between 4 million and 10 million or more of *undescribed* species, many of which are thought to be concentrated in the canopies of tropical forests).

Documenting a few tens of thousands of micro-organisms has given us knowledge of only a small percentage of these species (about 1%). Undescribed micro-organisms are legion. They form an enormous mass of living matter, which although invisible to us, is indispensable to ecosystems for the recycling of organic matter and for its contribution to the carbon and nitrogen cycles, among other functions.

Among these, we can mention fungi such as yeasts; protists, bacteria and eukaryotic micro-organisms (i.e. whose cell contains a nucleus) such as microscopic unicellular algae.*

* For more details see

Figure 1, Estimates of the proportion of described and undescribed species in the eukaryotic group (p. 12).

Biodiversity encompasses familiar species …

Left:
Zebra, Tanzania.

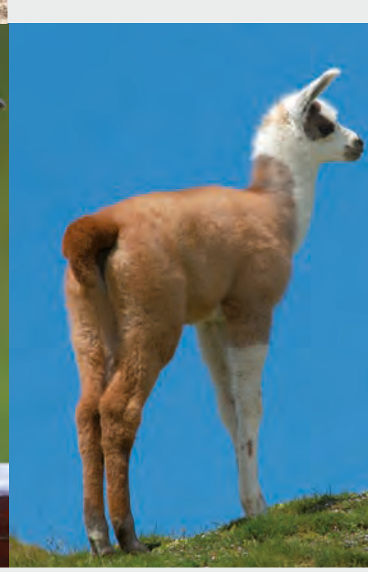
Bottom, from left to right:
Giant panda

Eurasian jay.

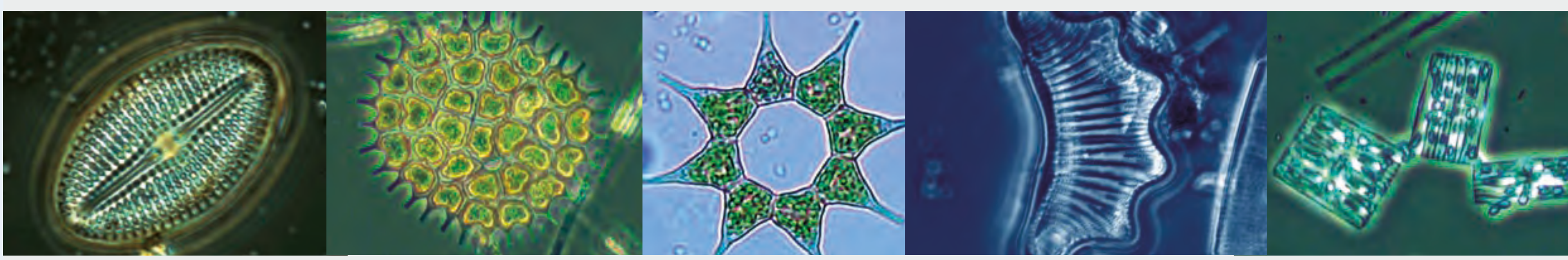
Llama, Peru.

Orchid mantis (Hymenopus coronatus).

Right:
Whiptail wallaby, Australia.



...As well as those that are less familiar.
Unicellular algae.



3. Described biodiversity and classification

Further exploration and study of biodiversity is essential. The discovery of new species can lead to the uncovering of new metabolic processes, which may be of use in the production of new medicines or improvement in the efficiency of industrial processes.

Species description and identification is part and parcel of biodiversity, and classification remains the tool that allows us to interpret objectively the data arising from our observations of biological life and the deductions we make on the basis of them.

Human beings (*Homo sapiens*) are the only species on Earth privileged to reflect on biological life and directly influence the biological world. The need to classify is virtually an inherent characteristic of human organization. By comparing living organisms humans have established a hierarchy of **taxa** or units of classification, which serve to group living organisms. These are based on shape, function or genetic characteristics, according to whether or not they share common features, from genes to species.

In particular, traditional classification has enabled us to divide the living world into six kingdoms: archaea, bacteria, protists, fungi, plants and animals.

It has also allowed us to highlight the concept of 'species' – the basic unit of the biological hierarchy.*

However, as our knowledge progresses, our classifications change.

The criterion for classification is the presence of a characteristic. However, taxa defined by the absence of a particular characteristic – as opposed to its presence – have proved less reliable than expected.

Traditional classification has, in a sense, been superseded and redefined, especially by techniques based on the genetic properties of organisms (see below).

* For more details see Vol. 2, Activity 1, A preliminary inventory of biodiversity (p. 6).

4. Species

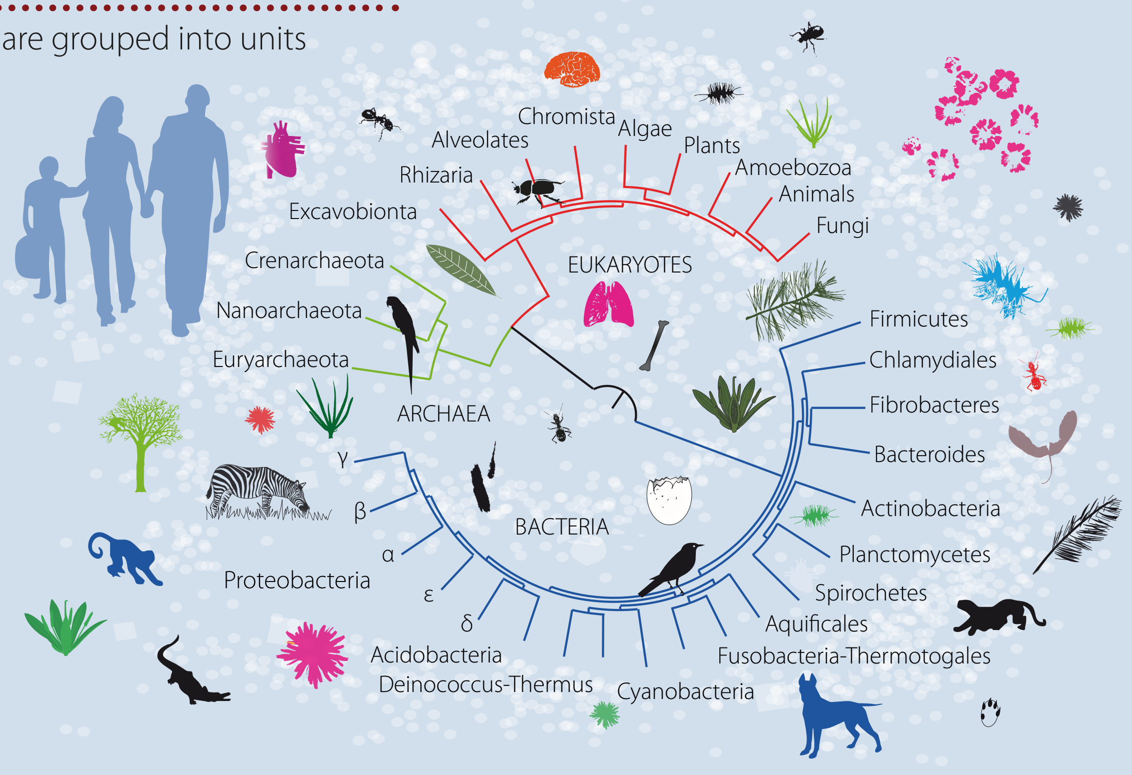
From a scientific point of view, 'species' is a practical and interesting concept, which although it suffers from certain limitations, allows us to distinguish between the different kinds of living organisms.

A species corresponds to a classification entity which groups together a population of living things that is interfertile (capable of interbreeding). This population is isolated from other populations from a reproductive point of view, and displays a specific set of physical characteristics.**

** For more details see Vol. 2, Activity 1, A preliminary inventory of biodiversity (p. 6).

FIGURE 2: TREE OF LIFE

Living things are grouped into units called 'taxa'



Reproduction between individuals of the same species must be able to occur under natural conditions (without artificial crossbreeding) and their offspring must be viable and fertile. This is not the case, for example, with two interfertile species, such as a horse and a donkey, whose offspring, a mule, would not be fertile.

In short, a horse and a donkey belong to two different species; and a mule is not a species but a hybrid.

The concept 'species' is rooted in the phenomenon of reproductive isolation which, on the one hand, prevents the exchange of genetic material between different species and, on the other, determines the existence and preservation of the characteristics peculiar to each species.

Reproductive isolation does not apply, however, to asexual organisms such as bacteria, which have their own reproduction mechanisms.

Over time and throughout the history of life sciences, the concept of 'species' has evolved.

Species are now regarded as resulting from the evolutionary process of species that preceded them. During *speciation*, new species appear because the gene pool is split into two distinct 'programmes'. This process unfolds over very long periods of time.

FIGURE 3: THE CONCEPT OF 'SPECIES'

A species groups all living organisms capable of reproducing together and whose offspring are themselves fertile. Living organisms of the same species resemble one another, more or less.

All of these dogs belong to the same species, *Canis Canis*.

Dogs. Public domain

These birds resemble one another but all belong to different species.

Royal penguin
© Serge Ouachée CC-BY-SA-3.0

Southern rockhopper penguin
© Samuel Blanc CC-BY-SA-3.0

Macaroni penguin
© N. Hanuise CC BY SA 2.5

5. Time/Evolution

Parnassius apollo.
© Jacob Hübner,
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Traditional classification has also been abandoned in favour of phylogenetic classification. This is based on the concept of evolution and the idea of a common ancestry (or phylogeny).

This enables evolutionary relationships to be detected between organisms sharing a common ancestor but which diverged a long time ago. Species divergence starts in populations within the original species. These populations evolve in a distinct way as a result of mutations, chance phenomena and owing to natural selection (certain features favouring a better adaptation are transmitted to a growing number of individuals from generation to generation).

The transformation of these populations results in the appearance of new species and the diversification of life forms.

Biodiversity is, thus, inseparable from evolution. It needs to be considered from a temporal perspective – as a dynamic process with its own temporal dimension.

We can refer to this process as the history of biodiversity.

Tube-dwelling anemone. © Luc Viatour CC BY SA 3.0

6. Extinction

The study of biodiversity consists of inventorying species, describing them and examining their lives over time. A species has a lifespan that is embedded in time and its extinction forms part of the natural course of the history of a biosphere.

The history of biodiversity is permeated with disappearances, with major crises involving the extinction of species. We know of five major crises caused by sudden, radical changes in the external environment. There is evidence of the disappearance of species on a massive scale between the end of the Permian era and the beginning of the Triassic Era, some 245 million years ago, when a massive extinction crisis occurred, wiping out 95% of species living at the time.

This means that only 5% of biological life from this period is responsible for all life forms existing today. Species extinction is therefore a natural part of evolution.

The number of individuals of a species can also increase or decrease over time, making this number useful for assessing the state of conservation of the species.

The number of species present in a given region can also be analysed at different points in time and can be a useful gauge for measuring changes in biodiversity in that region, variations in climatic conditions and soil properties over time.

Current levels of knowledge about the evolution of biodiversity now allow us to estimate rates of species extinction.

The present rate of species extinction, according to current knowledge, is 100 times faster than at any previous time in the history of the biosphere.

While 95% of biological life died out in 4 million years during the great Permian crisis, the present accelerated

FIGURE 4: GEOLOGICAL TIMESCALE

The Earth's history can be divided into major periods. The transition from one period to the next has sometimes been marked by major disturbances. Such was the case, for example, 65 million years ago (the boundary between the Triassic and Jurassic periods) when the dinosaurs died out

From the most recent (today) to the most ancient

Era	Period	Epoch	Age in Ma
Quaternary			1.7
Tertiary	Neogene	Pliocene	5.3
		Miocene	23.5
	Paleogene	Oligocene	34
		Eocene	53
		Paleocene	65
Secondary	Cretaceous	Late	96
		Early	135
	CRISIS: Boundary between the Cretaceous and the Jurassic		
	Jurassic	Late	154
		Middle	180
		Early	205
	CRISIS: Boundary between the Triassic and the Jurassic		
	Triassic	Late	230
		Middle	240
		Early	245
	CRISIS: Boundary between the Permian and the Triassic		
Primary	Permian	Late	258
		Early	295
	Carboniferous	Pennsylvanian	325
		Mississippian	360
	Devonian	CRISIS	410
	Silurian		435
	Ordovician	CRISIS	500
	Cambrian		540
Precambrian	Proterozoic		2 500
	Archean		3 800

Falklands wolf by John Gerrard Keulemans.
Public domain

rate of extinctions has taken place over 160 years, which makes it a matter of deep concern.

However, it is important to note that when going so far back in time, we cannot give a precise timeframe, given the present state of our knowledge. It is therefore possible that the majority of extinctions during the Permian period were compressed into a shorter time than 4 million years, for example, 250,000 years.

The current acceleration in extinctions is linked largely to the increase in human activities since the start of the industrial age, the transformation of ecosystems for agricultural purposes, the over-exploitation of natural resources, the fragmentation and loss of habitats, invasive foreign species, and pollution and climate change, to name only the most direct causes.

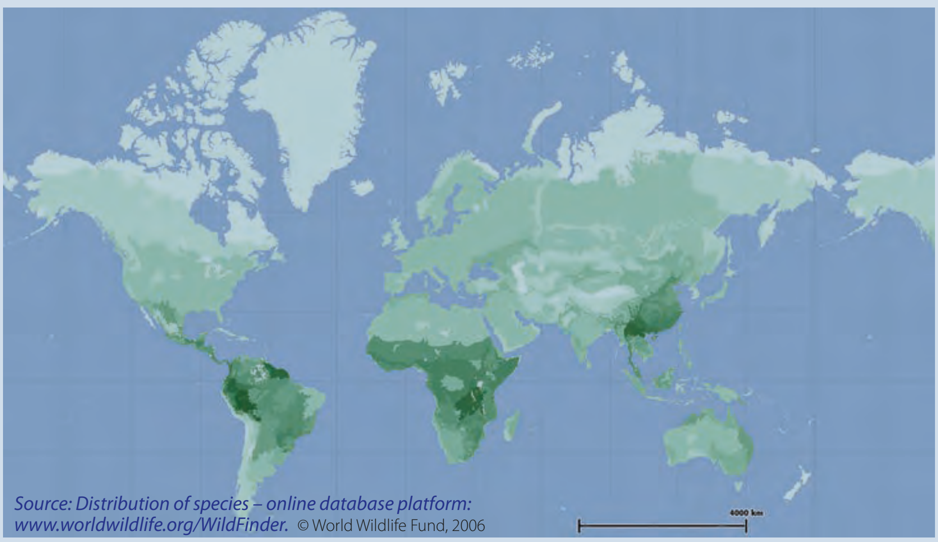
As highlighted by *GBO3*, the Living Planet Index (LPI) is a reliable, tried and tested evaluation tool that enables us to analyse the size of populations of wild species over time. Between 1970 and 2006, the overall value of the LPI in the case of wild populations of vertebrates plummeted by almost a third (31%) worldwide. Figure 5 below shows that the most drastic decrease in size occurred in tropical regions. This does not mean that the state of biodiversity deteriorated more in these regions than elsewhere. Indeed, examination of the Index over a period of several centuries shows that populations of species from temperate regions declined just as much, if not more, in relation to their size prior to the industrial age. Their present increase, which is very relative, is due to the abandonment of agriculture and the reforestation of certain land areas no longer used for growing crops or for livestock. The analysis, however, draws attention to the serious and constant erosion of the biological diversity of tropical regions.

Drawing on recent findings, close examination of trends revealed by the LPI concerning populations of species worldwide, show, for example, that 42% of amphibian species populations and 40% of bird species populations are in decline.

More precisely, in the case of birds, 44% of waterfowl populations (out of 1,200 evaluated) have been in decline since 1980, while populations of farmland birds have declined by 50% in Europe over the same period.

These figures are significant from a scientific point of view and require an effective response on the part of society in support of biodiversity.

FIGURE 5: BIODIVERSITY AROUND THE WORLD



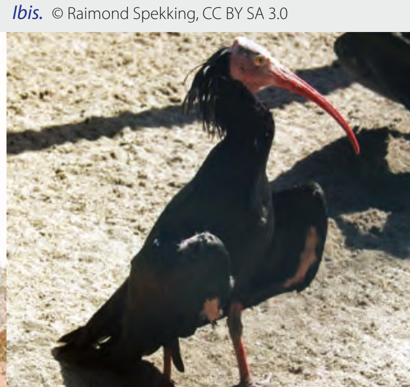
Source: Distribution of species – online database platform: www.worldwildlife.org/WildFinder. © World Wildlife Fund, 2006

Species richness
0 - 150
151 - 300
301 - 450
451 - 600
601 - 750
751 - 900
901 - 1 050
1 051 - 1 200
1 201 - 1 350
1 351 - 1 500

Number of species recorded in the ecoregion (wide geographical area defined by a unique set of features: climate, geology, soil, fauna, etc. There are approximately 1,500 ecoregions in the world).

Over the last 160 years, many plant and animal species have died out. Human activity has usually played a part in these disappearances through hunting, deforestation and the introduction of invasive species.

Male quagga by Nicolas Marechal. Public domain



Ibis. © Raimond Spekking, CC BY SA 3.0

Lonesome George, last example of a tortoise species (Chelonoidis abingdonii) *found on the Galapagos Islands. He died on 24 June 2012.* © Mark Putney, CC BY-SA 2.0

The diversity *of ecosystems*

A basic definition of biodiversity concerns 'ecological' or 'ecosystemic' diversity. This corresponds to the diversity of ecosystems found on Earth.

Roseate Spoonbill. © Olaf Oliviero Riemer CC BY SA 3.0

1. What is an ecosystem?

An ecosystem is a dynamic complex formed by a community of living organisms and the physical, chemical and geographical environment in which they live. The community of species and the environment interact as a single functional unit.

The different species that make up the community or **biocenosis**, namely plants, animals, micro-organisms and human beings, influence one another in a variety of ways. Interactions between living organisms in an ecosystem are called **biotic** factors. These include relationships involving food, predation, competition and parasitism, which link species to one another.

Species are also dependent on **abiotic** (non-biological) factors in the environment, such as climate, soil, relief, space and light.

An ecosystem is thus made up of interactions between the biotic and abiotic factors that characterize it. More specifically, it consists of a network of relationships, interactions and interdependencies woven between its constituent elements which enable life to be sustained and to develop, as well as the flows of energy between the species that inhabit the ecosystem.

An ecosystem is a dynamic system comprising a community of living organisms and the physical, chemical and geographic environment in which they live.

2. The diversity of ecosystems

When we speak of ecosystemic diversity, we are not simply talking about an inventory of species in an ecosystem; we are also talking about the diversity of physical environments, the habitats peculiar to a combination of species, the interactions that occur within natural populations and the energy flows that vary between ecosystems.

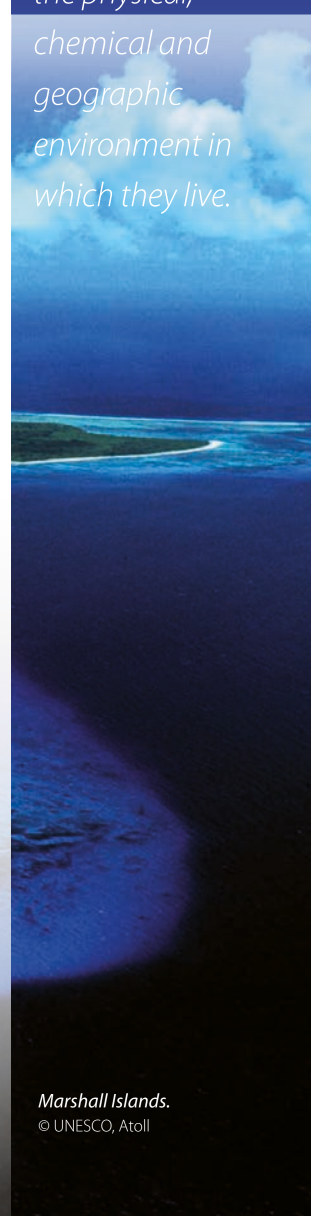
Diversity of physical environments

The multitude of physical environments found on Earth present a wide range of physicochemical characteristics that influence the species living in them.

The resources of a natural environment – the presence of reserves of surface or groundwater, the structure of the soil, its richness in mineral salts and nutrients – and the environmental conditions created by temperature and rainfall (or specific conditions like altitude and its influence on the amount of sunshine) impact on the presence and development of particular species in that specific environment.

Only species that are adapted to those resources and conditions will live or co-exist in them. Thus, the purple gentian prefers south-facing mountain ridges, halophytic plants develop best in saline soils, a bird like the nutcracker, whose basic diet consists of conifer seeds, lives on the upper edges of forests on the mountain slopes in temperate regions.

A species living in a given environment will invariably be subjected to the influence of other species in the surrounding area, which provide it with its food without which it cannot develop and breed.



Marshall Islands. © UNESCO, Atoll

Diversity of interactions within populations of species

* For more details see
Vol. 2, Activity 2,
An illustrated diagram of the fabric of biological life (p. 11).

The food chains and trophic networks of relationships between species allow matter and energy – vital to every living organism – to circulate and the dynamic complex that constitutes an ecosystem to be sustained.*

Among the various interactive biological processes between two species, aside from feeding and predation, it is important to highlight *symbiosis* – a relationship of mutual benefit for both interacting species.

For example, orchids of the species *Ophrys sphegodes* exist in a symbiotic relationship with bees of the species *Andrena nigroaenae*. The plant develops certain strategies designed to attract the insects, which by feeding on the nectar, transmit the pollen from one orchid to another, enabling the plant to reproduce and spread to new territories.

Cross-pollination through the interplay of species that come into contact is just one example of the possible interactions between one living organism and another. However, this example is a crucial one since it involves pollination, a function essential to maintaining the prerequisite conditions for life on Earth.

Regarding the function of pollination on a global scale, the diversity of living species on Earth enables relationships between plants and a wide range of biological pollinating agents – birds, bats, bees and bumblebees, butterflies and other insects – to be established, providing the basis for the functioning and maintenance of ecosystems, which are themselves very varied.

In a given population, the network of relationships between species therefore structures the ecosystem's stability by creating precise and indispensable ecological functions.

Dahlia. © J. Weber, INRA

Masked booby, Phoenix Islands (Kiribati). © UNESCO / Jane Adams

Diversity of energy flows in ecosystems

The interactions between species and the circulation of matter and energy generated by these species are part of a wider mixing process involving organic substances and the mineral substances absorbed by living organisms to enable them to grow and reproduce. These substances are subsequently expelled in the form of waste and rapidly broken down so that they can be re-used.*

This recycling of elements corresponds to the flow and transformation of chemical compounds or major elements such as carbon, oxygen, nitrogen and water. These maintain the conditions for life within the biosphere by circulating in forms that can be assimilated by organisms, and in mineral or gaseous forms as part of the planet's **biogeochemical cycles**.

Functional ecology is concerned with highlighting the diversity of flows of major elements, energy flows and flows of matter in accordance with environments.

Each environment is different and these flows depend on the interactions of species within a specific environment, or to be more precise, on the species that make up the ecosystem. What matters most is not the total number of species present, but the ecological characteristics of the most abundant species.

As soon as key species exist in an environment and fulfil certain ecological functions, the ecosystem takes shape and can be studied.

* For more details see
Vol. 2, Activity 2, An illustrated diagram of the fabric of biological life (p. 11).

Spider orchids and bees of the species *Andrena nigroaenae* are involved in a symbiotic relationship. The flower's appearance attracts the bee, which feeds on the orchid's nectar. In doing so, it becomes covered in pollen, which it then deposits on the next orchid. Orchids cannot reproduce without the bee transporting the pollen, and the bee cannot feed itself without the orchid's nectar.

Bee (Andreane nigroaenea).

Spider orchid (Ophrys sphegodes).

Identifying and interpreting an ecosystem

Even in a harsh environment where living conditions are difficult, an ecosystem can be dynamic and productive, in terms of biomass and goods that can be used by humans, if the dominant species plays a major part in maintaining and stabilizing living conditions.

For example, the semi-desert of acacias found in the arid regions of Australia is home to several dozen flowering plants (herbaceous and ephemeral) including acacias. However, the most numerous species (up to 10 times as common) are insects that live on shrubs and grasses and feed on plants or other insects. Other insects constitute the soil's fauna together with decomposers such as bacteria and fungi.

Conversely, the kangaroo, although it is a very important and typical species of this ecosystem, is not a dominant species. In contrast, the various species of ants present in the environment can accomplish in just three days a considerable amount of work to maintain the ecosystem.

Ants work the soil in different ways. They dig and excavate it by loosening and moving it to build their nests. They also perform the role of scavengers by breaking down the dead organisms they come across (90% of dead insects are decomposed in this way), thereby making a valuable contribution to the recycling of nutritious elements in the soil. As such, they simultaneously bury organic matter and aerate the soil by turning it over, bringing to the surface matter that has been broken up into small particles. They both structure and enrich the soil at the surface and at greater depths.

Avid consumers of seeds, ants often eat only the husk leaving the rest of the seed, without affecting its capacity to germinate. They also help, therefore, to disseminate and promote the germination of large numbers of seeds in the environment. In short, without ants an ecosystem would be a very different place.

Ecosystems cannot be reduced to their spatial dimensions; they vary in size. A dynamic and clearly defined ecosystem, such as a pond, with its very specific resources and conditions, will be much smaller in relation to the surrounding area than a conifer forest.

Rather, we use the term ecosystem when an environment is sufficiently independent or defined to shelter certain key species that will determine the composition of the biocenosis (i.e. all the living organisms that live together in a given space); to enable the life cycle to occur between these species; and to allow matter, energy and macro-elements necessary for maintaining local environments and their physicochemical conditions to be transferred. The ecosystem includes the whole set of relationships and interactions at work in this dynamic complex.

It is possible to compare the biodiversity of different ecosystems, since they consist of more or less complex communities of species.

Biodiversity is nevertheless a condition of their stability, especially when they are exposed to disturbances, whether the cause is external such as a fire or a prolonged period of drought, or internal as in the case of the disappearance of an important species.

An ecosystem can be weakened or even destabilized by the disappearance of a species. In such cases, the species represents more than a 'missing link', or a small hole appearing in the fabric of life; it constitutes a discontinuity in the sum of interactions between the different elements. The stitches in the fabric unravel, as it were, the hole becomes larger and the entire ecosystem suffers as a result.

The disappearance of a species of bird can mean that fewer plants of a particular type germinate, leading to a reduction in the population of these plant species and a decrease in the populations of insects that feed on them, among them valuable predators that destroy harmful organisms.

An ecosystem can also evolve into a less stable state over time. This is known as **ecological regression**. Conversely, if the species it shelters, regardless of their numbers, find the right conditions for full development and breeding, the ecosystem can evolves towards a state of theoretical stability, called a climax state.

Consequently, it is important to look at ecosystems both in terms of space and time. Ecosystems have a strong temporal dimension. Never static, they exist in constant movement and evolution.

Cranes, Zuvintas, Lithuania.

The diversity
of genes

The type of biodiversity that is the most difficult to grasp is genetic diversity or diversity within a species. This means that every individual of the same species is unique.

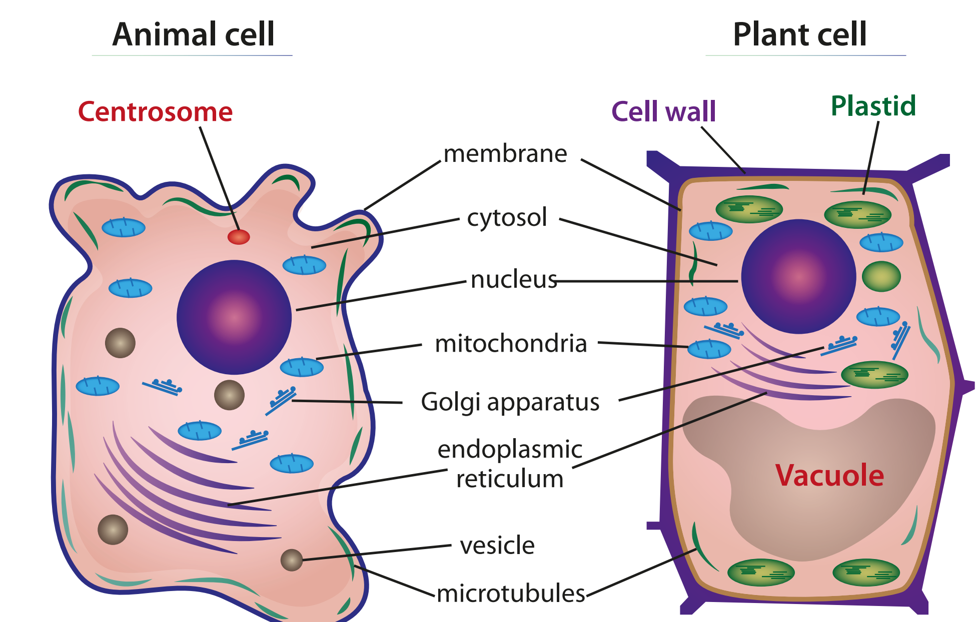
1. Cells

Cells are the basic units and building blocks of biological life. They form the structure of all living organisms. Some organisms (e.g. bacteria) consist of just a single cell, while others (e.g. animals) contain billions of cells.

Numerous chemical reactions and transformations take place within the cell including respiration, fermentation and photosynthesis.

To sum up, cells are the building blocks of which all living things are made, but they are also the engines that allow the organs of multicellular organisms to function and unicellular organisms to stay alive.

FIGURE 6: PRINCIPAL CHARACTERISTICS OF ANIMAL AND VEGETABLE CELLS

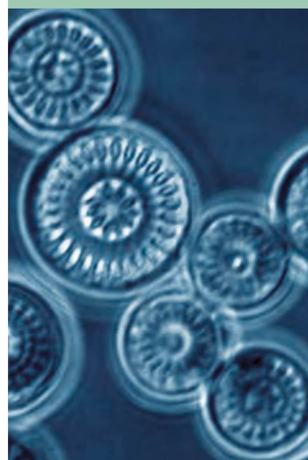


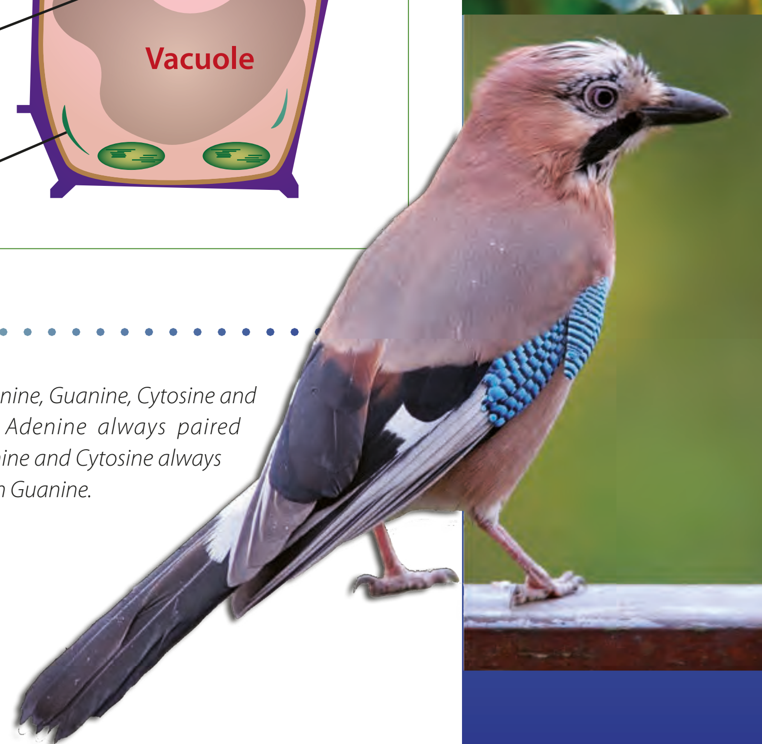
2. DNA

In the centre of a eukaryotic cell is the nucleus. Inside this protective nucleus is the DNA. In prokaryotic cells (bacteria and archaea), the DNA is not protected by a nucleus, but remains present in the cell.

DNA is a long molecule, the full name for which is 'deoxyribonucleic acid'. It can be described as follows. *P: Phosphorous, Sugar: Deoxyribonucleic, Nitrogenous bases: Adenine, Guanine, Cytosine and Thymine. Adenine always paired with Thymine and Cytosine always paired with Guanine.*

From top to bottom:
Unicellular algae. © J-C Druart, INRA
Dahlia. © J. Weber, INRA
Eurasian jay © Luc Viatour CC BY SA 3.0



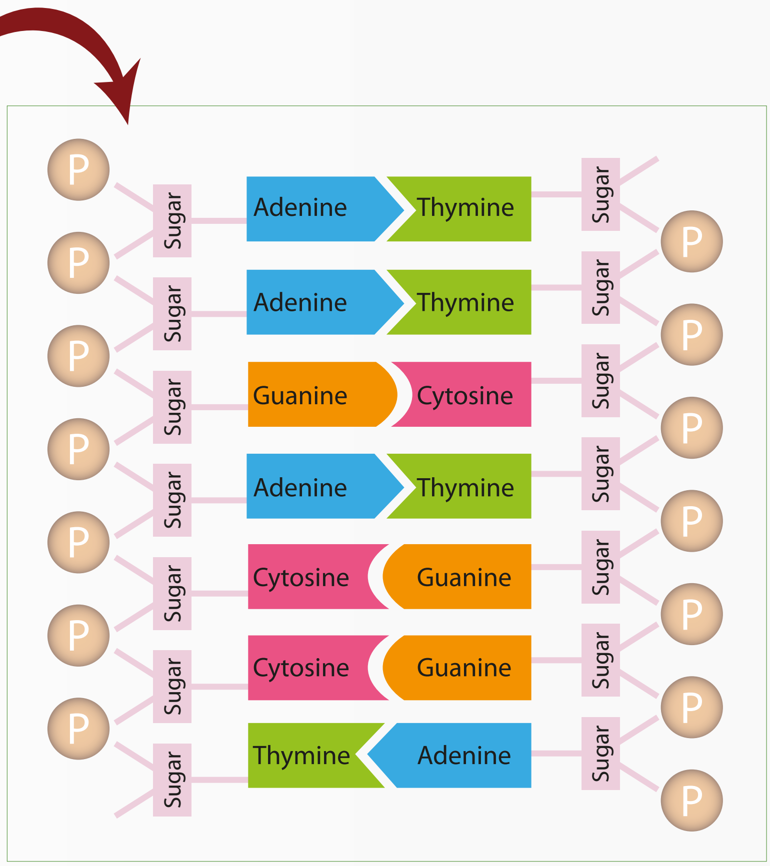


DNA is made up of two columns usually referred to as chains, which are connected by nitrogenous bases. There are four different nitrogenous bases: adenine, guanine, cytosine and thymine. The sequence of these bases in each chain (A-A-G-A-C-C-T) is, in fact, a code that enables information to be stored in the cells. A specific amino acid is associated with each segment of three nitrogenous bases (a codon). When a DNA molecule in the cell is 'read', the result is a release of amino acid. This is what allows the body to make insulin, for instance, which lowers the sugar level in our blood, or to produce adrenaline when we are afraid, which allows us to runner faster and for longer.

In addition, the information contained in DNA also includes eye colour, body size, type of coat or feathers, the number of bones in the skeleton and so on. Each sequence of nitrogenous bases that encodes a particular piece of information is called a gene, and the information is referred to as **genetic information**.

FIGURE 7: SCHEMATIC REPRESENTATION OF DNA

The molecular organization of DNA allows it to encode information



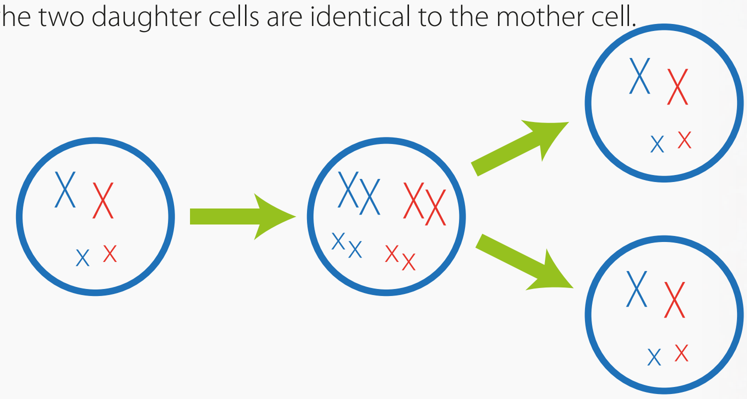
P: Phosphorous, Sugar: Deoxyribonucleic, Nitrogenous bases: Adenine, Guanine, Cytosine and Thymine

3. What has all this to do with biodiversity?

Living organisms reproduce in two ways – either by mixing the genetic material of a male and a female or by producing an identical copy (cloning). The first case is referred to as sexual reproduction with the ensuing offspring different from both their mother and their father. This is called **genetic mixing**. This mixing is the quickest way of introducing individuals into a population that will have characteristics best adapted to the local environment. These individuals will live longest and have the most descendants. Hundreds of generations later, they will be completely different from their distant ancestors, and a new species will have been produced.

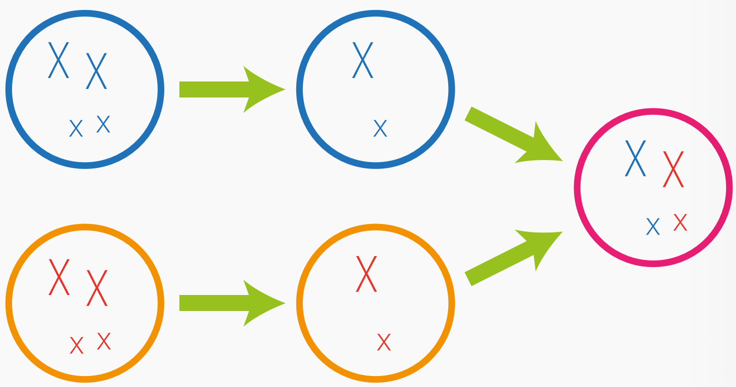
Asexual or sexual reproduction: what is the difference?

In the case of asexual reproduction (cloning), the two daughter cells are identical to the mother cell.



In the case of sexual reproduction, the child is different from the two parents: genetic mixing has taken place.

Father



Mother

Diversity
of habitats, biomes and landscapes

A habitat is the set of characteristics of an environment that allows an animal or a plant to live and reproduce normally.

1. How do species maintain their environment?

Environmental diversity affects the structure of ecosystems and their communities of species. Conversely, ecosystems also maintain the diversity and heterogeneity of these same environments.

The concept of 'habitats' helps to shed light on the ways the physical environment (including its physical and chemical conditions) and the diversity of species that inhabit it maintain one other.

First and foremost, a habitat refers to all the elements and characteristics of an environment that provide adequate conditions and resources for the population of a given species to live and reproduce.

The concept of a habitat is also defined in relation to the species or combination of species living there. For example, among the climbing birds found in European forests, the preferred habitats of many woodpeckers are hollow trees with brittle bark inhabited by wood-eating insects. However, for one particular species of woodpecker, which is not content with insects but also feeds on cones, only one particular species of conifer in a specific environment will make a suitable habitat.

An 'optimal' habitat optimizes the reproduction of the dominant species, so that this species shapes and maintains the environment.

Let us take the example of a dominant tree species (e.g. oak, beech, birch, Arolla pine, eucalyptus) in a favourable forest habitat. The species exists in equilibrium with the local climate, maintains a cohesive community of living organisms that contribute to

Both animal and plant species can influence their environment, especially if they are very dominant. For example, conifers acidify the soil. However, other plants, such as deciduous trees, do not like acid soils. Thus, the larger the coniferous forest, the more acidic the soil, which in turn promotes conifer growth.

The soil of deciduous forests allows plants to grow beneath the trees. Trifinio Fraternidad Biosphere Reserve, Guatemala and Honduras.
© UNESCO, ICF Honduras

The soil of coniferous forests is too acidic to allow undergrowth.
© M. Michel, INRA

its growth, and above all 'builds' its environment. By helping to form the forest, the species creates a microclimate that forms part of the general climate. It also affects the environment by altering the nature of the soil. For example, spruce acidifies the soil of the forest where it grows, producing a thick humus that changes the soil composition to its own advantage and enables it to proliferate.

Many species thus help to shape, build and maintain extremely heterogeneous environments, at the same time creating and diversifying living conditions for other species.

Species diversity must be considered in relation to habitat diversity. Likewise, variety of habitats must take into consideration the abundance of species.

2. From habitat to biome

The boundaries of habitats are ill defined. They may be small (sometimes too small to be sustainable and meet a species' needs) or very extensive, in the case of migratory species and species with large ranges.

How exactly can we define the habitat of a gnu or a swallow?

Ecology and biogeography specialists use the plant characteristics of habitats when trying to describe or define them. This is because plant life is very apparent when observing natural or semi-natural ecosystems (shaped to a degree by human activity). Plants shape the spatial structure of ecosystems, reflect changes in their soil and geological substrata, and determine their temporal rhythms.

Acidic heathland, alpine meadow on limestone, rhododendron heath, sclerophyllous forest (Mediterranean brush and woodland), maquis scrub and creosote desert (the creosote bush being a sub-shrub species typical of North American deserts) are all plant formations or habitats in the broad sense, supporting a patchwork of habitats.

Specialists have identified a number of ecosystem complexes across the planet that they call **biomes**, where environmental conditions and habitat structures are similar. These are characterized by their prevailing vegetation and animal species.*

Biomes reflect the ecological conditions of a biogeographical area, determined by its soil and climate, and are divided into zones with bands of homogeneous vegetation.

Some 14 terrestrial biomes have been identified, including tropical rainforest, tropical and subtropical savannah, Mediterranean scrub, temperate deciduous forest, temperate grasslands, tundra and polar deserts,

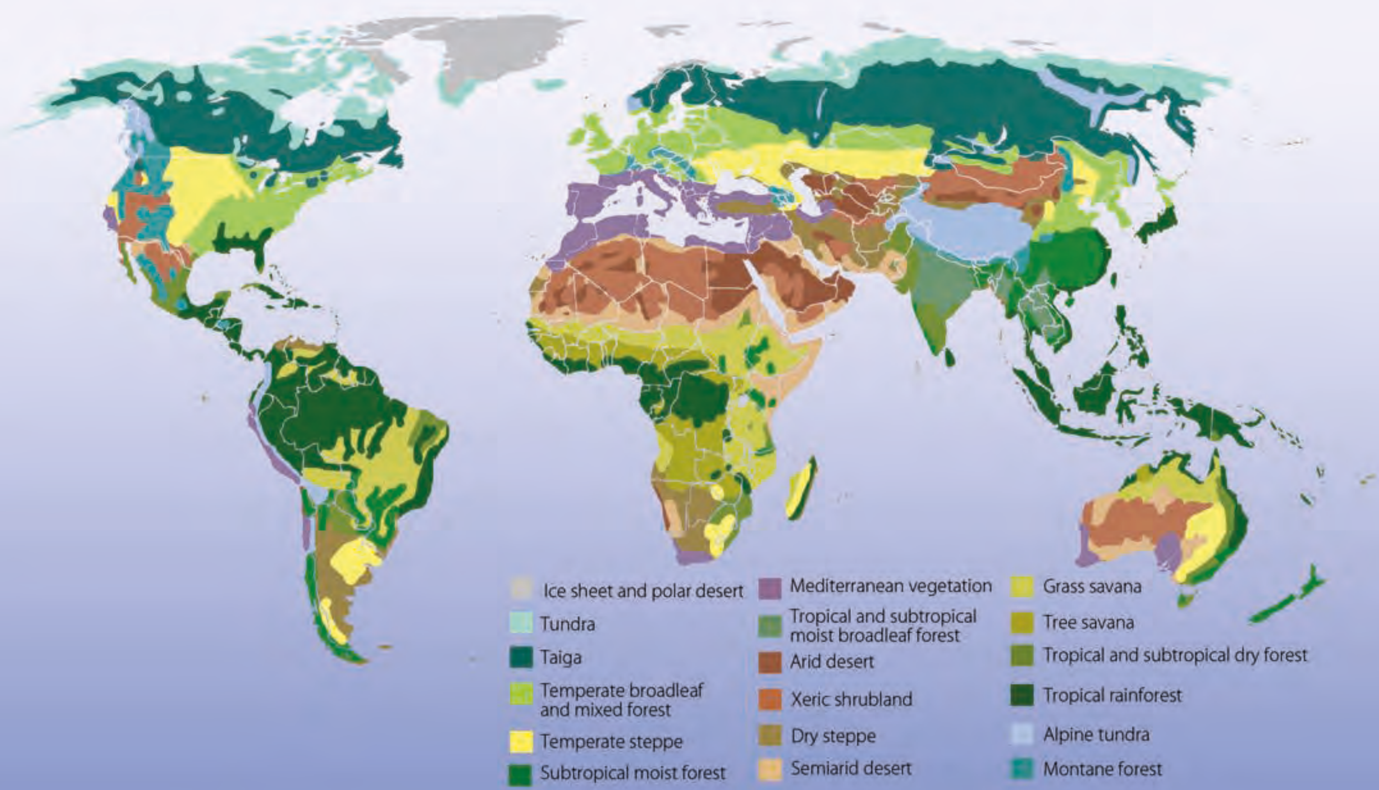
Biomes are defined as contiguous areas with similar ecological conditions in terms of climate and soil to which are added zones with strips of homogenous vegetation.

*** For more details see**

Vol. 2, Activity 5, A global map of biomes (p. 26).

FIGURE 8: THE MAIN BIOMES IN THE WORLD

Based on a map by Sten Porse



and taiga. There are also aquatic biomes that may cover a vast stretch of wetlands (freshwater biome) or an area of coral reef (marine biome).

The merit of dividing environments into biomes, grouped together into ecozones, is to be able to study and map biodiversity across the biosphere, and make comparisons between species and habitats in different continents but belonging to the same biome. This division also facilitates response strategies (biodiversity conservation, plans for resource access and use, etc.) reflecting not administrative boundaries, but the dynamics of biodiversity within ecosystems and landscape.

In the temperate grassland biome, for example, it is important to compare insect communities in the aerial stratum, which will consist of different species according to whether they are found in the Ukrainian steppe, the Argentinean pampas or the Great Plains prairie of the United States.

The study of biomes shows that the richest, most biologically diverse biome is tropical rainforest. Similarly, considerable variations in biodiversity are observed across the globe, with one general tendency: biodiversity is highest at the equator and lowest at the poles, and seems to decrease linearly between these two points. Nevertheless, a more detailed study of marine biomes, about which we still know very little, might challenge this finding.

3. Preserving habitats to conserve species

One of the major causes of the species loss and biodiversity decline that we are currently witnessing is the destruction, deterioration and fragmentation of habitats as a result of human activity.

Over the past hundred years, many natural habitats have steadily been converted into arable farming land to meet people's food requirements.

It is thus estimated that 35% of the world's mangrove forest has disappeared and over 70% of Indonesia's virgin forest has been cut down. Habitats have also been disrupted and fragmented by the passage of roads, lines of communication and pipelines (oil and gas) and as a result of the dismemberment of old agrarian systems or the diversion of watercourses.

Biodiversity conservation has evolved from protecting species to protecting whole populations of species and ecological networks of habitats, with a greater emphasis on geography.

While habitats must be preserved in size and number if they are to be sufficiently large and varied

The Great Barrier Reef is home to hundreds of aquatic species.
Clownfish and anemone. © Glenn Edney, UNEP GRID-Arendal

and accommodate an abundance of species with varying needs, they must also be preserved in their ecological integrity.

Habitats must not be cut off from one other; there must be adequate connectivity through green corridors or spatial structures allowing functional links between habitats and ecosystems generally and different habitats of the same species. This helps migration and the natural dispersal of species. The corridors may be hedges, tree-lined banks, former railway lines, windbreaks or natural borders.

Many species need to leave their habitats and sometimes travel a long way to reach resources. There exist 'feeding areas' (often seasonal) for birds and rodents, 'migration corridors' for butterflies and toads, and sometimes 'migration routes', with the grey whale covering some 20,000 km every year between its feeding grounds and breeding areas. Biodiversity conservation therefore seeks to preserve interconnected habitats that constitute important networks, with various methods and techniques used to link habitats ecologically through green corridors.

By the same token, ecosystems are not studied in isolation. A biome is an assemblage or complex of ecosystems, whose concept is drawn from the relations and exchanges between these systems.

Ecology focuses on the structure and operation of ecosystems. To this end, it highlights the notion of ecological scale. The organization of living organisms is studied on the basis of taxonomic units (thereby improving their classification), from the position of an individual or species in its environment to populations of species, followed by the community or biocenosis.

Ecology highlights the geographical distribution of these units over areas of varying size, such as the biotope or habitat, ecosystem, biome or the entire biosphere.

4. Conserving biodiversity in ecosystems and anthropogenic landscapes

The attempt to study biodiversity in a scientific context and conserve it involves dividing up living organisms according to their environments, whether these are vast swathes of the biosphere or specific biotopes.

Human beings are present in all these environments and form part of the living world, the ecosphere.

Although a biome is a large landscape of a uniform nature, it is made up of a mosaic of ecosystems large and small, natural and semi-natural, sometimes radically changed by human activity or clearly artificial, created by human communities, as in the case of some desert oases based on intensive farming.

With regard to practical governance and policy planning for biodiversity management worldwide, it is important to underline the key role played by the *Convention on Biological Diversity*.

It is also important to explain the role and scope of existing action networks for conserving biological diversity.

*** For more details see**
A brief historical survey (p. 11).

The Convention on Biological Diversity

At the international level, the Convention on Biological Diversity is a legally binding treaty adopted in 1992, with 196 parties to date, which seeks to provide a practical and immediate answer to the extinction crisis and the general decline in living species.*

The Convention arose out of concern about the current loss of biodiversity and a realization of its importance in sustaining human life on Earth.

It has three main objectives:

- Conservation of biological diversity
- Sustainable use of the components of biological diversity
- Fair and equitable sharing of the benefits arising out of the utilization of genetic resources.

On top of these broad conservation goals, at the 10th meeting of the Conference of the Parties to the Convention, held in Nagoya in October 2010, the representatives of the signatory states drew up a strategic plan for the coming decades, including a vision for biological diversity leading up to 2050 and objectives for 2020. At the same time, they developed means for implementation and a mechanism for monitoring and evaluating progress towards common goals.

In addition, the Parties to the Convention adopted what is known as the 'Nagoya Protocol'. This is an international agreement whose aim is to share fairly

Red kite.

and equitably the benefits arising out of the utilization of genetic resources, thus contributing to conservation and the sustainable use of biodiversity.

The Convention on Biological Diversity takes an **ecosystem approach** to conservation. This approach is a strategy for integrated management of land, water and living resources that promotes conservation and the sustainable use of biodiversity in an equitable way among peoples.

The approach has proved extremely relevant and has provided a suitable framework for achieving the Convention's objectives in practice.

It is based on the application of appropriate conservation methods to various levels of biological organization (genetic, species-based and ecosystem-based) and, if necessary, the restoration of natural processes, functions and basic interactions between organisms and their environment. It provides comprehensive management of ecosystems, emphasizing the continuous links between all components, including humans in terms of *cultural diversity*.*

* **For more details see** Cultural diversity (p. 47).

It highlights functional ecology, which analyses energy flows and material flows in terms of environmental factors. Key questions include 'Which organisms and processes generate these flows and how do they react to human-induced variations in the environment?'

The approach provides a clearer understanding of the effects of biodiversity depletion and habitat fragmentation. It also aims to restore the benefits deriving from ecosystem functions for the people concerned.

In practice, the ecosystem approach is used to describe and think through environmental problems, such as controlling invasive species, with the aim of drawing up an action plan to solve such a problem.

Accordingly, a number of preliminary questions reflecting the principles of the ecosystem approach, must be raised:

- Has management of the problem been decentralized to the lowest appropriate level?
- Have the possible effects of management activities on other nearby or adjacent ecosystems been considered and analysed?

Agua y Paz Biosphere Reserve, Costa Rica. © Alberto Hernandez-Salinas

- What steps can be taken to conserve ecosystem structure and functioning as a matter of priority and maintain the services that it provides?

Conservation of biodiversity is also crucial for the designation of biosphere reserves under UNESCO's Man and the Biosphere (MAB) Programme.

UNESCO MAB Programme: biosphere reserve network

The general perspective, objectives and activities associated with the Convention's ecosystem approach have many points in common with the 'biosphere reserve' concept promoted by UNESCO as part of its Man and the Biosphere (MAB) Programme.

Biosphere reserves make up an extensive international network of protected areas, covering 669 sites in 120 countries so far, where local communities, official authorities at different levels (local, regional and national), businesses, and scientific and educational institutions seek to pool their efforts to develop integrated conservation management. The latter combines research, education and conservation of biological, ecological and genetic diversity for the purpose of developing local resources.

Concerning the selection and management of sites, the intention behind the biosphere reserve conservation project was initially to consolidate large sites containing natural ecosystems. These ecosystems are now under threat and are confined to ever-smaller areas. Some of them are 'representative', supporting species and habitats typical of the biodiversity characterizing a region, and are a focus for conservation work.

The network also identifies biodiversity hotspots – areas where high concentrations of endemic species are facing exceptional habitat loss.

The management of biosphere reserves in hotspots is also a key focus of conservation, with priority measures determined as appropriate.

The statutory framework for the biosphere reserve concept was laid down in the Seville Strategy (1995), along with some permanent goals, such as extending a conservation area to cover multiple conservation

Fontainebleau Biosphere Reserve, France. © Alberto Hernandez-Salinas

units across a region (bioregional) and ensuring that operative links are maintained between them.

These links are not only ecological, passing through green corridors and restored land cover, but also logistical, implying social and economic development.

The Lima Action Plan for UNESCO's Man and the Biosphere (MAB) Programme and its World Network of Biosphere Reserves (2016-2025) emphasized the need to apply scientific expertise to biodiversity management and conservation within the network. It recommended making use of the reserves for applied research focusing on problems generated by human activity. Sites were thus to be used for surveys of flora and fauna; collecting and analysing ecological, socioeconomic, meteorological and hydrological data; and studying the effects of pollution. They were also to provide an opportunity for research into in situ and ex situ conservation of genetic resources. The recently adopted Lima Action Plan confirmed the role of biosphere reserves as sites for applied research to test solutions to human-induced problems affecting biodiversity and people.

Since biosphere reserves cover terrestrial and/or marine ecosystems, they can traverse national borders. The first transboundary reserves were set up in 1992 with the aim of protecting and managing cross-border ecosystems through cooperation between the relevant states. Among the examples, we can mention the 'W' region biosphere reserve in West Africa, which covers over 1 million hectares of forest and wetlands in Benin, Burkina Faso and Niger.

The European Union and the Natura 2000 network

The **European Union** for its part has provided EU member states with a common framework for conserving species and natural environments through the *Birds Directive* (1979) and the *Habitats Directive* (1992).

These two directives were brought together through the creation of a European ecological network, **the Natura 2000 network**, with the dual goal of preserving biological diversity and enhancing Europe's natural heritage.

The network is based around special areas of conservation (SACs) introduced by the Habitats Directive, now known as 'Natura 2000 sites'. Their purpose is to conserve ecological areas noted for the rarity and vulnerability of the species living there and of their natural habitats.

There are now 25,000 such sites extending across Europe. As such, Natura 2000 is actively involved in preserving natural and semi-natural habitats of interest to the community throughout the European Union.

The red panda is found only in the forests of the Himalayas. This species is currently under threat due to the destruction of its habitat.

Red panda, Nepal © Peter Prokosch, UNEP GRID-Arendal

These habitats are of interest to local communities for both their key ecological role and their rarity. They are typical of particular biogeographical regions and highlight a range of outstanding areas, from the upland meadows of Casto Verde in Portugal to the flood plains of Lower Austria.

In fact, the Natura 2000 network plays a key role in promoting the sustainable development of these remarkable rural areas.

The network is designed to counter the erosion of biodiversity, for example, by preserving habitats essential to the existence and reproduction of endemic wild species. Otherwise these species could simply disappear from the area as a result of environmental pressures, as happened with the Cry violet in France. In addition, the network specifically seeks to develop human activities and practices conducive to the equilibrium of these habitats, while ensuring growth and the sustainability of local socio-economic balance.

Stakeholders in the sites, whether farmers, residents, mere users, elected representatives or experts, work together to manage their areas and promote the emergence of income-generating activities associated with ecotourism, the creation of local products, and the growth of sports, clubs, crafts and educational activities.

Landscape ecology

Landscape ecology can also play a part in biodiversity management and conservation.

In its contemporary sense, landscape denotes the product of interaction between social practices and biophysical processes.*

This implies a variety of timescales: human historical time, political time and people's daily rhythms. There are also the varying timescales of biophysical processes: the Earth's time, geological time, species' lifespans and the lifespans of individuals within species.

The interconnections between natural timescales (lifespans, biochemical cycles) and social timescales within already varied landforms and geological formations enable us to better understand the huge diversity of landscapes.

Variations in the way living environments are shaped from one society to another, in conjunction with the pace of change in natural environments, have increased landscape diversity.

The abundance of rural landscapes was a significant factor in promoting biodiversity, highlighting the co-existence of a wide variety of landscapes, until modern farming methods led to their homogenization.

Nowadays, many farming landscapes are synonymous with pesticide and herbicide use, groundwater pollution problems and a decline in numerous species.

* **For more details see**
Vol. 2, Activity 6, People, landscapes and terroir (p. 30).

Desertification, Namibia.

While landscapes can be considered in terms of time, they are also anchored in space.

Landscape ecology looks at the dynamics of biodiversity with regard to landscape integration, studying interactions between ecological processes, the dynamics of human activities and landscape structures.

'Landscape structures' refer to the systems formed by objects, the physical elements of a landscape and the relations between these elements. A landscape element may be a landform element such as a plateau, a vegetation element such as a hedge, or a building or infrastructure such as a village or a bridge. These elements are structured through various spatial relationships: juxtaposition, superposition and inclusion. The interrelationships can be either tangible (hedges, banks) or intangible (ditches).

The whole forms a landscape structure such as a vineyard landscape, a vineyard on an undulating landform or an urbanized small valley.

How does this landscape structure evolve in time and space?

Landscape ecology focuses on the nature, size and arrangement of landscape 'patches', which may be open environments or closed environments, within ecosystems and biomes.

It specifically concentrates on the size and connectivity of these patches, which will determine species' access to their resources.

By identifying lines of communication, underlying patterns and visible connections between environmental elements, on the one hand, and barriers and fragmentation processes, on the other, this landscape ecology helps to protect the former and mitigate or offset the impact of ecosystem fragmentation due to human activity and infrastructure.

For example, traditional rural landscapes constitute often-noted examples of natural resource management and a satisfying quality of life.

The **European Landscape Convention**, adopted in July 2000, works to maintain and enhance the quality of landscape, whether rural or urban.

The idea of enhancing everyday landscapes, closely linked with maintaining biodiversity, is linked to UNESCO's notion of conserving heritage landscapes through the **World Heritage Convention**.

Pont du Gard, France.

Fact sheets

Biodiversity can be defined as 'the variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems'.

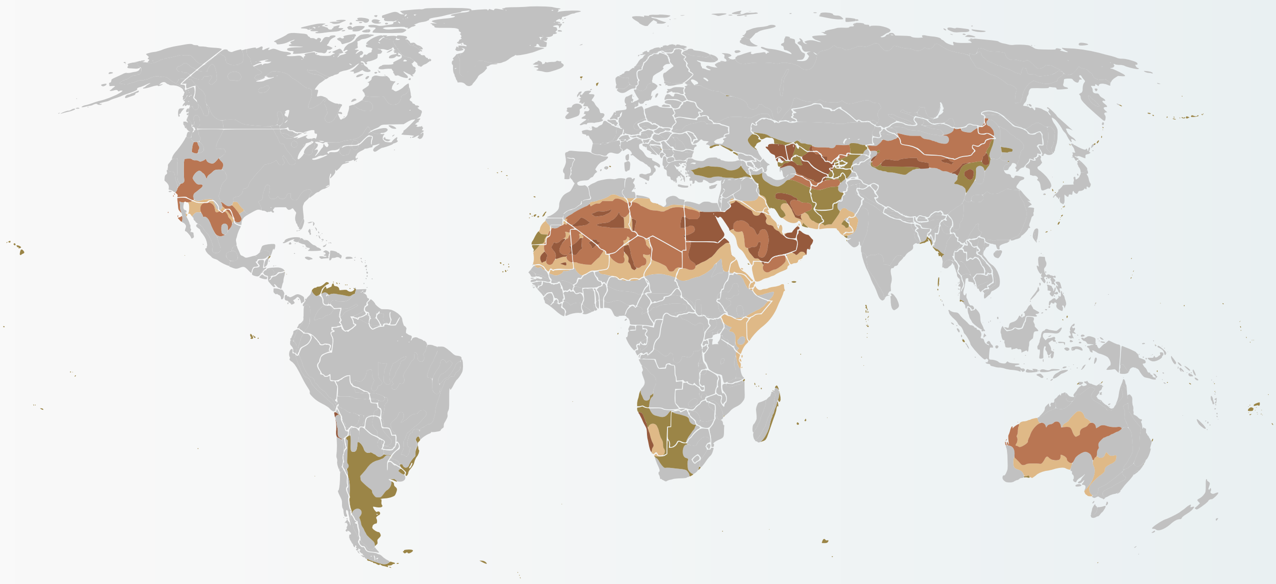
Biodiversity can be observed at different levels – at the level of the organism, the population, the habitat or the landscape.

Faced with such diversity, scientists have throughout history sought to classify individuals (into species), habitats and so on. Ecosystems, in particular, are grouped according to climate and plant life. The groups in question are called biomes. There are 14 terrestrial biomes, including grasslands.

Deserts

FIGURE 9: DISTRIBUTION OF DESERTS IN THE WORLD

Based on a map by Sten Porse



Village in the Atlas Mountains, Morocco.

Arid regions, semi-deserts and deserts cover one-fifth of the world's land surface, an area the size of Africa.

These are particularly hostile environments. The temperatures alone would be enough to make deserts hostile to life: during the day, the heat reaches record levels, only to be lost in a cloudless sky as soon as the sun sets, giving way to bitterly cold nights. And yet, in spite of the lack of water and the extreme temperatures, life has established itself in these deserts.

At dawn and at dusk the desert springs to life. Mice, ground squirrels, jerboas, foxes and reptiles emerge from their hiding places to look for food. Most of these animals spend their time in deep burrows, where the temperature is more constant and they can shelter from the heat and the cold.

As soon as rain falls, the plants flower. Seeds that have lain in the burnt soil germinate and, in turn, yield other seeds, all within a few weeks. The explosion of small plants encourages the activity of numerous animals, which take advantage of the temporary pools to satisfy their need for water.

Where water is present in oases, life is abundant and human populations settle. Dromedaries, in Arabia and North Africa, and camels, in Asia, tolerant of the heat and lack of water, allow populations to move between water sources.

Mountain oasis in the Tunisian Sahara, Chebika.
© C. Madzak, INRA

Below, from top to bottom:

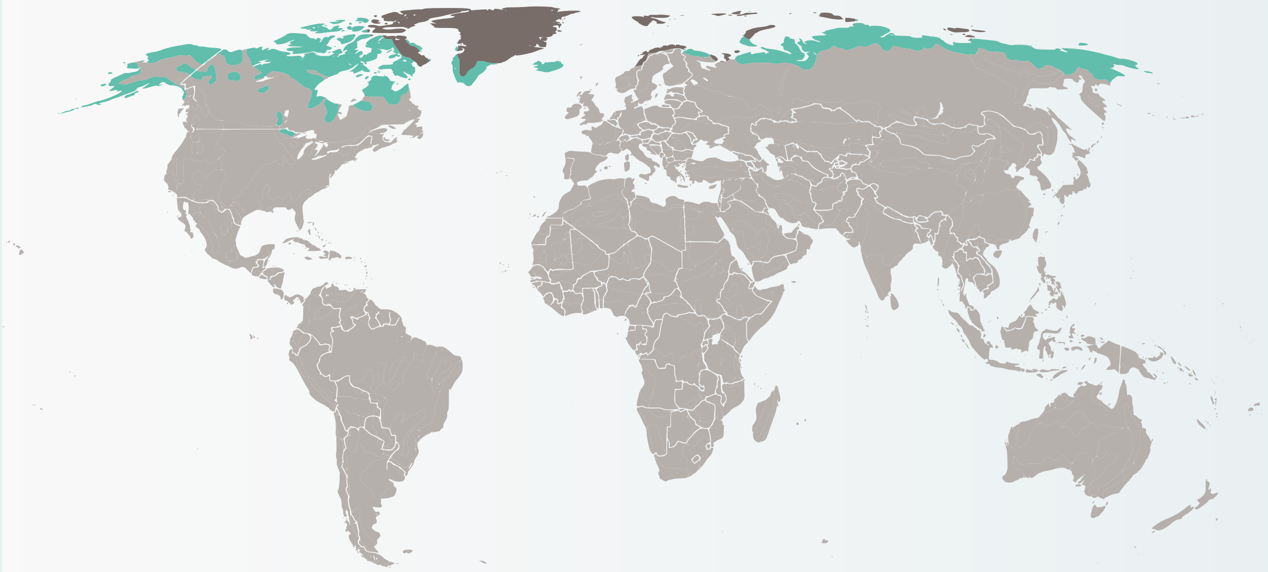
Fennec. © Dierk Schaefer CC BY 2.0
Oryx and guinea. © Hans Hillewaert, CC BY SA 3.0
Dromedaries in the Tunisian Sahara. © C. Madzak, INRA

Fact sheets

Polar regions

FIGURE 10: DISTRIBUTION OF POLAR REGIONS IN THE WORLD

Based on a map by Sten Porse.



Vinciguerra Glacier.

Life on Earth depends primarily on light and heat from the sun. Consequently, the poles, where the periods of light and darkness can each last six months, are exceptional habitats. The living organisms that inhabit these regions must adapt to the intense cold and changes in light.

There are two polar regions: the Arctic in the North is a vast expanse of landlocked water; the Antarctic in the South is a continent covered by ice and surrounded by ocean. Adapted to the cold, the plant and animal life at the North Pole is very different to that at the South Pole. The examples described below are all taken from the Antarctic (South Pole) and the surrounding coastland.

The Antarctic is home to various species of seal, including the Weddell seal, the Ross seal, the crabeater seal and the leopard seal. They live, feed and reproduce in similar environments: the sea, ice floes, land ice and the shores of the Antarctic continent.

Penguins have inhabited the southern oceans for more than 50 million years. They only leave the ocean to nest and to shed their coats. They can be seen from the Antarctic continent to as far north as the Galapagos Islands, near the equator. The ocean is the true habitat of penguins. In order to nest, they choose remote coastlines, washed by waters in which food is plentiful. All have dark upper bodies and a white front, but their size and head markings vary from species to species.

In the Antarctic, the seas are much richer in food than the land areas. As a result, of the 43 bird species that nest there, 40 are sea birds.

On the coasts that border the Antarctic continent, in Patagonia and Tierra del Fuego, for instance, summer conditions are more hospitable. They allow flowering plants to become established, and both animal and plant life is accordingly richer.

Calceolaria uniflora, Patagonia. © Serge Ouachée, CC BY SA 3.0

Magellanic woodpecker, Tierra del Fuego. © Serge Ouachée, CC BY SA 3.0

Gentoo Penguin, Antarctica. © Serge Ouachée, CC BY SA 3.0

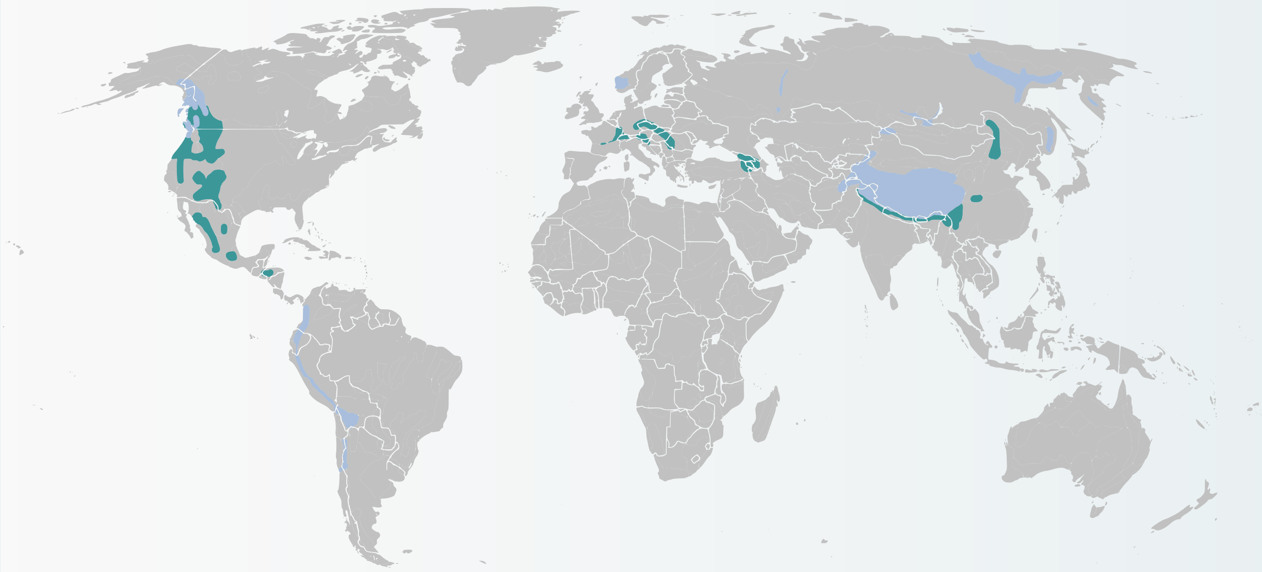
A strong swimmer, the leopard seal hunts penguins in shallow waters. It sometimes preys on young elephant seals as well.

Leopard seal. © Serge Ouachée, CC BY SA 3.0

Mountain regions

FIGURE 11: DISTRIBUTION OF MOUNTAINOUS REGIONS IN THE WORLD

Based on a map by Sten Porse.



Mountains account for 5% of the Earth's land area, or nearly 18 million km². The animals and plants that live in them are adapted not only to the relief, but also to the rarefied atmosphere, the lack of rain and the cold.

In temperate regions, at elevations above 2,500 metres, the trees become more sparse, giving way to shrubs, then to grassland, lichen and mosses, and finally to bare rock. Above 3,000 metres exists a world of permanent snow, cold and wind. The climate in these areas (known as the snow line) is similar to that of the polar regions, but without the resources offered by the sea.

The same division of plant life into zones is found everywhere on the planet, but the boundaries between them are determined by altitude. In Scandinavia, the forest ends at an altitude of less than 600 metres, whereas at the equator conifers can still grow at 3,900 metres.

To summarize, mountains pose a real challenge to biological life. And yet, in spite of the fierce winds, the thin air and the barren soil, numerous species manage to survive.

The European marmot lives at an altitude of between 800 and 3,000 metres.

Marmot.

Numerous goat species have colonized the mountain regions including ibexes, chamois, mouflons and wild goats among others.

The ibex, an animal that is highly skilled in negotiating the steep rocky slopes, has a wide hoof that bulges at the heel, with a soft area called the sole.

Chamois are the smallest members of the goat family and have a lifespan close to 25 years.

The Markhor is a species of goat threatened with extinction that lives in the West Himalaya at altitudes of 800 to 4,000 metres.

The snow leopard, a high-altitude predator, lives in the remote valleys of the mountains of Central Asia, in Siberia and Altai, at altitudes of up to 5,500 metres or more. Local people call it the 'phantom of the mountains'.

The mountain hare frequents mountain environments all year round. Its coat, white in winter and grey in summer, allows it to merge with the background and escape its predators.

Mouflon. © Dave Pape, CC BY 3.0

Hare . © U.S. Fish and Wildlife Service, Public domain

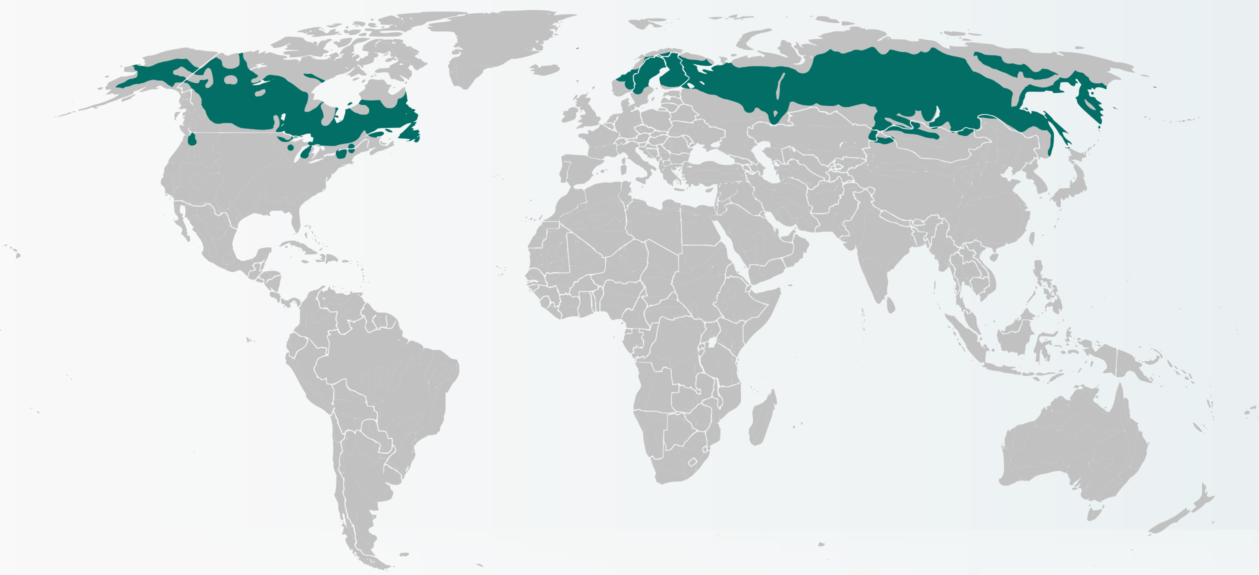
Chamois. © Friedrich Böhringer CC BY SA 3.0

Snow leopard. Dave Pape, Public domain

Northern conifer forests: the Taiga

FIGURE 12: DISTRIBUTION OF NORTHERN CONIFER FORESTS IN THE WORLD

Based on a map by Sten Porse.



Siberian tiger.
Dave Pape, Public domain

The northern conifer forests stretch in a long green ribbon from Norway to the Kamtchatka Peninsula, and from Alaska to Labrador, with only the Pacific and Atlantic Oceans in between. The dominant trees (firs, spruces and pines) often form dense and dark populations. The trees that grow in these forests are the same everywhere in the world, with the same animals inhabiting the forest. Elk, reindeer, weasels and brown bears are at home on territories stretching from Siberia to Scandinavia and from Scandinavia to Canada.

The vastness of the Taiga and the harshness of the conditions there have allowed the environment to remain wild and virtually undisturbed until recent times.

Beaver. © Luc Viatour CC BY SA 3.0

Below, from top to bottom:

Squirrel. © Gilles Gonthier, CC BY 3.0

Moose. © Hagerty Ryan, U.S. Fish and Wildlife Service

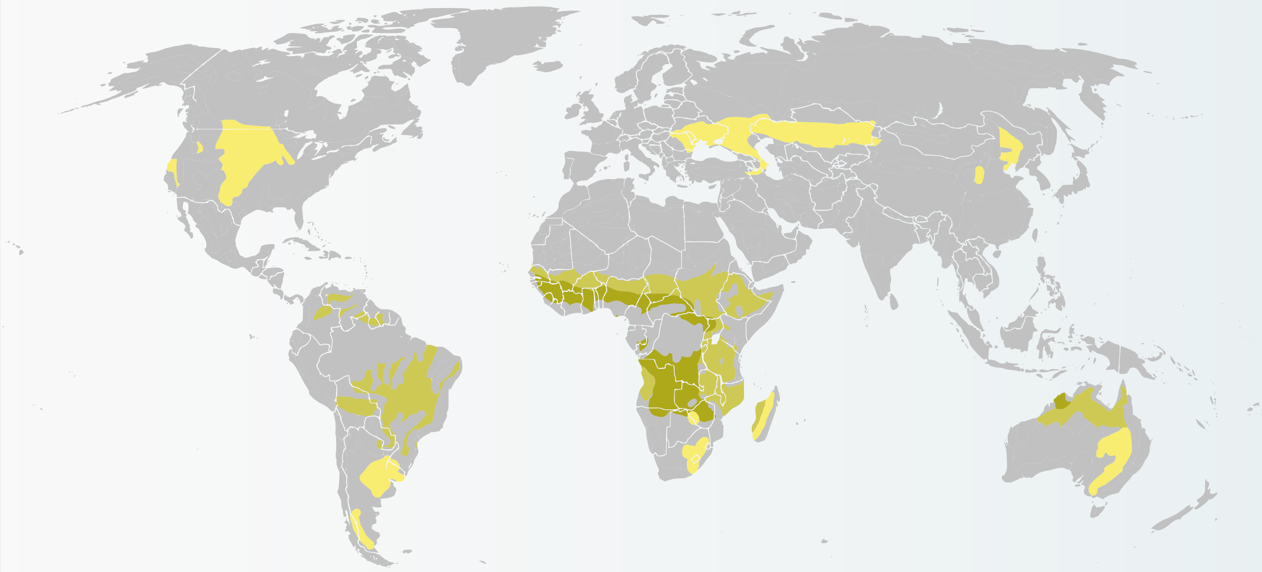
Kodiak bear. © Aconcagua CC BY-SA 3.0

Male grouse. © Mdf, Wikimedia, CC BY SA 3.0

Grasslands

FIGURE 13: DISTRIBUTION OF GRASSLANDS IN THE WORLD

Based on a map by Sten Porse.



Serval.

Grasslands separate forests from deserts. They form transitional areas where dry and wet climates come together, and where drought is always a lurking menace. There are two types of grasslands: temperate or tropical.

Temperate grasslands are found in the interiors of continents, where the summers are hot and the winters are cold, and where a carpet of short grass covers the soil. Temperate grasslands cover the steppes of Eurasia, the South American pampas and the Australian prairies.

Tropical grasslands are located in regions where temperatures are high all year round and rainfall is confined to summer. The plant life consists of tall grasses, reaching up to 3 metres in height, and large-crowned trees growing far apart. They include the savannahs, which cover a third of Africa, and are also present in Australia and the South American campos.

The grasslands are home to the largest of the herbivores and the swiftest of the carnivores, where the best weapon of defence is either speed or size.

A key strategy consists of hunting or travelling in groups. Thus, gnus migrate in herds consisting of thousands of individuals and hyenas hunt in packs when night falls.

In Africa, many animal species exploit the grasslands. Most are highly specialized and do not compete with their neighbours.

Herd of zebras. © Hans Hillewaert, CC BY SA 3.0.

African elephant. © Rob Hooft, CC BY SA 3.0

Hyena. Dave Pape, Public domain

Ground Squirrels. © Hans Hillewaert, CC BY SA 3.0

Cultural diversity and biodiversity are intimately linked and the role of traditional and indigenous knowledge in conservation actions and policies, and the management and sustainable use of biodiversity, needs to be highlighted and encouraged. The same is true for awareness raising and education on biodiversity.

Chief Raoni, one of the main opponents of deforestation of the Amazon rainforest. © Jose Cruz ABr, CC BY 3.0

Hmong girls walking back from Bac Ha. © Philip Turner, CC BY NC SA 2.0

Cultural *diversity*

We cannot conserve the natural environment unless we appreciate the human cultures that continue to shape it.

Every culture possesses a system of thought, belief and representations, as well as a set of knowledge and practices.

Human action with respect to the environment, including management itself, is a social act and an expression of culture.

Cultural diversity and biological diversity are inextricably linked, and the role of traditional and indigenous knowledge in policy and action relating to the conservation, management and sustainable use of biodiversity must be highlighted and promoted, together with biodiversity education and awareness.

Indigenous peoples have long been able to sustain ways of life that put very little pressure on local natural resources. It is fair to say that, through their lifestyles, these peoples have helped to maintain the ecological integrity of their areas.

Nowadays, things have changed as the balance between people's needs and the regenerative capacity of natural resources has been destroyed.

A number of factors have converged to bring about this change. These include the conversion and degradation of natural habitats (the heaviest pressure on biological diversity), the various effects of climate change and a variety of other factors. The combination and convergence of these factors has resulted in significant biodiversity loss, and is explored further in Part 3.

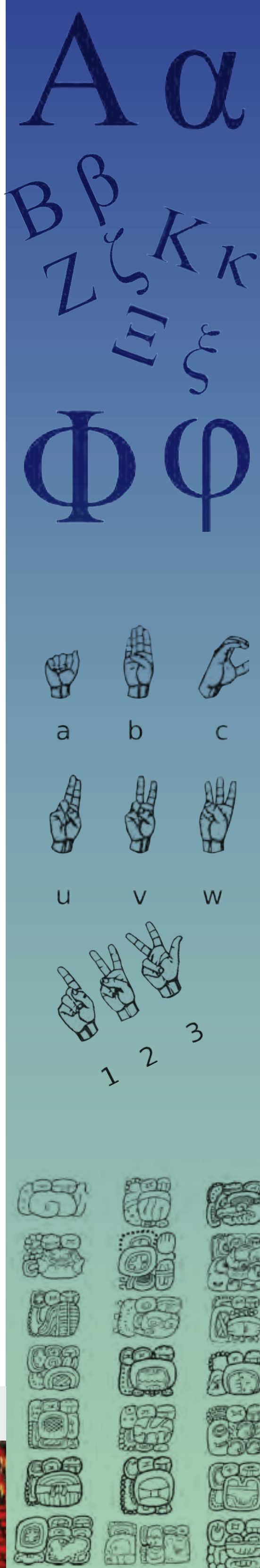
Looking ahead, it is essential to make the most of traditional ecological knowledge within a stronger scientific framework, with a view to developing a people-centred conservation approach that reintroduces sustainable methods of resource use and management.

Collaboration and exchange must be encouraged or stepped up between local populations and broader communities of scientists, experts and policy-makers at all levels, from local to international, to pursue planning and development policies that include effective conservation at both the national and supranational level.

It is therefore important to consider and study in detail traditional customs that limit the effects of resource utilization, determine land use, reflect an understanding of human beings as part of a wider living community, and foster respect and consideration of nature.

We need only mention the ingenuity that people have shown in developing foods and tastes based on a few plant species from their local ecological heritage, or the cultural diversity that reflects the wealth of qualities found in species, whether in products of European regions or the extraordinary nutritional quality and concentrated tastes of tropical and African plants.

A further example of such ingenuity is the traditional use of plant resources for building and crafts, where



Different alphabets throughout the world and across time. From top to bottom:
Greek alphabet. Public domain
American Sign Language (ASL). Public domain
Maya script. Public domain

Persian textile. © Fabien Khan

people breed one plant rather than another on account of its specific qualities; for example, using one tree species for the thickness and hardness of its wood, and another for lightweight wood that is easier to work and handle.

Ways of demonstrating the combined ecological, cultural and socio-economic value of biodiversity include providing a fresh role for local knowledge in both the conservation and the development of ecosystems, and emphasizing the local aspects of socio-economic growth and its links with natural resource management through environmentally responsible firms and services.

* **For more details see**
Part 2, Biodiversity and the cultural services of ecosystems (p. 148).

Biodiversity holds extraordinary development potential. However, the possibilities inherent in optimizing the biological and genetic resources of different regions remain largely unexplored, as does the promotion of their merits.

It is not hard to imagine the benefits of genuine enhancement of rural landscapes, with full development of income-generating activities tied to exploratory, appreciative, general and specialist activities, targeted ecotourism, production and sale of local products, and sports and club activities, as well as 'creative' activities linked both to heritage and contemporary culture.

These points are considered in detail in the discussion on the links between biological diversity and cultural diversity, and the potential of biocultural diversity, at the end of Part 2.*

The term 'biocultural diversity' is used in this kit only to point out the importance of the links between biological and cultural diversity, and it is not meant to have a normative connotation.

Elephants and their mahouts. © R. Le Bastard, INRA.

Girls from Southeast Europe in traditional dress.
© Zeke, on Wikimedia Commons CC BY 3.0

Flowers handcrafted from corn leaves, Tabasco, Mexico. © Alfonso Bouchot, CC BY 3.0

Italian ingredients. © Zagat Buzz, CC BY NC SA 2.0





Part 2

The contribution of *biodiversity* to *human wellbeing* and the risks associated with its decline

Top-left:
Cotton flower. © J. Weber, INRA

Right, from top to bottom:
Sheep. © S. Normant, INRA
Buffalo in a Chinese province. © C. Madzak, INRA
Silk worms, Hoi An. © Thierry Borie, Public domain

Introduction

1. People at the heart of the biological world

As we saw in the first chapter, biological diversity refers to all existing animal species, plant species and micro-organisms, and to biological life in general.

It also includes genetic variations, characteristics peculiar to species and the assemblage of those species within ecosystems and, more widely, biomes.

Biodiversity therefore encompasses ecosystems and the ways in which they are organized at the level of the landscape.

Since the origins of humanity and the appearance of the genus *Homo* in Africa about 2.4 million years ago, humans as a species have interacted with other species within ecosystems. These interconnections make up the fabric of life of which human beings are an integral part.

About 475,000 years ago, *Homo erectus* learnt to use and carry fire, demonstrating for the first time human uniqueness.

No longer just hunters or gatherers, these individuals had the capacity to create tools and evolve from a natural to a cultural state.

At this point, they began to harness and adapt natural systems for the benefit of the human communities they founded.

In fact, the development of human societies is the story of the harnessing of the planet's natural systems for the benefit of human beings, with a view to ensuring increasingly comfortable living conditions for an increasing number of individuals.

Once human groups created settlements, they began to farm. They domesticated plants and animals, and gradually towns started to dot the landscape. Urban concentrations became possible once a way was found of feeding them. In the Late Middle Ages, the traditional rural landscape in Europe underwent radical change; towns sprang up everywhere treating the countryside as their adjoining gardens. The towns grew in size during the industrial era, forcing improvements in agricultural productivity to feed these growing urban centres.

Today, the proportion of the world's population living in towns is constantly increasing: by 2030, three-quarters of the human race will be city-dwellers. Our lifestyles are sometimes so sophisticated and so technologically advanced, especially in the developed countries, that it is easy to obtain the impression that we no longer depend on natural systems.

However, the fact is that all of us who inhabit the great metropolises on the planet, such as Paris, Shanghai, Bangkok or New York, are *in* nature and depend entirely on the entire range of benefits, common goods and products that it provides.

Indeed, these natural goods and products underpin our human communities and societal organizations, from the most indispensable, such as the air we breathe and the water we drink, to the natural resources we exploit.

Today, it is vital, more so than at any other time in the past, that we understand the true value of nature, both from an economic point of view and as a source of benefits that enrich our lives in ways that are more difficult to quantify.

About 475,000 years ago, Homo erectus domesticated fire. It created more sophisticated tools and began to develop and modify the ecosystems it occupied to its advantage.

Campfire.
© Zouavman Le Zouave CC BY SA 3.0

But why is it so essential that we learn to recognize the value of nature?

The fact of the matter is that natural systems, which we thought would last forever, are now showing signs of exhaustion. The global capital of resources and production mechanisms, embedded in biological life, is being eroded. Biodiversity, which is basic to the functioning of those systems, is becoming impoverished on an unprecedented scale and more quickly than at any time in the history of humanity. Furthermore, the direct causes of this impoverishment show no signs of abating and are even on the increase.

For thousands of years, humans have benefited from biodiversity, which has contributed in numerous ways to the development of human cultures.

Conversely, human beings have played a key part in the evolution of biological diversity, both at the genetic level and at the level of ecosystems, by 'collaborating' with nature through the creation of semi-natural ecosystems and agricultural landscapes.

In Europe, so-called 'harvest' plants – weeds that grow in fields such as poppies or cornflowers, and plants that grow on the roadside, such as wild chicory – are linked to the flourishing of local crop diversification and the emergence of a wide range of plants, animals and natural environments, which reached its peak about two centuries ago. A third of all central European flowering plants (angiosperms) are thus connected with various kinds of traditional agriculture.

In recent decades, however, human activity has shifted towards a more 'predatory' exploitation of nature. Our intensive use of resources to increase production of all kinds of food and other products is placing such a strain on the Earth's natural functions and resources that the capacity of ecosystems to meet the needs of future generations is being compromised. Areas of tropical rainforest and mountain forest are still being converted into farmland for crops and livestock on a massive scale; rivers are being diverted from their natural courses to feed reservoirs, resulting in the loss of important biotopes; wetlands are disappearing, marshland is being drained for coastline development and car parks, and mangroves – those dense, precious forests that grow in tropical areas on the mudflats exposed at low tide and which protect the coasts – are being cleared to make way for tourist facilities and intensive shrimp farming.

Transforming ecosystems in this way not only disturbs local environments, it also results in the loss and fragmentation of habitats, and the displacement and dispersal of a large number of species. These species are forced to look for temporary shelter or to live in alternative habitats, where they are able to survive for only a short time, at very low reproductive rates and with a shorter lifespan.

Consequently, if these populations continue to decline at present rates worldwide, 12% of all farmland breeding birds, 25% of mammals and 42% of amphibians will face the threat of extinction during the next hundred years. The numbers of inland freshwater

By 2030, three-quarters of humanity will live in cities. Lifestyles in developed countries will be so sophisticated and so technologically advanced that they will encourage the impression that we no longer depend on natural systems.

Johannesburg, South Africa © Evan Bench, CC BY 3.0

For millennia, human beings have made use of biodiversity in numerous ways that have contributed to the development of human cultures. For example, henna is a thorny shrub found in the tropics, from which is extracted red and yellow pigments that are used as plant or textile dyes.

Henna tattoos on a bride, Tunisia. © Rais67, CC BY SA 3.0

species have fallen by 50%, not to mention the depletion of numerous populations of saltwater fish. According to latest estimates, stocks of fished species having fallen by 90% in many parts of the world.

The phenomenon of extinction and erosion of biodiversity that we are now witnessing is the result of changes in the ways we use and exploit natural resources, together with the problems of pollution, climate change and the release of nutrients connected with them.

It is therefore urgent that we rethink our use of natural assets and appreciate the real value of nature in terms of the wellbeing of populations, and as the basis for the organization of human societies.

2. The Millennium Ecosystem Assessment and the concept of 'ecosystem services'

In 2000, the United Nations Secretary-General, Kofi Annan, commissioned a report entitled the *Millennium Ecosystem Assessment* (MEA), which allows us to identify and define the value of nature and offers tools to quantify it.

The MEA is an assessment of the current situation made over a four-year period, pooling the expertise of 1,360 scientists from 95 countries, for the purpose of evaluating – on a proper scientific basis – the extent and consequences of the changes ecosystems have undergone, in terms of their fundamental contribution to the existence and wellbeing of humanity.

A central concept that emerges during the assessment is that of 'ecosystem services'.

Ever since we began building cultures and societies, we have relied on the presence and availability of natural resources, which we have enjoyed to the full. It would seem appropriate to describe at this point this common good that we obtain from nature.

FIGURE 14: DECREASING SPECIES NUMBERS

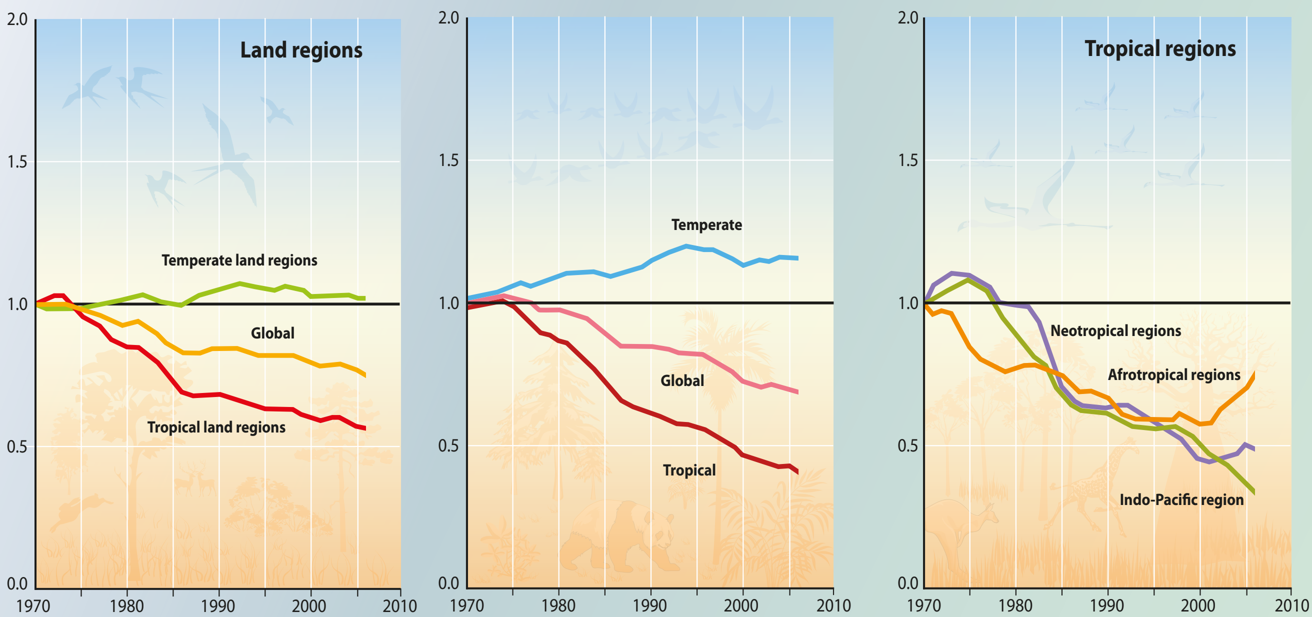
During the last few decades, humans have played a major role in the evolution of biodiversity by intensively using natural resources and radically changing ecosystems. This has had a considerable impact on the animals and plants that thrived in those ecosystems.

The Living Planet Index (LPI), which measures trends in thousands of vertebrate species populations, fell 52% between 1970 and 2010.

The drop in biodiversity was greater in the tropics (60%), while in temperate regions some populations increased slightly.

The Living Planet Index takes into account the populations of over 2,300 mammals, birds, reptiles, amphibians and fish from all over the world, which are monitored through 7,100 observation points located in different parts of the planet.

Source: Adapted from the WWF / Zoological Society of London based on the Global Biodiversity Outlook (GBO3).



Perceiving ecosystems as units that provide populations with services is a point of view that follows naturally from the kind of development – both social and human, economic and environmental – advocated by the 15th of the Sustainable Development Goals set by the United Nations Member States: 'Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss'.

In particular, it enables us to become more familiar with and to analyse in detail the natural processes that communities depend upon in order to develop their societies, often without giving these processes much thought.

The idea of 'services' provided by ecosystems allows us to accurately identify the contribution the latter make to our wellbeing.*

They secure for us material goods, products, natural resources in the wider sense, open spaces and land where we can move about and work, and favourable conditions with regard to our daily existence, the climate, the atmosphere, plant growth and soil maintenance, so that we are able to live out our lives on Earth and cater for our basic needs.

They enable us, for instance, to carry out our essential bodily functions: breathing, eating, drinking, growing and, where possible, improving what we eat, by tasting, growing and harvesting.

They also allow us to fulfil the deeper needs of our identities as human beings, including by developing in different areas, creating and building, relating to others, living in harmony with our fellow beings, ensuring harmonious living conditions for our descendants, and respecting and promoting the context that makes this possible.

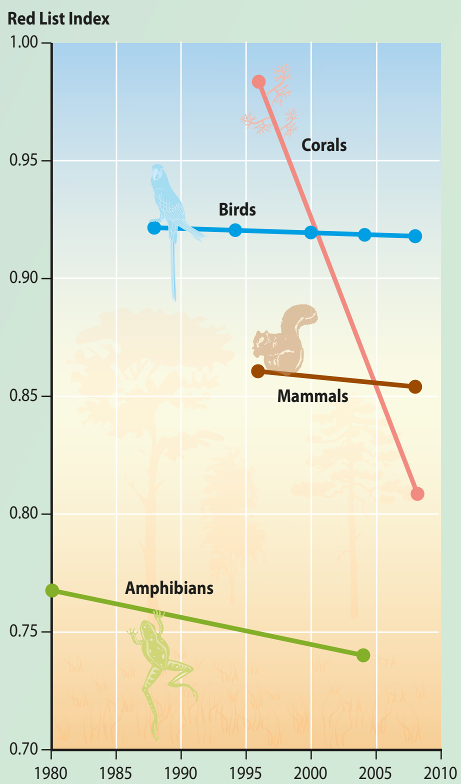
Ecosystems therefore provide numerous essential services. The Millennium Ecosystem Assessment identifies these different services and focuses first on the most precious – **provisioning services**.

These cover the tangible goods that we get from nature, such as all our food, natural fibres, molecules that are useful or have a pharmaceutical value, energy

* For more details see
Vol. 2, Activity 7, The interplay of species, services and products (p. 35).

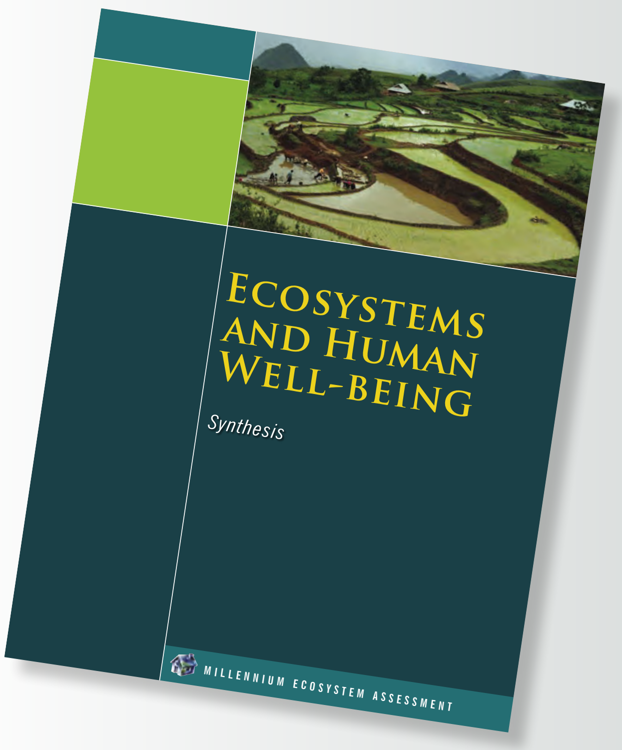
FIGURE 15: RED LIST INDEX

There are many animal and plant species currently under threat as a consequence of human activities, as indicated in the International Union for the Conservation of Nature (IUCN) Red List.



Source: Based on the Global Biodiversity Outlook 3.

A report entitled the 'Millennium Ecosystem Assessment', commissioned by the UN Secretary-General, Kofi Annan, in 2000, proposed tools and instruments to study and quantify the natural capital of ecosystems.



resources from firewood to biofuels, and products that are less directly 'commercial', such as oxygen, freshwater reserves and soil – especially topsoil.

Other services are known as **regulating services**. These are the benefits that derive from the maintenance and regulation of the natural systems linked to ecosystems. They involve the regulation of the local and global climate, the natural purification of water, the natural treatment of waste, and the regulation of diseases and harmful organisms such as pests, as well as invasive species.

The Millennium Ecosystem Assessment also defines another category of services: **cultural services**. These consist of the intangible benefits we obtain from ecosystems through the development of cognitive systems; through our capacity for awareness, reflection and analysis; and through aesthetic experiences and spiritual enrichment. These include benefits of a sensory, intellectual and spiritual nature, together with knowledge systems, ethical, social and cultural values, and benefits that are recreational in character, which belong to the world of leisure.

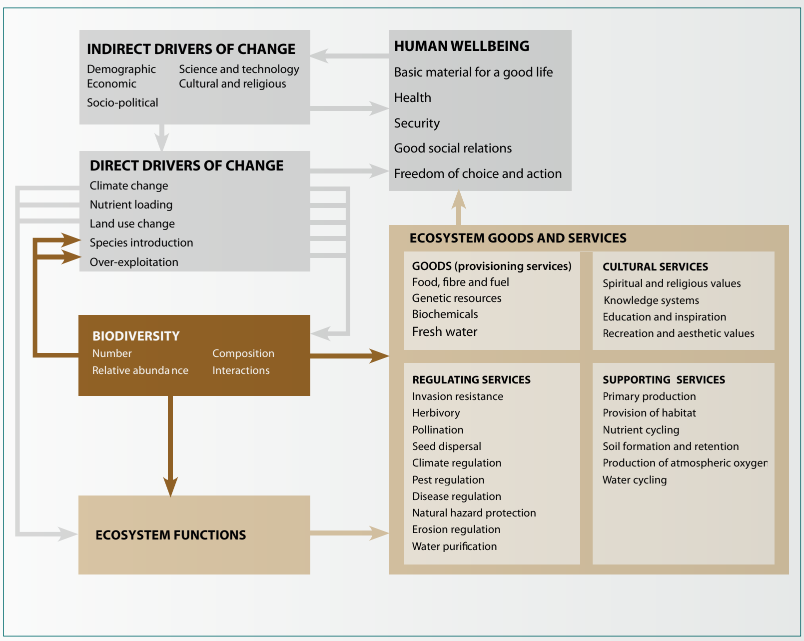
Lastly, **supporting services** refer to services necessary for life on Earth and for the production of all other services. These services are tied to the natural processes of ecosystems, including the production of biomass, the nutrient cycle, soil formation and retention through the recycling of dead organic matter, the provision of natural habitats and the carbon cycle.

If we consider each group of services in isolation, the importance of biodiversity in ensuring their proper functioning soon becomes apparent. Biological diversity underpins the benefits we obtain from ecosystems:

- The trophic basis of land ecosystems constitutes the first link in the food chain, with the release of nutrients into the soil, brought about by the combined contribution of scavengers, decomposer insects, fungi and bacteria.
- All plants produce their own plant matter, feeding a large number of organisms and providing the basis for communities of living things.
- Without the variety of pollinating agents, plants could not reproduce and harvests would not be productive.
- Without the natural availability of biodiversity, such as that deriving from freshwater ecosystems (rivers

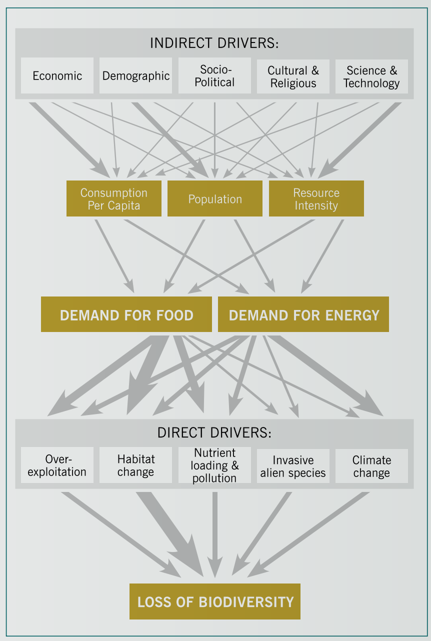
FIGURE 16: ECOSYSTEM SERVICES

The many benefits that ecosystems provide were clearly expressed in the Millennium Ecosystem Assessment.



Biological diversity, the functioning of ecosystems, services provided by ecosystems and drivers of change.

Source: Global Biodiversity Outlook 2.



Links between the demand for food and energy and the decline in biodiversity.

Source: Global Biodiversity Outlook 2.

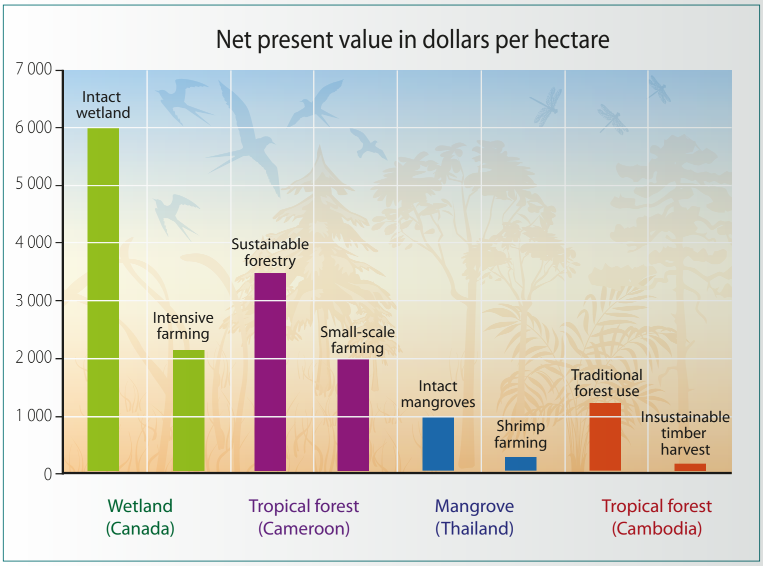
rich in fish, fertile marshland), many dependant populations, especially those located in neglected rural areas, would be deprived of an important source of food supply with a high nutritional value.

- Trees growing on slopes enable surface runoff to infiltrate into the soil. Their disappearance removes a natural defence against mudslide risks, floods and erosion.

- The disappearance of this varied landscape, produced over the centuries by the combined efforts of nature and human communities, and spread across the surface of the planet, is disturbing local and global climates and resulting in a decline in cultural identity.

To summarize, all the elements mentioned above that arise from ecosystem services form part of the fabric of life and the life systems constituted by the planet's biological diversity.

FIGURE 17: BENEFITS OF ALTERNATIVE ECOSYSTEM MANAGEMENT



Economic benefits arising from alternative economic models.

Source: Global Biodiversity Outlook 2.

3. Assessing the state of ecosystems

Evidence of their degradation and of a parallel decline in biodiversity

The Millennium Ecosystem Assessment clearly shows that almost two-thirds of the services that nature provides for humankind are in decline, with the corresponding degradation of ecosystems inevitably affecting the species that inhabit them, resulting in a clear decline in biodiversity.

Among the services studied during the Assessment, only four showed improvement as a result of human-induced changes. These were: crop production and harvest yields, livestock farming, aquaculture and, to a certain extent, carbon sequestration, although the latter occurred at the expense of the other services.

Among the degraded services were: fish catches, water supply, the capacity of ecosystems to treat soil pollution, water purification, protection against natural disasters, air quality control, climate control at both local and global levels, and erosion control, in addition to numerous cultural services.

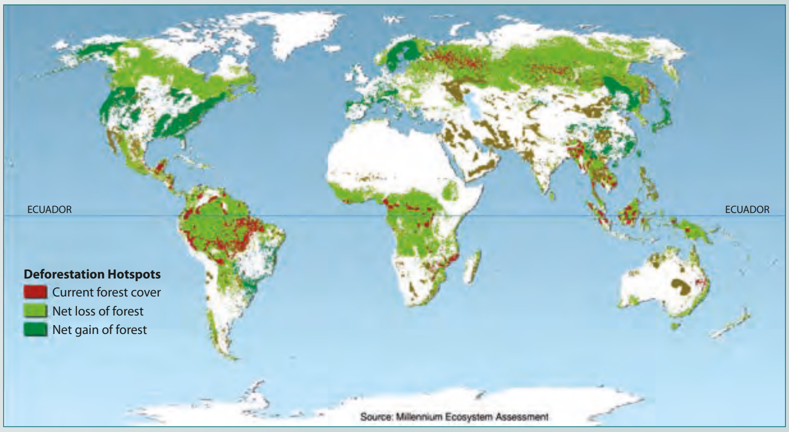
The ecosystems providing these services were modified and developed for the needs of the population before their degradation was noticed. The modification in question was often drastic, even if it occurred over a relatively long period. For example, forests or semi-natural grasslands were converted into grazing areas; small fields were consolidated into vast, seemingly endless expanses of monoculture; and mangrove forest was cleared to make way for the farming of shellfish or the over-exploitation of particular species. Such changes weaken the capacity of ecosystems to sustain populations, replenish stocks and provide for communities.

According to the Millennium Ecosystem Assessment, the modified ecosystems subject to these continuing human or natural pressures are no longer able to function efficiently or to provide the services they initially procured.

In such contexts, the modifications induced by human communities often lead to degradation. The implications of this process require further analysis to allow degradation to be better understood and slowed down.

As a result of a comprehensive review that appeared in an earlier edition of the *Global Biodiversity Outlook (GBO2)*, published by the Secretariat of the Convention on Biological Diversity, certain trends can be detected in modifications to ecosystems. Two such trends are set out below.

FIGURE 18: DEFORESTATION HOTSPOTS



Source: Global Biodiversity Outlook 2.

1st trend:

The conversion of forest ecosystems into agricultural land is happening at a worrying rate. Since 2000, an estimated 6 million hectares of primary forest has been lost annually.

In many cases, these rich and ancient ecosystems, composed of several strata, are transformed into intensive monocultures. Of all the different types of forests, tropical rainforests in mountain areas are disappearing most quickly, with significant consequences for global warming.

We do not sufficiently appreciate the extent to which forests store significant quantities of carbon, an element found in the cellulose and starch of plants. When trees are felled on a massive scale and then burnt (either as fuelwood or in slash and burn agriculture), this carbon is released into the atmosphere in the form of CO_2, adding considerably to the greenhouse effect.

In certain regions, crop irrigation surpassed the quantity of available freshwater.

2nd trend:

Despite the wide range of ecological functions performed by freshwater ecosystems, these are now under serious threat from new developments undertaken by communities.

The creation of dams and the establishment of water-harvesting systems have substantially changed freshwater ecosystems. These installations benefit irrigated agriculture and industrial activities, but disturb the natural flow of numerous rivers, the effect of which is to reduce the flow of sediment, which builds up behind dams. Unfortunately, these sediment deposits are the main source of nutrients for estuary ecosystems, which play a major ecological role as natural filters of pollution.

Wetlands, moreover, act as catchment basins for large quantities of water that pour downstream during heavy rainfall. They therefore play an active part in protecting communities against flooding.

We should also be concerned about deficiencies in the supply of freshwater to certain populations.

Freshwater reserves are not equally accessible worldwide, resulting in some populations suffering from thirst. © UN Photo/Fred Noy

In contrast, other areas are subject to flooding and repeated inundations. © H. Duval, INRA

Since 1960, the amount of water retained by dams has quadrupled and artificial reservoirs now contain more water than naturally flowing rivers.

Large rivers such as the Nile in Egypt and the Yellow River in China no longer reach the sea at certain times of the year, and local use of freshwater now exceeds renewable reserves, which means that underground reserves are being over-exploited.

In some regions where resources are limited because of water stress, this excessive use of resources is simply not sustainable and leads in the short term to a real deficiency in water supplies to populations.

Simply by analysing these two trends, it is clear that human activities have, for decades, reconfigured ecosystems to promote the intensive exploitation of resources, and increase harvest production and other intensive uses of the environment with a view to optimizing short-term profits.

Ecosystem services with no commercial potential, such as pollination or the natural regulation of pollution, receive little attention and their preservation or maintenance is not prioritized in ecosystem management. However, when an ecosystem functions ineffectively or does not function at all, it is weakened and its ability to provide provisioning services is compromised.

If we look at a typical example, the process of converting an ecosystem to monoculture, the implications are not difficult to grasp.

- The process begins with the modification of traditional agricultural practices towards production of a single crop.
- Companion plants, ruderal plants and harvest plants are eradicated to allow higher yields of the crop, to which artificial fertilizer is applied.
- Ecological corridors, such as hedgerows, copses and individual trees, and sparse forests are cleared, breaking up natural spaces. As a result, numerous species are consigned to small, semi-preserved spaces.
- Lacking real eco-landscape continuity, the environment can no longer offer some species an optimal or even viable habitat. They may be forced to migrate in search of a habitat that caters for their needs. The least ubiquitous (i.e. very specialized species found only in specific areas) are weakened by the degradation of the ecosystem, while the most ubiquitous (i.e. species found more generally) will try to survive for a time in these 'sub-optimal' habitats. As far as the vast majority of species are concerned, populations soon decline or are broken up.

Queensland, Australia.
© Qld Environmental Protection Agency, UNESCO

- In ecosystems that have become impoverished in terms of species diversity (and often polluted by a surfeit of leached fertilizer), processes such as natural cycles of soil formation and regeneration, the recycling of macroelements, and natural activities of pollination, germination and reproduction of plants and gene flow, occur less easily. Moreover, the total amount of nitrogen produced by human activities and thus made available to organisms increased nine-fold between 1890 and 1990, with the result that even the natural processes themselves have been modified.

- Furthermore, regulating services are stretched beyond their capacity to deliver as a result of decreases in the populations of local plants, depolluting plants, natural predators and pollinating agents; a fragmented litter, inhibiting the formation of humus; and the continuous release of excess nutrients.

- Overall, the ecosystem becomes less resistant and its capacity to regulate soil and water pollution, to process waste naturally and to control diseases, pests and invasive species is compromised. Once the regulating services are weakened, provisioning services are soon affected, resulting in increased risk of exposure to food insecurity for populations in many regions.

Biodiversity is therefore the keystone – both the source and the sustaining force – of ecosystem services. And the services provided by thriving ecosystems rich in biological diversity are the key to the wellbeing of human beings.

FIGURE 19: SPATIAL PLANNING

At a landscape level the blue and green belts represent the distribution of rivers and streams (blue belt) and the mass of forests (green belt).

Intensive agricultural exploitation changes the natural layout, which disrupts ecological corridors and fragments space.

Green and blue belt. © Ministry of Ecology, Sustainable Development and Energy (France)

Every ecological function and every supporting service corresponds to a network of interconnections in the fabric of life. If we allow a hole to appear in the fabric or other damage to occur, this is tantamount to damaging ecosystems themselves.

Roztochya, Ukraine. © UNESCO

4. Assessing the rapid erosion of biological diversity

We have now established a connection between the impoverishment of biological diversity and degraded ecosystems, as well as between the degradation of ecosystem services and the threats to human wellbeing.

Although we are beginning to understand the stakes, the rapid disappearance of genes, species and habitats continues unabated. While it is rare for a known species to disappear within the span of a human lifetime, it is estimated that, over the last 150 years, humans have increased the rate of extinction worldwide by a factor of more than 1,000, compared to the 'natural' rate observed in the course of history.

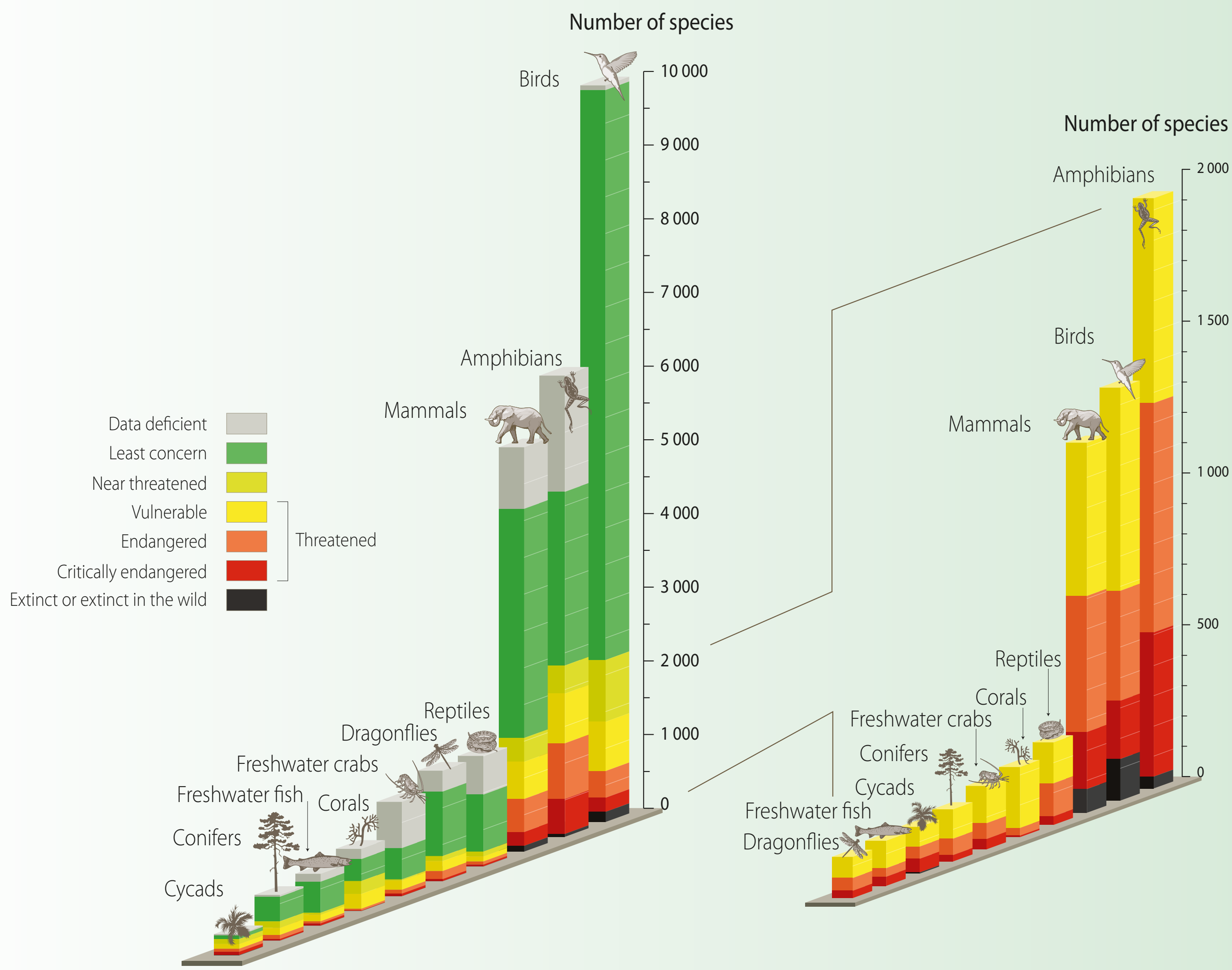
Species that have fallen victim to this powerful wave of extinction include the Southern gastric-brooding frog (*Rheobatrachus silus*) in Australia, the Caspian tiger (*Panthera tigris virgata*) in Central Asia, and a tree species of the Fabaceae family, *Sophora toromiro* on Easter Island, all of which have disappeared in the course of the last 50 years, although the last of these which died out in the wild is now being reintroduced.

On the basis of data and indicators compiled under the Convention on Biological Diversity, to which we return later, it is possible to specify some of the key aspects of biodiversity erosion.

- The loss of natural habitats directly caused by human activity is having a significant impact on the current decline of species. Continued deforestation is causing the disappearance or fragmentation of the richest and most highly

FIGURE 20: SPECIES EXTINCTION RATE ACCORDING TO THE RED LIST

Human activity is causing an increase in the rate of species extinction. The IUCN Red List currently estimates that just 40% of species fall into the category of 'least concern'.



Source: Global Biodiversity Outlook 3.

developed habitats on the planet. Breaking up forests in this way disturbs whole communities of species and deprives many forest ecosystems of the ability to regulate air quality, the flow rate of watercourses and even the climate – as well as the capacity to prevent soil erosion and reduce landslide risks. Coastal and marine ecosystems likewise bear the scars of anthropogenic pressures. On many coastlines, seaweed forests (a mixture of green, brown and red algae), sea-grass meadows and coral reefs are disappearing. Hard-coral cover, which is known to shelter 30% of all documented marine fauna and to provide an effective defence against coastal storms or tidal waves, has decreased by 10% to 50% in the Caribbean over a 20-year period. With the degradation and fragmentation of natural habitats, species are consigned to increasingly smaller spaces. As a result, they are less and less abundant and their populations are declining.

- Another factor contributing to these falling numbers is direct over-exploitation of resources by local inhabitants. Increased efficiency in the fishing industry, for instance, combined with more intensive practices, has decimated local populations of larger fish such as tuna, cod, swordfish and bass, with 80% of tonnage lost in places, according to estimates.

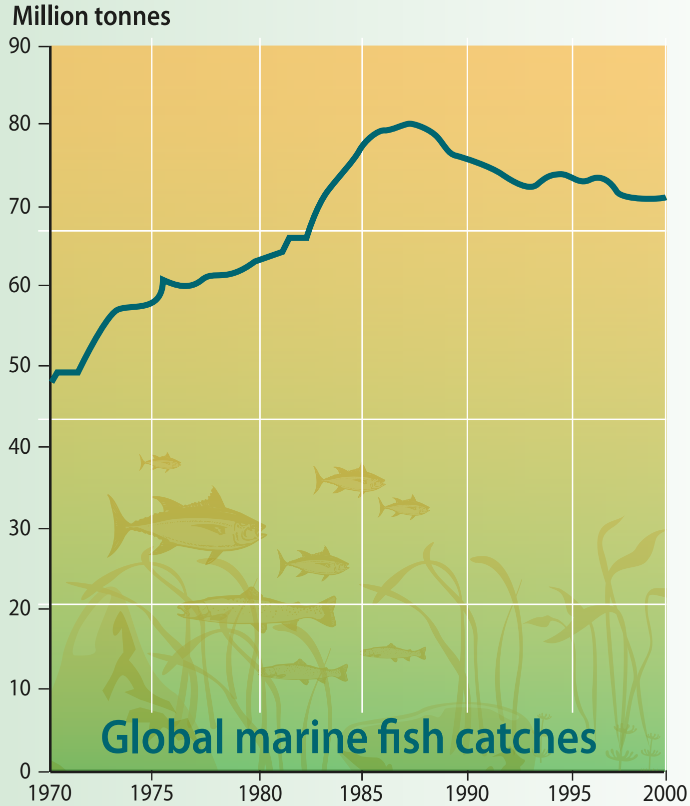
- Apart from the decline in species populations analysed by the Living Planet Index (see. p. 54), variety between and within species has decreased significantly worldwide. Human activity is creating landscapes that are becoming increasingly simple and uniform, and in which lifeforms are becoming less and less varied. The farming methods applied to them are damaging biological diversity, at both the species and gene level, and are threatening thousands of species with extinction, as we can see for ourselves by studying the majority of existing agricultural ecosystems.

- One other factor explains the increasingly uniform distribution of species on Earth, which results in the threat of extinction for many: the loss of populations of species unique to certain regions (what we call 'endemic species') and the invasion or introduction of species from other regions. Species are often displaced by human populations and transported elsewhere as specimens, samples or genetic material. Unfortunately, a species introduced from elsewhere can significantly alter local biological systems and the services they provide. It can eliminate other species, weakening endemic species in particular, and cause genetic diversity to be permanently lost. Genetic erosion also contributes to the global decline of biodiversity. At the global level, the range of genetic differences between species has decreased, indeed plummeted, especially in the case of crop plants, livestock animals and wild species that are widely exploited for commercial purposes.

FIGURE 21: EXPLOITATION OF MARINE RESOURCES

Intensive fishing has led to a reduction in fish stocks. For example, cod has practically disappeared from the Canadian coast. When the top layers are stripped of fish, then the nets are cast to even greater depths to catch new fish stocks.

Source: Millennium Ecosystem Assessment



An American alligator and a Burmese python in a deadly embrace, Everglades, USA Park. © L. Oberhofer, Public domain

5. Assessing the risk of extinction

At this stage in the proceedings, it seems important to obtain a clear picture of species populations and extinction risks with regard to this last point in particular.

Although conservation measures have reduced extinction risks for several species, they are still increasing for a significant number of other species.

At present, the authoritative reference tool and the most comprehensive inventory, at the global level, of the conservation status of living species, both plant and animal, is the **Red List** of the International Union for the Conservation of Nature (IUCN).

The Red List assesses the extinction risk of species in terms of specific categories that determine the extinction probabilities, assuming the conditions of existence for this species do not change. Thus, species are placed in categories corresponding to their extinction risk level. The risk is assessed on the basis of knowledge and information provided by the work of thousands of scientific experts throughout the world.

The Red List Index assesses the average risk of extinction for species over time. Its work shows clearly that the threat of extinction is increasing for all groups that have been fully assessed.

Corals are among the groups of living creatures whose extinction rates are rising the fastest.

Coral crab attacking a red pencil urchin, Hawaii.

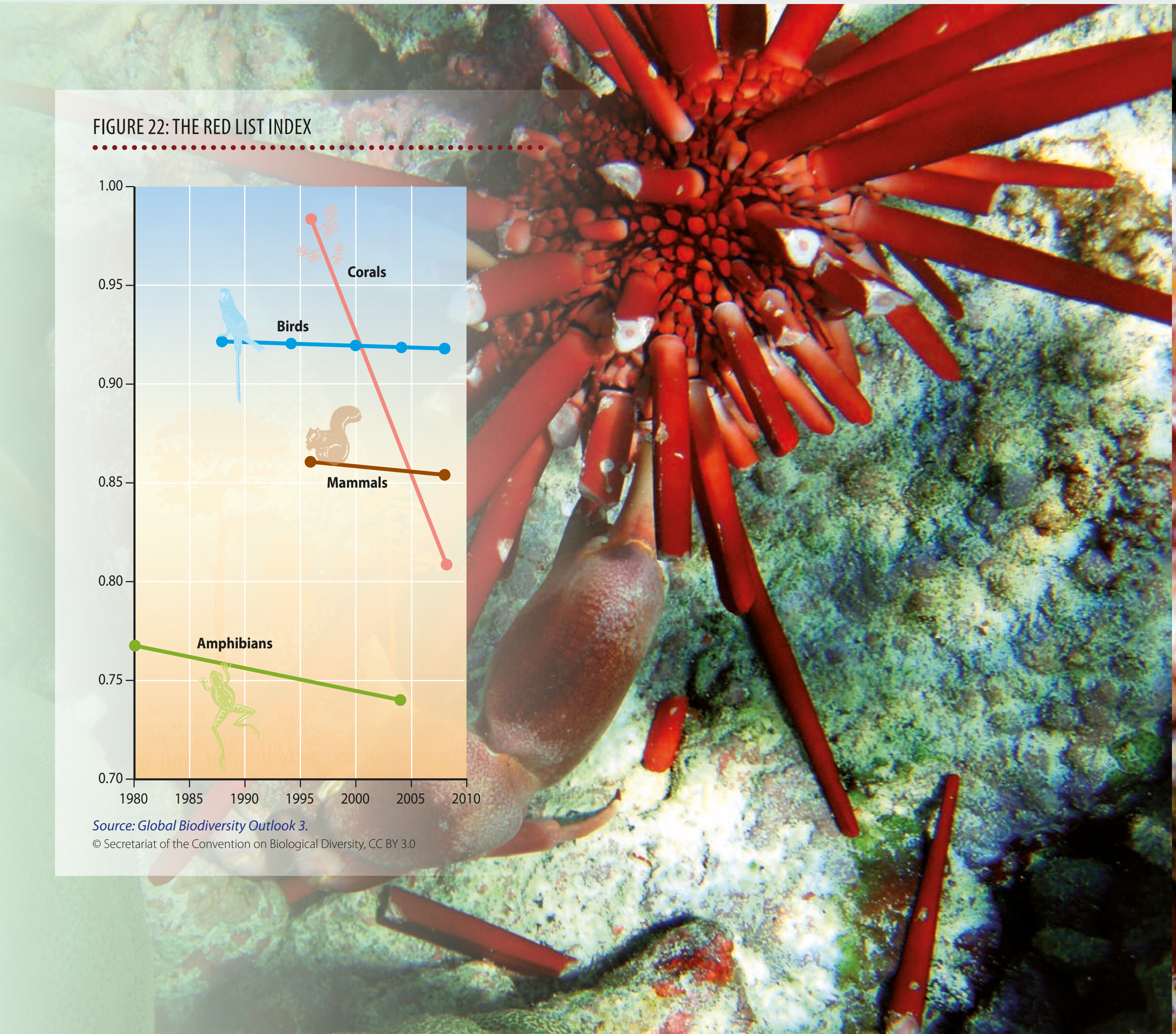


FIGURE 22: THE RED LIST INDEX

Source: Global Biodiversity Outlook 3.

Of all the groups featured, corals register the biggest increase in extinction risk. They are currently deteriorating at an alarming rate. Formed from the symbiotic relationship between an animal, the cnidaria – a relative of the sea anemone – and an alga, the zooxanthella, corals continuously build an outer skeleton from minerals present in the oceans. It is the accumulation of these skeletons that form coral reefs. Global warming, ocean acidification and the presence of pollutants combine to cause the death of the alga and its expulsion from the coral. The latter then goes through a 'bleaching' stage, losing its colour and dying.*

At the global level, the families of species exposed to the highest risk of extinction are amphibians, with the risk increasing all the time. Whether in Europe or more markedly in Latin America, Central America and the Caribbean, we are seeing a worrying decline in the populations of these species. A combination of factors are triggering this phenomenon, including global warming and an increase in ultraviolet radiation, the emergence of new fungal diseases such as chytridiomycosis, and factors not to be underestimated, such as over-exploitation of their use in medicine, and at the local level as a foodstuff.

*** For more details see**
Biodiversity and supply: aquatic ecosystems (p. 110), and the contribution of biodiversity to supporting services (p. 134).

The tunicate Atriolum robustum *on a* Siphonogorgia godeffroyi *(the branches consists of one or more corals).*

6. The vital importance of preserving biological diversity to ensure a sustainable future for all

In view of the sheer scale of the erosion of biological diversity, it is important to recall the emphasis the Convention on Biological Diversity places on the contribution of biodiversity conservation to the attainment of the Sustainable Development Goals, in particular Goal 15: 'Sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss'.

Biological diversity is the basis for all development, precisely because it provides for all human communities in all countries – including the poorest on the planet – not only the means of securing their wellbeing, but also the means of subsisting at the most basic level.

Thanks to the natural products it provides, it constitutes a food safety net for many poorer families who make use of these products as supplements or substitutes, depending on individual circumstances. In the event of a crisis or natural disaster, it protects these families against absolute poverty and famine. It is therefore important to preserve biological diversity at local levels and to strengthen agro-biodiversity, in order to eradicate hunger and malnutrition.

But whether it is a question of essential products, of developing agricultural or forest products that secure an income for many rural households or of the genetic material used in the production of crops and livestock in developed countries, all food produced in the world is the result of the biological processes at work in nature.

Variety of products used in human food. © J. Weber, INRA

The blue spots on the French cheese Roquefort are due to the development of the mould genus Penicillium.

Roquefort. © Chris Waits, CC BY SA 3.0

Our food and our supplies of freshwater – needs vital to our survival at the global level – are both services provided by biodiversity. To this extent, the efficient functioning of food chains is a form of capital that has enormous economic value. The medical services provided by biodiversity should also not be discounted. Although a certain number of medicinal molecules are now manufactured in laboratories, they were originally discovered in nature. Aspirin (acetylsalicyclic acid), for instance, is present in willow bark, penicillin is synthesized by moulds (microscopic fungi), and arnica is a yellow flower that grows in mountain areas, in addition to many other species that help to keep us healthy.

If we wish to attain the Sustainable Development Goals, it is therefore essential that we fully understand and analyse the true value of biological diversity.

To this end, the following sections focus on the contribution biodiversity makes to each one of the services that ecosystems provide for human beings.

The Sustainable Development Goals

In 2015, the United Nations adopted the 2030 Agenda for Sustainable Development. Seventeen goals called the Sustainable Development Goals (SDGs), comprising 169 targets, were approved. The aim of the SDGs is to achieve prosperity, health, equality, inclusion and peace for all of humanity. At the same time, the goals stress the importance of keeping our planet habitable by protecting its natural resources and promoting renewable energy.

Goal 15 'Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss' is of particular interest , especially within the context of the United Nations Decade on Biodiversity (2011-2020). Biodiversity loss remains one of the great global challenges of our time. The causes of biodiversity loss can be direct or more complex arising from economic, social and cultural factors.

Humankind thrives on Earth because of a very delicate balance in the ecosystem. The loss of biodiversity inevitably means that we risk upsetting this balance. The role of ecological sciences combined with a well-oiled science policy interface is, therefore, more crucial than ever if we want to maintain our planet's incredible species richness – not just for us but for the generations to come.

The Sustainable Development Goals

www.un.org/sustainabledevelopment/

Goal 1. End poverty in all its forms everywhere

Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Goal 3. Ensure healthy lives and promote well-being for all at all ages

Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

Goal 5. Achieve gender equality and empower all women and girls

Goal 6. Ensure availability and sustainable management of water and sanitation for all

Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all

Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

Goal 10. Reduce inequality within and among countries

Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable

Goal 12. Ensure sustainable consumption and production patterns

Goal 13. Take urgent action to combat climate change and its impacts

Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development

Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

There are only a few remaining primary forests, that is, non-planted forests that have not undergone human intervention likely to permanently disrupt ecological processes.

Biodiversity and provisioning: agro-ecosystems

Provisioning services ecosystems provide a variety of products including food, fibres, energy resources such as firewood and biofuels, wood (timber and sawn wood) and genetic resources.

Use of these services among communities has increased steadily over the latter half of the twentieth century. When resources are used faster than they can be renewed, the capacity of ecosystems to provide these services to future generations is compromised.

Although use of provisioning services varies across the globe, we must recognize that in some areas it is not sustainable.

Conversion of natural or semi-natural ecosystems for the purpose of farming, logging or other intensive uses has brought about significant changes in land cover in many regions of the world.

These transformations have often caused a sharp decrease in woodland and a decline in traditional agrarian landscapes such as open-field polyculture, pastoral landscapes in all their diversity, and the tree-dotted fields of Mediterranean ecosystems.

The conversion of traditional agro-ecosystems has led to the fragmentation and destruction of habitats associated with agricultural biodiversity. This has gone hand in hand with the depletion of genetic diversity.

In the case of forests, thousands of years of activity have reduced their area to approximately 30% of its former size. There are only a few remaining primary forests, that is, non-planted forests that have not undergone human intervention likely to permanently disrupt ecological processes.

Biodiversity of species and ecosystems provides various services to populations, including food, construction materials, food and so on. A hank of flax fibres.
© J. Weber, INRA

1. Farming for food

Nutrition is the assimilation by living organisms of food materials that allow them to function.

We humans are no exception: intake of the nutrients contained in our food is vital to our organisms.

We consume organic material and are constantly interacting with it. Our digestive tract, an ecosystem in its own right, hosts billions of microorganisms that issue from hundreds of species (bacteria, archaebacteria). These are essential to our digestion as they break down molecules including cellulose and starch.

Release of energy from food is a basic characteristic of living organisms, as is the transmission of that energy. All plants and animals are potential food, and this process of consumption sustains life.

Across the living fabric of the Earth, competition rages among individuals of every species to ensure the resources needed for their survival and reproduction. But biological interaction is not a matter of competition and predation alone. As we have already seen, valuable cooperative relationships also exist among individuals and species.*

* For more details see
Vol. 2, Activity 9, Agro-diversity: a sustainable production process? (p. 49).

Human beings have exploited other living species throughout their existence and have long relied on a sustainable association with plants and animals to create and develop their various forms of civilization.

Upon discovering that they could sow and harvest certain wild cereal grasses instead of gathering the cereal at random, humans began to make rational use of food plants. They went on to breed the varieties best suited to the extraordinary range of ecological conditions on land, resulting in considerable enrichment of biodiversity. This can indeed be called a fruitful partnership: by developing crops to ensure a certain degree of food security, the human race has helped to enrich the web of life.

Nowadays, with ecosystem degradation, many of the points on which the relationship was balanced have been destroyed. It is important to identify them and endeavour to restore the balance wherever it has vanished.

From a semi-natural habitat …
© Archives Normandie 1939-45, Public domain

… To an intensive agricultural landscape. © Nicolás Pérez, CC BY-SA 3.0

2. Traditional agrarian systems and biodiversity

The process of plant and animal domestication began some 10,000 years ago in the Fertile Crescent region of Mesopotamia, an area covering what is now Iraq, Iran and Armenia. Because it was possible to rapidly build up crop and seed reserves and engage in trade, the process of settlement and urbanization began to develop. Domestic plants and animals spread out from these regions, in particular to Europe.

According to surveys, over 500 species and varieties of fruit, vegetables, spices and fruit trees were bred in the Fertile Crescent. Today the Food and Agriculture Organization of the United Nations (FAO) lists some 250,000 crop varieties of which 7,000 are still grown. To achieve so many varieties, farmers and researchers have drawn extensively on local biodiversity.

From left to right:
Genetic seed biodiversity (sunflower, soybean, canola, faba bean, beans, corn and peas). © C. Nicolas, INRA
Pea seeds. © P. Albaret, INRA
Different varieties of seeds: coated peas, pea seeds without treatment, wheat grains coated and untreated wheat grains. © G. Berthier, INRA
Different varieties of tomato. © F. Carreras, INRA

Throughout history, farmers have improved seed from their own crops by mixing it with related wild species in order to increase genetic diversity and resistance to microclimates.

In the case of wheat, tetraploids such as Khorasan wheat and durum wheat exist in the wild. Durum wheat (*Triticum turgidum* ssp. *durum*) has been extensively crossed to withstand commercial agriculture and now provides most of our pasta.

After various crosses, Khorasan wheat (*Triticum turgidum* ssp. *turanicum*) has produced our common wheat (*Triticum aestivum*). However, it is still grown uncrossed and sold under the name 'kamut'. As a species, it has a much higher protein and mineral content than standard wheat.

In Ethiopia, it is common practice to separate, select, sell and sow wild sorghum seed, which is planted with cultivated species of sorghum to encourage cross-fertilization.

The FAO estimates that some 1.4 billion farmers, most of whom subsist on low incomes, continue to improve their crops with the help of local plants.

Diversifying crops

* **For more details see**
Vol. 2, Activity 11.1, Dialogue and action on sustainable agriculture (p.62).

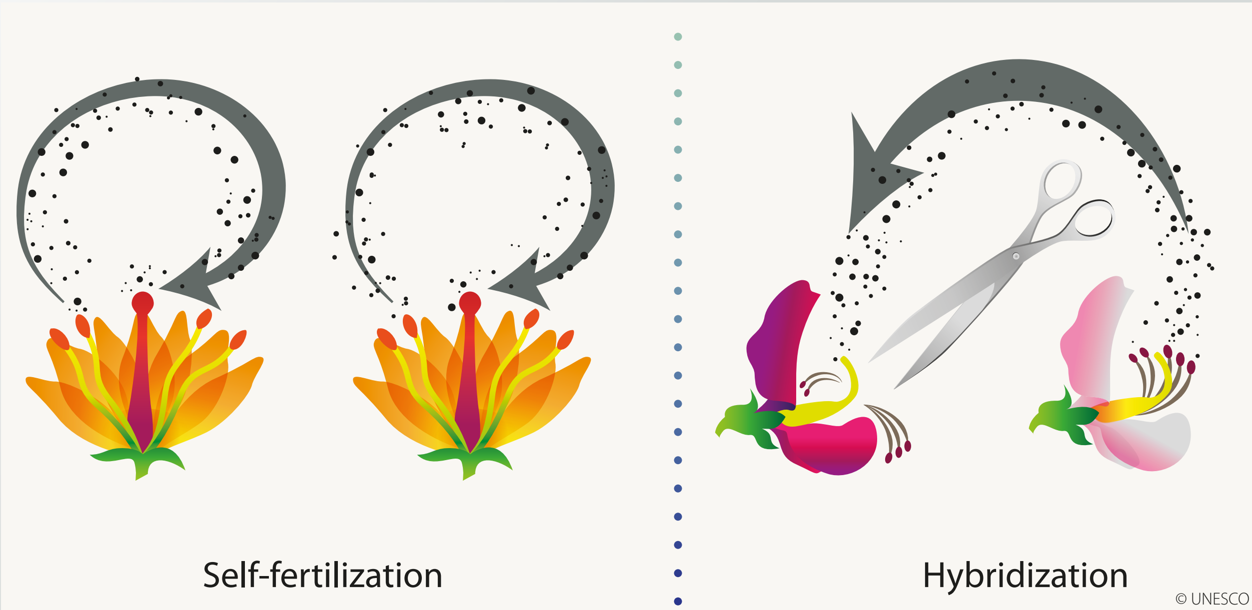
On layered terraces in the Andes, the practice of alternating crops by level and associating crop species on each level reflects centuries of observation and a thorough knowledge of wild indigenous species, as well as ecological gradients (i.e. aspects of the environment that vary according to altitude and affect the species composition of communities).

There are several dozen species of wild bean (*Phaseolus*) and some 200 species of wild potato in Central and Latin America, from which crop species have been carefully bred.* Maintenance of diversity within species is another remarkable feature of traditional field systems in the Andes. Several hundred varieties of potato are grown there, including some that are extremely frost-resistant. Varieties sometimes co-exist in different groups in the same field, and farmers classify them by the ecological niches that determine the size of their tubers.

Today, there are 7,000 plant varieties grown worldwide.

Diversity observed in barley (Hordeum vulgare). © E. Boulat and A. Didier, INRA

FIGURE 23: SELF-FERTILIZATION AND HYBRIDIZATION OF PLANTS



Improvement process of plants. © Clermont Terrand Theix Lyon, INRA

Many varieties are grown for the same plant species. Each variety meets a specific need including consumer demand, drought resistance, frost and fruit size. From left to right:

Different potato varieties of potato. © C. Maitre, INRA
Different varieties of chillies and peppers. © C. Slagmulder, INRA

Using indicator plants

Other traditional farming practices that sustain and make use of local biodiversity include the use of indicator plants and green manure to assess and improve soil quality.

In regions where the topsoil is shallow and valuable or where the soil is subject to harsh climatic conditions, farmers are usually able to name, classify and describe indicator plants. The information provided by the plants is only valid above a certain number of individuals, but if an area is densely populated by a species, this generally reflects not only the mineral content of the soil (e.g. whether limestone or siliceous), but also its nutrient content (an excess or lack of organic matter and the nature of the nutrients present, such as nitrogen or phosphorus). In temperate regions, a dense population of stinging nettles (*Urtica dioica*) usually indicates a heavy concentration of iron and nitrates in the soil. Nettles also remove pollution by metabolizing these elements to fix them organically.

On pasture degraded by a nitrogen surplus we often see populations of spiny plants such as spiniest thistle (*Cirsium spinosissimum*), together with other characteristic plants such as monkshood (*Aconitum nappelus*) in the Alps. Decalcified pasture is usually invaded by bristly Poaceae such as mat grass (*Nardus stricta*) or similar grasses in other regions. In the Venezuelan Andes, where wheat and quinoa are still grown twice a year, farmers use indicator plants on a continual basis to assess the state of the soil, so as to check whether it has deteriorated between crops or is still rich in nutrients.

If a grass such as rat's-tail fescue (*Vulpia myuros*) is thriving in or around crops, a farmer will want to leave the field fallow, whereas the presence of a Fabaceae such as lupin or chocho (*Lupinus paniculatus*) suggests even nitrogen distribution and therefore sufficiently fertile soil.

Aconitum napellus.

Using legumes

Generally speaking, leguminous plants from the Fabaceae family, such as alfalfa, clover and vetch, provide valuable inputs.

Through their root nodules these plant species fix atmospheric nitrogen in the soil, making it available to other plants. They present definite benefits, particularly when introducing and maintaining crops without the constant use of fertilizers.*

In Africa, Asia, Latin America and wherever crop rotation is used, farmers plant cereals annually (wheat, barley, maize) after first planting green manure, mainly in the form of legumes. The latter often belong to wild or local species, such as the various lupins of Latin America that enrich sandy soils or various species of clover including crimson clover (*Trifolium incarnatum*).

The cereal crop planted after the alfalfa or clover subsequently benefits from the nitrogen input fixed by the legumes.

When crops are hard to establish, farmers resort to intercropping or alley cropping, using hedges of shrubby legumes to ensure that the crops benefit continuously from the presence of legumes.

In Burundi, farmers and agronomists have experimented with leguminous plants grown as hedges between rows of coffee trees and have measured over time the benefits of nitrogen fixation for coffee production.

Shrubs, which in Africa are native species of the Calliandra genus (*Calliandra calothyrsus*), the African locust bean (*Parkia biglobosa*) or the pigeon pea (*Cajanus cajan*), are used to divide up the crop alleys. Farmers prune them to mulch the crops, which are thus fed from two sources – by soil nutrients through their roots and by the minerals released by decay of the legume leaves on the surface.

*** For more details see**

Vol. 2, Activity 9, Agro-diversity: a sustainable production process? (p. 49).

Wild bee on buckwheat flowers. © J. Weber, INRA

Preserving weeds

All weeds are useful crops. For example, weeds are home to hundreds of species of insects, such as bees involved in pollination.

Conventional farming landscapes have long maintained populations of weeds belonging to wild species, which when associated with crops present real ecological benefits.

Throughout history, human beings have used tools, fire and the introduction of cattle to open up vegetation. Typical agro-ecosystems, characterized by the appearance of grassland, hay fields, open-field polyculture and closed-field systems, as well as continuity of cropping methods, such as three-year rotation with a fallow period, have enabled the development of crop weeds, either planted in environments modified by human activity or established naturally.

These crop weeds, which include poppies (*Papaver rhoeas*), cornflowers (*Centaurea cyanus*), corncockles (*Agrostemma githago*) and corn marigolds (*Chrysanthemum segetum*), have adapted and evolved together with the crops to the extent that they are now very associated with them. Such is the case of the corncockle, which releases the seeds from its capsules only once the wheat has been harvested. In other cases, new crop plants such as rye (*Secale cereale*) have been bred directly from weeds.

This mutually beneficial arrangement continued until recently, when intensive farming led to the clearing and even eradication of weeds and cornfield plants by weedkillers. Ruderal plants living by the wayside on banks, in wall cavities and on heaps of earth also similarly from such farming approaches despite their usefulness. Chicory (*Cichorium intybus*) and thistles (*Carduus ssp.)*, for example, loosen clayey soils that are too hard-packed. All these weeds and cornfield/ruderal plants are good for crops: they constitute a unique store of genes and strengthen biodiversity. Just a few species (40 or so in temperate regions) support several hundred insect species – including diptera (such as hoverflies), ladybirds and lacewings, which are all natural predators of aphids.

In providing a habitat for natural pest predators, these plants protect crops and limit the use of artificial inputs whose effects on human health have not been fully evaluated. Furthermore, these plants are often melliferous and play a major role in guaranteeing crop pollination.*

Agro-ecosystems have long been able to preserve ecological niches for wild plants and animals. However, there is increasing cause for concern regarding the disappearance of these last refuges of nature, which usually represent below 1% of potential farmland, as paths are being obliterated and the smallest ditches are being filled in.

Together with wetland plants, cornfield plants are among the species most at risk in temperate zones. This is of concern as their disappearance radically reduces local biodiversity.

* **For more details see**
Vol. 2, Activity 11.3, Dialogue and action on sustainable forest husbandry (p. 71), and Activity 12, The school garden, a biodiverse garden (p. 73).

Floral diversity on a field border.
© G. Louviot, INRA

Traditional landscape management and biological diversity

Farming landscapes maintained by farmers and shepherds, using methods suited to local requirements, not only preserve relatively high genetic diversity within crops and livestock, but also sustain the biological diversity of wild species. Such landscapes are found all over the world and have grown out of the application of a huge body of knowledge and cultural practices, which are constantly being renewed, and are responsible for landscapes with significant agricultural biodiversity. Some examples of these systems are given below:

Psiculture paddy.
© FAO, Lena Gubler

Rice-fish farming has been practised in China since at least the Han Dynasty 2,000 years ago. Fish are introduced into the paddy fields to provide fertilizer, soften soils, and eat larvae and weeds, while the rice provides shade and food for the fish. The high quality of the fish and rice thus produced directly benefits farmers through high nutrition, lower labour costs, and less need for chemical fertilizers, herbicides and pesticides.

Terraces in the Sacred Valley of the Incas.
© FAO, Antonello Proto

In the valleys of Cusco and Puno in Peru, the Quechua and Aymara peoples employ a form of terracing that allows them to grow different crops, such as maize and potatoes, and graze animals on steep slopes at altitudes ranging between 2,800 and 4,500 metres. This system supports as many as 177 varieties of potato, domesticated over many generations. It also helps to control soil erosion.

Satoyama landscape, Sado, Japan.
© FAO, Parviz Koohafkan

Japan's satoyama landscapes are small mosaics that consist of various types of ecosystem, including secondary forest, irrigation ponds, rice paddies, pastures and grassland, from which landholders have traditionally harvested resources such as plants, fish, fungi, leaf litter and wood in a sustainable manner. Satoyama landscapes have evolved out of the long-term interaction between people and the environment. Activities such as the periodic clearing of forests and the harvesting of forest litter prevent the system from being dominated by a few species and allow a greater diversity of species to exist within it.

3. Polyculture and food supply in poor rural areas: current developments

Over generations, rural communities in areas with harsh climates and poor or rugged terrain have acquired a stock of knowledge and skills enabling them to live off the land and remain healthy.

Traditional farming methods have long guaranteed a degree of food security and ensured relative nutritional value.

A large number of farmers farm small areas where, in additional to cash crops, subsistence crops are vital.

Accustomed to making the most of crop diversity, these farmers grow traditional cereal crops, such as common buckwheat or foxtail millet in the Himalayas or central India, at the same time as pulse crops, such as kulthi beans (*Macrotyloma uniflorum*) or mung beans (*Vigna radiata*), which are eaten dried, whole or 'split' for the famous 'dal'.

In other regions, such as Africa, cereals and legumes are also combined with traditional green leafy vegetables; in Uganda these include dark green leafy vegetables

Pink cosmos flowers. © F. Carreras, INRA such as green amaranth (*Amaranthus hybridus*), nakati (*Solanum aethiopicum*), cassava and sweet potato.

If a crop is less productive, this can often be offset by the use of local strains.

... It is estimated that one-third of the 6,500 domesticated animal breeds are currently threatened with extinction.

Food supply for traditional societies nevertheless depends on one staple product. Maize, cassava, sweet potatoes, peanuts, pigeon peas, lentils, cow peas, yams, bananas, plantains, millet and sorghum are staple foods for millions of the poorest people, providing them with a significant proportion of their diet and food energy.

To offset a certain degree of dietary monotony, most communities have moved towards a more balanced and varied diet. Since their main dishes are very calorific but low in nutrients, communities have also used traditional vegetables or collected wild species to meet their vitamin and mineral needs.

Thus, the gathering of fruit and wild forest produce is widespread, with people widely aware of their high nutritional value.

In dry areas, the jujube (fruit of the jujube tree) is widely appreciated for its flavour and vitamin content. While the vitamin C content of an orange is 57 mg/100 g, the content of a baobab fruit is 200 mg/100 g and that of a jujube is as much as 500 mg/100 g.

The leaves of the 'desert date' or 'soapberry' (*Balanites aegyptiaca*), a plant still relatively common in the Sahel and the Middle East as far as Pakistan, are a source of calcium providing 1,000 mg/100 g, while a few dried leaves (approximately 33 g) of the baobab (*Adansonia digitata*) when eaten in the form of a condiment provide an individual's daily calcium requirement.

The bittersweet fruit of *Balanites aegyptiaca* is sucked as a substitute for dates, and young leaves are eaten as vegetables or as a sauce with pearl millet.

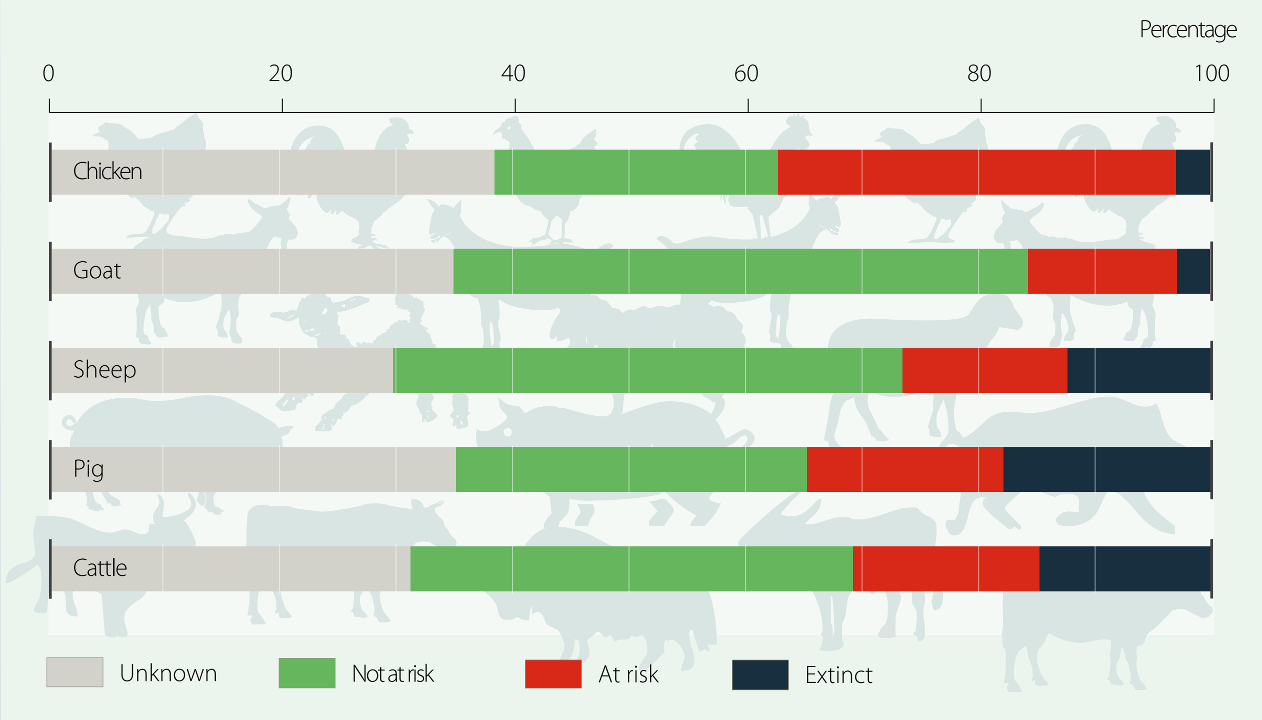
While communities have always understood the role of native plants in conserving the local ecosystem and the benefits of using biodiversity and wild species to vary and expand their diet, it has to be recognized that indigenous knowledge concerning local foods and traditional farming practices is now being eroded and agricultural diversity is declining, resulting in food insecurity and malnutrition in many parts of the world.

Because of various combined pressures arising from population growth and the demand for profitability in agriculture, which is itself due to a wider market economy moving towards global integration, many growers have neglected polyculture and traditional farming methods in favour of intensive farming of a single crop with a view to obtaining quick profits.

FIGURE 24: RISK OF EXTINCTION FACING CATTLE BREEDS

Large numbers of breeds of the five major species of livestock are at risk from extinction. More generally, among 35 domesticated species, more than one fifth of livestock breeds, are classified as being at risk of extinction.

Source: FAO



The third edition of the *Global Biodiversity Outlook* (*GBO3*) paints a worrying picture of the limited number of species used for food by human beings.

The greater part of the food supply for almost half the world's population comes from a few varieties of three mega-crops (rice, wheat and maize), while a significant number of crop varieties have been neglected and sometimes abandoned, and are now at risk of extinction. The same phenomenon is reported in livestock farming, where it is estimated that a third of the 6,500 domesticated breeds are currently facing extinction.

Concerning rice agriculture, interesting cultivars have been obtained for years, selecting and cross-breeding different strains of the same species, ***Oryza sativa L.*** In Latin America and the Caribbean, FAO estimates, though, that production has reached a plateau and that it is difficult to maintain yields in intensive irrigated rice agriculture.

This being so, it is easy to imagine the drastic consequences of a bad harvest.

To this are added two other worrying factors: the threats associated with disturbances (various crises, economic recession, natural disasters, drought and flooding exacerbated by climate change) and the harmful effects of monoculture on people's wellbeing.

In many regions, such as Kenya, where black bean (njaha) crops have given way to intensive maize farming, monoculture has had an adverse effect on overall food intake. Eradication of many bean strains has led to considerable depletion of the agricultural genetic stock, and intensive farming itself has resulted in soil impoverishment.

A combination of all these factors explains why 13% of the world's poorest inhabitants are today still undernourished and at risk of food shortages at a time when food insecurity in general has been decreasing for half a century.

Undernutrition remains a serious public health problem worldwide, responsible for over 15% of chronic and infectious diseases, which are caused mainly by protein and nutrient deficiency.

What is food security?

Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.
(World Food Summit, 1996)

Food sovereignty is defined as the right of peoples and sovereign states to democratically determine their own agricultural and food policies.*

Source: www.fao.org/docrep/013/al936e/al936e00.pdf
* *There is no international definition of food sovereignty.*

Flock of sheep in mountain pastures.
© M. Meuret, INRA

The erosion of genetic diversity has led to a substantial deterioration in ecosystem food-provisioning services in poor areas. In a crisis, communities can no longer fall back on natural products, and ecosystems therefore no longer act as a safety net protecting them against absolute poverty and starvation.

As *GBO3* emphasizes, it is important to preserve agricultural biodiversity in order to rid rural communities of hunger and malnutrition.

Conservation and sustainable use of biodiversity offer the possibility of reducing poverty and improving human wellbeing. Reversing biodiversity decline is a key element of the 2030 Agenda and contributes to progress in achieving the Sustainable Development Goals of eradicating extreme poverty, achieving health and education for all, preserving the environment and promoting international cooperation.

Environment for the Sustainable Development Goals

The Poverty Environment Partnership (PEP) is a network of international development and environment agencies and NGOs including UNDP, UNEP, IIED, IUCN and WRI. In 2005, it took its message to the World Summit in New York, based on a body of analytical work and consultation that clarifies the complex relationship between poverty reduction and environmental sustainability: 'The world's poor depend critically on fertile soil, clean water and healthy ecosystems for their livelihoods and wellbeing.' The Partnership recommended that donor support focus on the following areas:

- Greatly expanding investment in environmental assets;
- Strengthening local institutions;
- Developing integrated approaches to putting pro-poor investment at the heart of national development – with poverty reduction strategies and sectoral planning at all levels;
- Instituting pro-poor changes in environmental governance;
- Promoting innovative market-based instruments to encourage pro-poor investment in environmental management and the provision of environmental services;
- Strengthening the information base for decision-making.

Source: Biodiversity, Development and Poverty Alleviation, www.cbd.int/doc/bioday/2010/idb-2010-booklet-en.pdf. © Secretariat of the Convention on Biological Diversity.

Different varieties of aubergine on a market stall. © C. Le Bastard, INRA

4. Genetic erosion, pollution and poor food quality

While biodiversity loss has a negative impact on ecosystem provisioning services in many parts of the world, exposing the poorest people to a shortage of subsistence food, it also has an adverse effect on ecosystem provisioning capacity in developed countries.

Specialization of production has resulted in the disappearance of polyculture and the appearance of landscapes lacking all variety.

Land consolidation has flattened the landscape, removing obstacles to agricultural machinery, obliterating hedges and paths, levelling banks and embankments, and eliminating remaining areas of natural vegetation.

Although the current trend is to reintroduce hedges and restore ecosystems, the habitat destruction and fragmentation associated with the decline of traditional agrarian landscapes has reduced the size and distribution of species populations and depleted genetic resources, as we have already seen. Moreover, with mechanization and the use of chemical fertilizers and biocides, modern farming methods have become so efficient that nature has vanished from crop ecosystems. This is problematic, since an ecosystem's capacity to eliminate undesirable organisms depends heavily on biodiversity, and is beneficial for food security.

The process of genetic erosion that we are witnessing is extremely alarming, since genetic diversity is crucial for the survival of plant health and adaptability over the long term. It plays a major role in ensuring high yields and providing a degree of disease resistance, particularly to new emerging diseases, through the presence of natural predators. It also strengthens ecosystem resilience – an ecosystem's capacity to recover and grow after suffering a serious disturbance, such as a fire, cyclone, a prolonged period of drought or spontaneous colonization by an undesirable organism. The growing problems of climate change and pollution render ecosystems increasingly vulnerable to these shocks and disruptions.

Today, over half the reactive nitrogen in the world's ecosystems comes from anthropogenic sources, particularly synthetic fertilizers produced to increase agricultural output, which has altered ecological balances.

Specialization of production has resulted in the disappearance of polyculture and the appearance of landscapes lacking all variety.

Some cover crops capture nitrogen from the earth, thereby decontaminating the soil. Examples of these crops include mustard and rapeseed.

Harvesting by hand in a mustard field, Rajasthan, India. © R. Le Bastard, INRA

* For more details see
Biodiversity and supply: aquatic ecosystems (p. 110).

The excessive levels of nitrogen and phosphorus in an ecosystem's plants, together with atmospheric nitrogen deposition, have caused both recurring pollution problems and water eutrophication. Ecosystem regulating services are insufficient to counteract these problems, as they have been damaged by the absence of predators and cleansing organisms.*

Given all these factors, conventional intensive farming does not seem to prioritize food quality and nutritional value or necessarily promote the supply of a wide range of high-quality foods relying on biodiversity conservation and guaranteeing a balanced diet.

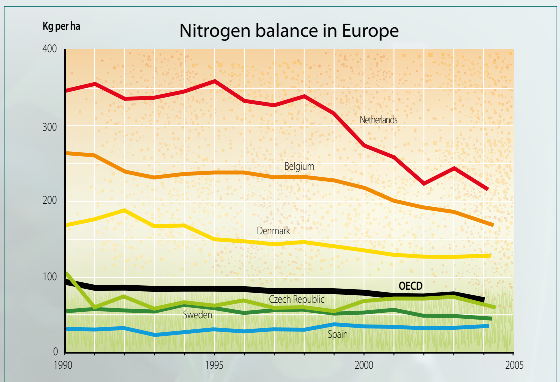
While hunger remains rife in developing countries, food consumption problems are also found increasingly in developed countries as a result of globalization, provoking dietary issues worldwide.

FIGURE 25: POLLUTION AND NUTRIENT LOAD

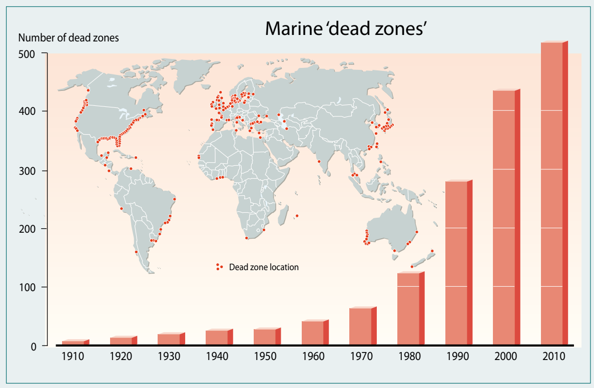
Pollution from nutrients (nitrogen and phosphorous) and other sources poses a continuing and growing threat to biodiversity in terrestrial, inland water and coastal ecosystems. Modern industrial processes such as the burning of fossil fuels and agricultural practices, in particular the use of fertilizers, have more than doubled the quantity of nitrogen in the environment compared with pre-industrial times.

In inland water and coastal ecosystems, the build up of phosphorous and nitrogen, mainly through runoff from cropland and sewage pollution, stimulates the growth of algae and some forms of bacteria, threatening valuable ecosystem services in systems such as lakes and coral reefs and affecting water quality. It also creates 'dead zones' in oceans.

While the increase in nutrient load is among the most significant changes humans are making to ecosystems, policies in some regions are showing that this pressure can be controlled and, in time, reversed.



Source: Global Biodiversity Outlook 3, p. 61. According to the OECD



Source: Updated from Diaz and Rosenberg (2008). Science

Cotton flower. © J. Weber, INRA

Ill health may be the consequence of either poor nutrition or overeating. In traditional societies, many foods eaten previously are now stigmatized as 'poor people's food' in favour of imports or the commonly sold products of modern farming. Imports are usually cheap products high in fat and sugar, such as fizzy and sugary drinks, processed meats and commercial white bread, which are considered more attractive despite their very low nutritional value.

** For more details see
Vol. 2, Activity 9, Agro-diversity: a sustainable production process? (p. 49).

The trivialization of food consumption in developed countries, symbolized by fast food, has gone hand in hand with a decline in quality and lack of variety in what is consumed, with these same sugar-rich junk foods being linked worldwide to growing rates of obesity and chronic disease in general.

When examining questions of food quality and human health, we must also consider the problem of food pollution and the presence of residues from pesticides, fertilizers, heavy metals, hormones, antibiotics and other additives in the food system and indirectly in large-scale livestock farming.**

Direct, complex links exist between farming, health and nutrition, as well as between biodiversity and nutrition. We therefore need to make improvements in human health an explicit goal of agricultural policy, as a matter of urgency.

5. Agriculture and development

Agro-biodiversity and food security

According to reports from international institutions (FAO, GBO, GEO, MA), agricultural research and development ought to concentrate on globally traded staple cereals, while also including a focus on rural communities' subsistence crops and the development of diversified crops and added-value niche products. This entails growing products designed to:

- cover community needs;
- meet unsatisfied demand in domestic markets (e.g. where demand may be high for local fruit and vegetables and could be further increased by raising awareness);
- develop export outlets.

Among these crops, mention may be made of non-wood forest products, local fruit and vegetables (widely appreciated), and locally produced commodities for industrial or food processing (crops for canning, confectionery or manufacture of juice, milk, oil or biofuels), as well as horticultural and aromatic crops.

Thus, food security programmes are predicated on agro-biodiversity and greater use of wild species and local plant breeds, as well as on forest products, biodiversity of aquatic resources (river basins, paddy fields, mangrove forests, etc.), and native livestock breeds, which although sometimes at risk of extinction are highly suited to the production systems of specific regions.

The aim is to develop a sustainable food sector that will gradually be incorporated into the local marketing system and then national and international ones, bolstering local markets and, with the aid of the micro-credit system in particular, promoting small, medium-sized and even micro-business start-ups and indigenous facilities, enabling farmers to diversify their sources of income.

Diversification of livelihoods encompassing subsistence crops, breeding and cultivation of local plants, agroforestry, aquaculture, livestock farming and the food-processing industry, while exploiting the potential of farm tourism, will help to ensure the sustainability of rural communities and conserve the local gene pool.

Research is also being carried out into the scientific basis of existing practices with a view to improving their economic and strategic efficiency.

Examples include the inhabitants of Sikkim and Bhutan, who earn a good price for the giant cardamoms they breed from species on their slopes; while other Himalayan farmers make sustainable use of wild species of lemon and mango by selling them in local markets. FAO's Mountain Products Programme supports improved local production, processing and marketing of saffron, one of the most expensive pigments and spices. Harvesting the crocus pistils is laborious work, but constitutes a sustainable and complementary source of income for numerous inhabitants of the Lesser Atlas Mountains in Morocco.

Saffron is among the most expensive pigments and spices. Harvesting the crocus pistils is laborious work, but constitutes a sustainable and complementary form of income for numerous inhabitants of the Lesser Atlas mountains in Morocco. © J. Weber, INRA

6. The IAASTD and the concept of multifunctionality in agriculture

The IAASTD (International Assessment of Agricultural Science and Technology for Development) is a recent United Nations report reviewing the situation of agriculture globally.

According to this report, successfully meeting development and sustainability goals worldwide requires a fundamental shift in agricultural policies, institutions, investment and, specifically, agricultural knowledge, science and technology that can affect capacity development.

The IAASTD emphasizes the concept of **multi-functionality** in agriculture – a term that highlights the interconnectedness of agriculture's different functions.

The concept of multifunctionality recognizes that agriculture provides environmental and social services, landscape amenities and cultural heritage, in addition to its primary function of producing food, fibres, biofuels and medicinal products. The services rendered are akin to public services, as no commercial market exists for their exchange. Multifunctionality thus encompasses a highly diversified production function and a usually unpaid public service function.

Among the environmental services provided by agriculture are soil conservation, flood prevention, maintenance of grazing (and therefore pasturage and hedges), wildlife protection and biodiversity management.

Agriculture's social services include its contributions to employment and the sustainability of rural communities, as well as food security at the local level in many parts of the world.

Agriculture also shapes the landscape. It contributes to the creation of a region's identity, providing aesthetic, recreational and wider cultural aspects in addition to its physical and social dimensions.

The concept of multifunctionality sees these functions as interlinked. Cattle farming in the Auvergne (France) or on cleared forestland in the Himalayas, for example, includes grazing, thereby maintaining hedges,

Zebu used for animal traction. © JP. Choisis, INRA

benefiting wildlife, and exerting an impact on the landscape and the environment.

The market finances certain aspects of agriculture including primary commodities, as well as processed products that may supply branches of the formal economy, such as agrotourism and the sale of renewable energy. Other functions, however, tend to be classified as common goods (biodiversity conservation, maintenance of the countryside) and apparently fall within the 'non-market' sphere.

It would therefore seem reasonable when managing these functions to waive market rules by providing financial incentives and compensation for environmental services.

This would allow environmental protection to become an 'output', linked to agricultural products through product quality seals or quality recognition.

Conversely, products of production processes that provide no environmental services should be liable to a form of compensation, subject to a tax that is payable not only by producers but by the entire supply chain (pesticide industry, seed sector).

The IAASTD report is crucial in this respect, since its recognition of the multifunctionality concept constitutes official acknowledgement of the importance of the environmental services provided by agriculture. This signals a new status for local agriculture and its role in meeting current challenges relating to sustainable resource management, food security and food quality.

These issues underline the need for the development of new global frameworks for consultation and economic regulation.

For the IAASTD, one major development and sustainability goal in agriculture is to improve the livelihoods of the rural poor. The assessment advocates measures to improve small-scale farmers' access to land and economic resources and increase their local value added. Farmers must be recognized as both producers and managers of ecosystems. It also recommends developments that recognize the value not only of farmers' knowledge, but also of agricultural and natural biodiversity, farmer-managed medicinal plants and local seed systems.

Agricultural knowledge, science and technology, working in relation with economic and political authorities and new institutional mechanisms, could help to diversify agricultural production in small farms, develop and popularize appropriate cultivars adaptable to specific local conditions, and promote the production of high-value crops.

A farm on the road to Osian, Rajasthan, India. © R. Le Bastard, INRA

Agricultural ecosystems, valued for the biodiversity of their cultivated or natural resources, are essential to life and human health.

Harvesting salt, Guerande salt marsh. © J. Weber, INRA

Different varieties of cucurbits. © M. Pitrat, INRA

Different food products from cereals.
© C. Maitre, INRA

Growing fields in the Vexin, France. © J. Weber, INRA

Harvesting by hand in a mustard field, Rajasthan, India.
© R. Le Bastard, INRA

Biodiversity
and supply: forest ecosystems

Forest ecosystems play a major ecological role in many parts of the world. They are home to more than half of terrestrial plant and animal species, and tropical forests alone contain over 50% of all these species.

Red deer.
© Luc Viatour, CC BY SA

This abundant biodiversity maintains and strengthens some of the richest ecosystems on the planet, providing a variety of resources upon which many populations rely for their day-to-day existence.

Forests thus play an important economic and social role with 400 million people worldwide making a living from exploiting forest resources. The supply services for these ecosystems respond to the commercial and industrial needs of local communities through the exploitation of timber, lumber, pulp for paper and various types of pulpwood. More broadly, they meet domestic needs for products that are not necessarily marketed, such as fuelwood (firewood, wood for cooking), various food products (grains, fruits, edible plants, fungi, fish and game), products from sampling, extraction and processing (gum, resin, oil, honey snf cork, depending on type), natural fibres (rattan, bamboo), and plants with medicinal and health value.

In respect to the latter, it is worth noting that 80% of the world's population use plants and traditional preparations as part of their daily health regime.

Despite the vital role that forests play in local and global ecosystems in terms of the repartition of different types of landscapes across the Earth's surface, their impact on the climate, and their role in linking landscape and production of local resources, forest habitats worldwide are in sharp decline.

Forest ecosystems are home to more than half of the plant and animal species on Earth. Tropical forests are home to the largest number of species.

Hoopoe. © Luc Viatour, CC BY SA 3.0

About one out of seven people in the world depend on forests for their livelihoods and eight out of ten for medical treatment.

Amazonian fruits. © FAO, R. Faidutti CFU000409

Forests play an important economic and social role.

1. Characteristics of the loss and degradation of forest habitats

The global situation and the loss of primary forests

As the third edition of the *Global Biodiversity Outlook (GBO3)* points out, prior to human interference, forested areas covered half the land surface of the planet.

Following millennia of human settlement and human activity, they have been reduced to 30% of their original area and currently cover 31% of the Earth's surface.

Globally, deforestation continues at an alarming rate, although – according to *GBO3* – it has shown signs of slowing down in some areas over the last ten years.

In the Brazilian Amazon, for example, deforestation has decreased to 70% locally, even though, cumulatively, 17% of the initial cover is still affected.

Deforestation is the result mainly of the conversion of forests to agricultural land (food crops to crops assigned to biofuels) and of the conversion of forests to pastures and crops for livestock. It also results from logging and infrastructure development: roads, shipping channels, housing, and sometimes exploitation of minerals or deposits, depending on the region.

Southeast Asia is one of the regions most affected by deforestation. As a result of increasing demand for biofuels, many forests have been converted to oil palm plantations.

When a forest ecosystem is transformed into a uniform industrial plantation, biodiversity disappears from the area never to recover.

International Union for Conservation of Nature (IUCN) Red List assessments show that habitat loss due to agricultural activity and unsustainable management of forests is a major cause of species extinction risk.

In addition, the Living Planet Index, as highlighted by *GBO3*, notes that the widespread impoverishment of forest habitats causes a marked decline in vertebrate populations, especially in tropical areas.

Accordingly, birds are exposed to significant risks of extinction in Southeast Asia. *GBO3* cites a recent study

Before human interference, forested areas covered half the land surface of the planet.

Remaining forests around the Great Wall of China.
© Peter Prokosch, UNEP Grid-Arendal

Forests are razed to make way for fields to develop roads, and build housing, among other activities. 70% of forests have disappeared due to human activities.

Arterial roads, Canada. © Peter Prokosch, UNEP Grid-Arendal

Assessments made for the Red List of IUCN (International Union for Conservation of Nature) show that habitat loss due to agricultural activities and unsustainable forest management is the major cause behind the threat of species extinction.

which claims that the conversion of forests to palm oil plantations has resulted in the loss of 73% to 83% of bird and butterfly species from this ecosystem.

Another example of deforestation involves the conversion of forests to farmland. Over 70% of mountain land is used for grazing and over 300 million of the world's people depend on livestock for their living.

With the increase of populations in some mountainous areas and the corresponding growth in demand for meat and dairy products, conversion of land for pasture and grazing has continued unabated, contributing to deforestation.

Tropical mountain forests are among those that disappear most quickly. Deforestation by fire to allow for the expansion of cattle farming and the cultivation of agrofuels is still ongoing in the Amazon rainforest.

Another feature of the degradation of forest ecosystems is the loss of their natural features as they come under pressure from the non-rational management of logging communities, sometimes with very little oversight. It would be wrong to think that local communities are the only ones responsible for this mismanagement. In reality, the use of forest resources often forms part of large-scale economic rationales. Therefore, it is important that adequate policies promoting the sustainable use of forest ecosystems are approved internationally and implemented at regional and national levels.

At the global level, a third of the surface area of existing forests is deemed to consist of primary forests. The latter thus cover less than 10% of the Earth's surface while hosting the bulk of terrestrial ecosystem biodiversity.

Primary forests are forests whose vegetation cover substantially corresponds to the original vegetation. These are highly natural ecosystems that have not been subjected to human interventions likely to disrupt or even influence ecological processes. Once a forest has undergone human intervention over an extended period of time, and has subsequently regenerated (reaching a natural equilibrium), it

70% of mountainous land is used for farming. The expansion of pasture land to meet the demand for meat and dairy products contributes to deforestation. Deforestation is also found in tea and rice fields at higher altitudes.

Rice cultivation.

The Amazon rainforest is still being destroyed by fire to allow for the expansion of cattle and agrofuels.
Burned rainforest, Sumatra. © Peter Prokosch / UNEP Grid-Arendal

The use of forest resources often forms part of large-scale economic processes. Wood often travels long distances before being used.
Floating logs. © Tony Hisgett, CC BY 2.0

Primary forests are forests where the vegetation cover comprises mostly original vegetation.

is called a **secondary forest**. This is the case, for example, if a primary forest is exploited or even cut down, then neglected for centuries. The forest regains characteristics of a primary forest, such as the presence of very old trees, numerous dead trees and species adapted to shade, but it retains the signs of human intervention, and as such is classified as a secondary forest. Very few primary forests remain. On the European continent, only a few pockets are still preserved – in Poland (Bielowieza), Bosnia and Herzegovina, and Scandinavia. Worldwide, primary forests are found principally in Brazil, Congo and Indonesia.

According to FAO's recent Global Forest Resources Assessment, some 6 million hectares of primary forest have been lost or modified each year since 1990, with no sign of any let up. This decline is due not only to deforestation but also to forest modification in the wake of selective logging and other human interventions. In a sense, these practices 'downgrade' the forests, reclassifying them from primary forests to modified natural forests.

The biological diversity of forests is relative, depending on the region of the world in which they are found. In the major centres of primary tropical forests – Amazonia, the Congo Basin and Indonesia – there is a great diversity of woody species with almost 300 different species of trees per hectare, whereas in temperate, boreal and sub-Saharan areas, some ten of the most common species account for 50% or more of forest biomass.

A primary or secondary forest can be recognized by the advanced age of the trees, and the density and frequency of dead trees.

Old oak, Isle of Vim, Germany. © Peter Prokosch / UNEP Grid-Arendal

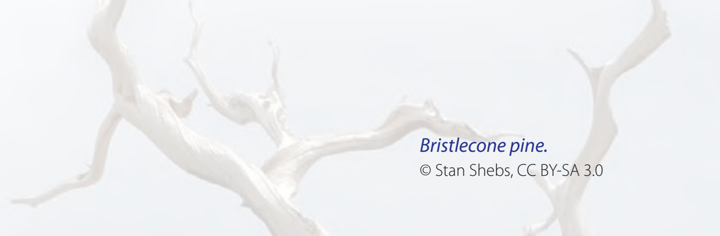
However, regardless of type, selective and indiscriminate logging in the very heart of primary forests poses a real threat to the percentage of native species present there.

According to *GBO3*, the rarest tree species, especially those with a high commercial value, are often threatened with extinction. FAO estimates that on average 5% of native forests are vulnerable, endangered or in critical danger of extinction. These may include species exploited for softwood timber, which is used intensively for furniture, objects and moldings, easy to handle and resistant to fungi. They may be particularly valuable species exported for decades, such as mahogany, ebony or less well-known types such as rosewood, iroko (a species of the Moraceae family), or trees used in medicine for centuries and also widely exported.

It should be remembered that in Central Africa rainforests have been degraded owing to the systematic, targeted exploitation of commercial species used in carpentry and cabinetmaking in European countries.

Selective logging of species leads to habitat fragmentation followed by the localized loss of companion plants and pressure on species dependent on the tree species that have been harvested or logged. The orang-utan, for example, is set to disappear by 2020, a victim of the disappearance of the forests of Borneo.

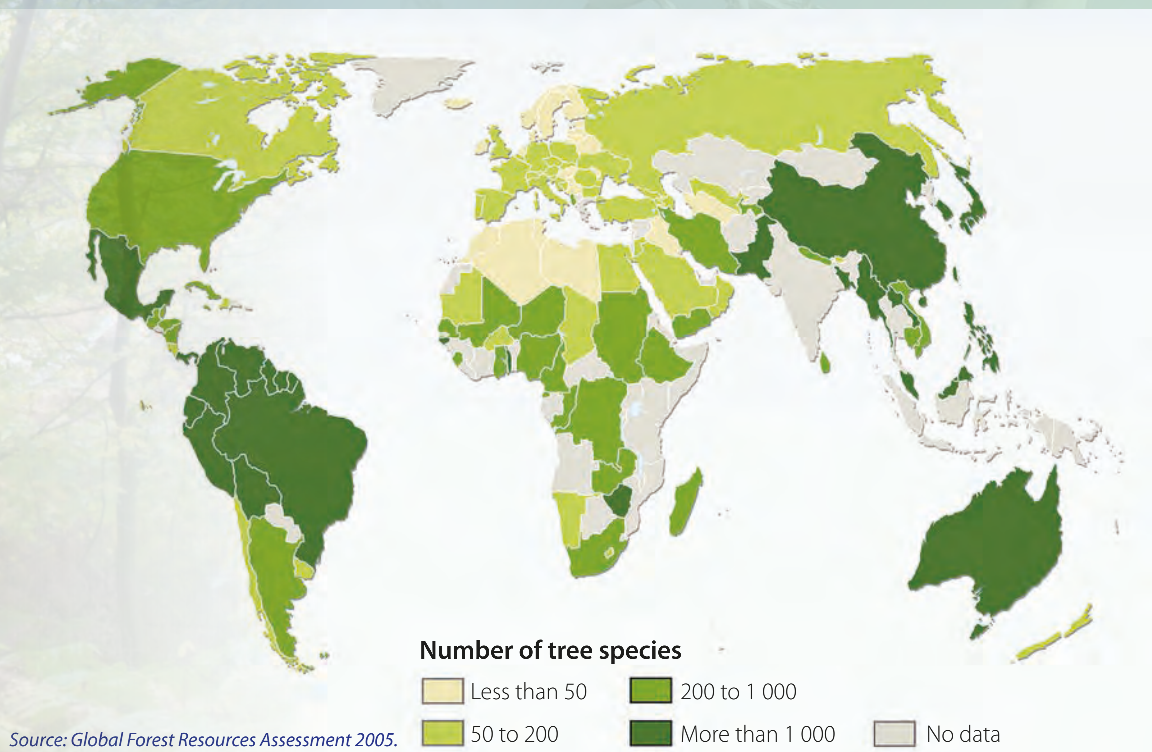
Worldwide, primary forests are located mainly in Brazil, Congo and Indonesia.



Bristlecone pine.

FIGURE 26: FOREST BIODIVERSITY

The biological diversity found in forests depends on their regional location in the world. In some tropical regions there are up to 300 species of different trees per hectare. While in temperate regions ten species represent 50% of forest biomass.



Source: Global Forest Resources Assessment 2005.

* For more details see
Vol. 2, Activity 11.3, Dialogue and action on sustainable forest husbandry (p. 71).

Native tree species do not necessarily acclimatize to disturbed environmental conditions; they produce offshoots with less genetic diversity; the population size decreases (sometimes the populations of species unique to some areas), along with their natural range.

Even selective harvesting of forest tree species can alter the genetic profile of the remaining populations if too many large specimens are taken, as they contain a rich diversity of genetic features.

For example, in European countries, handicraft wood species including valuable hardwoods such as cherry, walnut and large maples that are among the species introduced in plantations do not grow everywhere and it has been observed that good specimens are scattered in the wild and are not optimally maintained.

As already pointed out in GBO2, it is important to appreciate that the biological diversity of secondary or semi-natural forests and planted forests is much less rich than that of primary forests. More and more forests are semi-natural forests where human intervention provides assisted natural regeneration through seeding or planting of native species.*

Slower deforestation does not mean slower loss of biodiversity

While *GBO3* reports a slowing down of deforestation in tropical countries and a general deceleration thanks to reforestation in temperate regions, as well as in China (due in part to lower demand for agricultural land), it should be remembered that the process of deforestation continues at a steady pace.

Morning fog in dense tropical rainforest in Kaeng Krachan, Thailand.
© Stephane Bidouze, Shutterstock.com

The overall slowdown in forest loss does not mean that there is a slowdown in the loss of forest biodiversity worldwide. Quite the opposite, in fact. To return to the above FAO estimate, the global area of primary forest decreased by 400,000 km2 between 2000 and 2010, which corresponds to an area larger than Zimbabwe.

Newly-planted forests are of little interest for biodiversity: they are often industrial plantations or managed solely for their commercial interest (wood production). Their one-track management approach is inadequate because it decreases the biological richness of forests by favouring some species over others and by standardizing habitats.

Forest habitat loss leads to a depletion of species, which are consequently no longer able to provide the resources needed to supply ecosystems.

These resources are then removed from rural communities that previously benefited from them.

The GBO-3 gives two examples of loss of irreplaceable forest habitat, including the *Miombo* savannah woodland. Its degradation is a serious loss of ecosystem supply for these communities.

Although logging intensifies the loss of forest diversity, timber resources are also open access resources that meet basic urgent needs such as cooking food or providing a livelihood.

The threat facing forest plants today is largely a result of harvesting procedures, deforestation and poor management. Competition for these dwindling reserves is intensifying. According to some estimates, 80% of the diversity of forest plant species can be expected to disappear as a result of management activities.

Looking up towards the canopy along the trunk of a giant rainforest tree, Ecuador. © Dr Morley Readm, Shutterstock.com

Miombo woodland. © Geoff Gallice, CC BY 2.0

2. Forest ecosystems: precious reservoirs of biodiversity

In hosting 50% of all the species on the planet – mostly concentrated in the tropical forests – forest ecosystems are reservoirs of biodiversity and resources.

A move towards the sustainable management of forest ecosystems requires a better understanding of the way they operate and greater focus on the services they provide for local communities. This means, on the one hand, developing sustainable management techniques and, on the other, taking greater account of the role of indigenous peoples in managing these ecosystems when designing development policies and establishing the legal framework for their implementation.

A source of wealth for the whole of humanity, a source of profit for those who exploit them, and a living environment for the many indigenous peoples who live near them, it is essential to manage them sustainably.

They provide materials that we find useful every day: timber, lumber, paper, packaging, fuel, medicine and genetic resources, fibres, etc.

Toucan. © MarcusVDT, Shutterstock.com

Tiger. © Kamonrat, Shutterstock.com

Source of wood and fibre

Wood is universally appreciated for its density, hardness, its relative flexibility (making it easier to work with) and high level of durability. It is an essential material for sustainable development since, despite being biodegradable, it is time-resistant. It is also a renewable resource when it is not overexploited: a hardwood forest in a temperate region takes about 80 years to regenerate.

Hardwoods, which have the asset of being resistant to wood-destroying fungi and wood-boring insects, are often rich in resin and tannins. They are a naturally durable, high density and consequently heavy and slow-growing species.

Many exotic woods such as ebony, ipe, ekki and guaiac fall into this category, as do olive and semi-hard woods such as walnut and chestnut which, once they have been properly dried, are very resistant.

In most parts of the world, people know whether to choose one plant over another by taking account of its specific qualities. When restocking becomes possible, the community determines empirically which species is best suited to each specific need.

In Africa, the desert date *(Balanites aegyptiaca)*, being prized for its strength and rot-proof qualities, is used to make everyday tools and timber frameworks; *Commiphora africana,* of the Burseraceae family, produces a light, versatile timber that is ideal for making large objects.

In Europe, pine, being a light species, is particularly suitable for making solid wood furniture.

Everywhere, the best species are in demand and some species combine the needs of traditional local usage with (sometimes illegal) domestic and international trade.

Papuan Korowai tribe in a tree house, Irian Jaya, New Guinea, Indonesia. © Sergey Uryadnikov, Shutterstock.com

Boats and houses on the Amazon river in Leticia, Colombia. © Jess Kraft, Shutterstock.com

Many NGOs have denounced the significant traffic in illegal wood and unbridled exploitation of certain species, which is deemed to be "deforestation" and is damaging to forest ecosystems as well as indigenous peoples. Trafficking may account for a shortfall of several billion euros for producer countries (see below).

Once they have been felled by loggers, the trees are pruned and pollarded. The logs are then transported to sawmills where they undergo initial processing.

The timber is cant-sawn for use in construction – wood is still the most widely-used building material globally. It is cut into various sections to be used as toeboards, joists or trusses as need dictates.

The best section of the log, the bolt, is peeled or sliced to make veneer and plywood. It is also used in the second processing stage when the wood is prepared for use by the furniture industry (flooring, panelling) and in carpentry.

Veneers have long been used in the traditional craftwork, cabinetmaking and marquetry favoured by every culture. In Europe there is a taste for the finer, more exotic species from afar, used to craft precious items.

Today veneers are used in highly modern buildings in developed countries for external and internal wall cladding, murals, sprung flooring, furniture or decorative pieces and the importation of precious, mostly tropical woods continues apace, even if this contravenes the rules.

CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) regularly updates an appendix and a database on endangered species worldwide.

Crane loads a log truck in southern Oregon, USA.
© TFoxFoto, Shutterstock.com

Sawing boards from logs in a modern sawmill.
© Genkur, Shutterstock.com

Among the woody plant species listed by CITES is Brazilian rosewood *(Dalbergia nigra)*, a wood that has long been popular but whose trade is now banned, and other species whose trade is controlled closely such as the African blackwood *(Dalbergia malanoxylon),* the African teak *(Pericopsis elata)* and the Spanish cedar *(Cedrela odorata)* from Mexico, Brazil and Peru, which is in demand for its particularly attractive dark brown hue.

Other species are becoming scarce and are constantly mentioned by organizations such as the Global Trees Campaign; they include zebrawood (*Microberlinia bisulcata*), which is known as zebrano in Germany and zingana in France. Zebrawood is a curiosity, a rarity, prized for furniture and veneer but habitat destruction poses a real threat to the species.

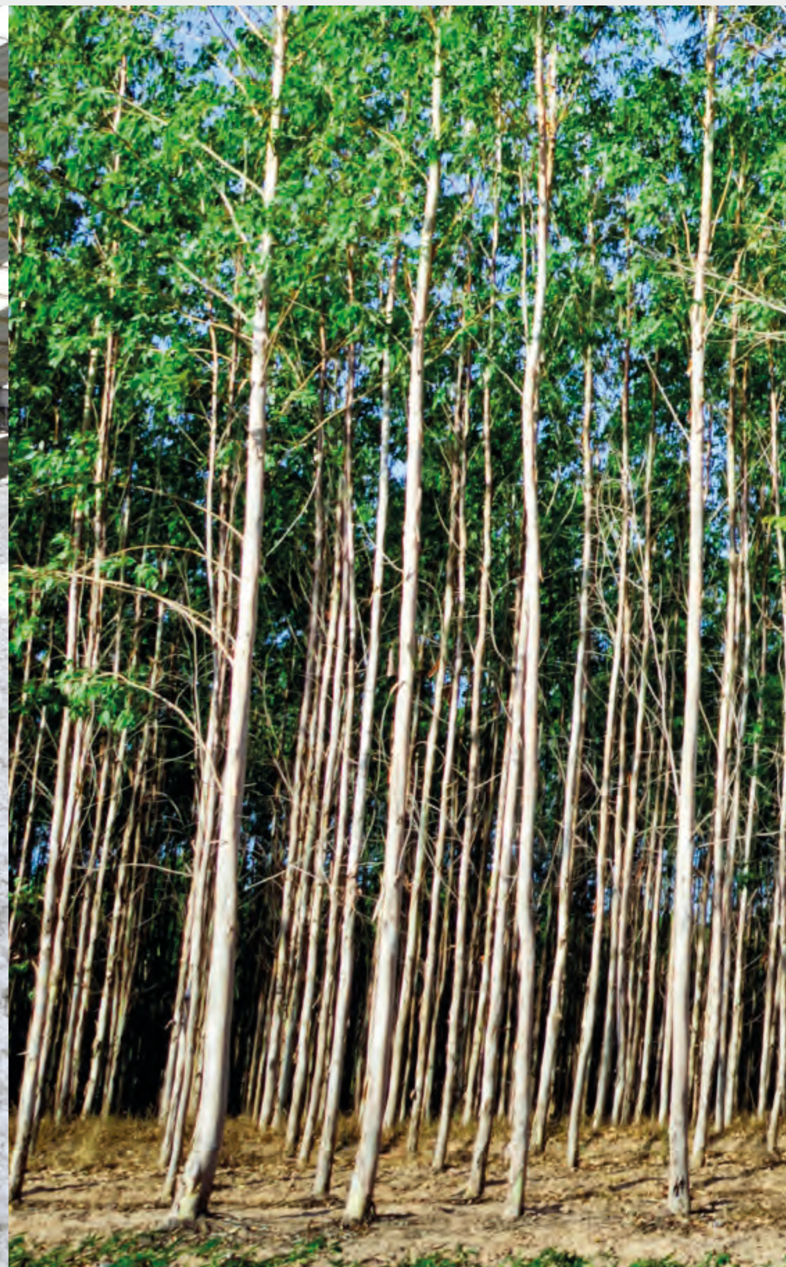
During the initial processing procedure, the poorer quality bolts, sawdust and wood waste are collected and crushed to make paper pulp or are pressed to produce particle board and fibreboard.

This pulpwood product is used to make chipboard and, especially, paper pulp, a paper-based material obtained from cellulosic plant fibres that have been isolated from the lignin contained in the wood. In industrial production, the fibres are crushed with water and then separated and pressed into a thin sheet. Most paper is produced from wood fibres but it can be made from any fibrous plant material such as bamboo, linen, raffia and especially reeds and hemp.

Pulp production requires large amounts of water and energy and accounts for 40% of forestry operations. The impact on the environment and biodiversity is considerable, owing to the many additives used to produce different qualities of paper, the impact of transporting it and the upstream felling and transportation of the wood.

Raw material for making paper.
© Li Chaoshu, Shutterstock.com

Plantation of eucalyptus trees for the paper industry.
© Jannarong, Shutterstock.com



The impact on biodiversity comes from the conversion of primary and secondary forests whose ecosystems have been relatively well preserved with intensive planting of eucalyptus, poplar and conifers (in Brazil a cultivated eucalyptus can be cut down every four years) which are only intended for paper pulp. Most industrially planted forests are owned by paper industries that run them on a cyclical basis.

The timber industry is an expensive one, given the chain of stakeholders involved in growing, felling, grapple yarding, transporting and processing the raw material. Rational management recognizes the importance of processing the wood on site and developing industrial infrastructures and local transport solutions with a lower economic and environmental cost. Private investment is widespread, from industrial felling which currently uses heavily mechanized equipment to fell trees in strips, leaving strips wide enough not to crush the young specimens, to anarchic, selective, subsistence felling, done on a shoestring.

For all these reasons, full traceability of the global wood supply chain is a major environmental and social challenge, but it also an issue for the timber industry in terms of economic efficiency and quality development.

Traceability involves monitoring the stages of the production chain from felling to first and second stage processing through to recycling, but it also involves forest management, as some eco-labels such as the FSC (Forest Stewardship Council) are seeking to establish.

In fact, wood industries are structured differently in different countries: they may be placed under the control of the State, but they may also be privately managed and poorly monitored at regional level. Brazil and Indonesia, for example, have recently banned the sale of logs and now only export sawn and planed timber, which provides better value-added for these countries; but many tropical countries export mainly logs, which raises the question of wild harvesting and the underlying destruction of forest ecosystems.

According to GBO-3, reduced deforestation in the Brazilian Amazon is partly a result of the recent integrated management of resources, thanks to measures taken jointly by government, the private sector and local authorities.

Boreal forest in the Yukon territory, Canada.
© Pi-Lens, Shutterstock.com

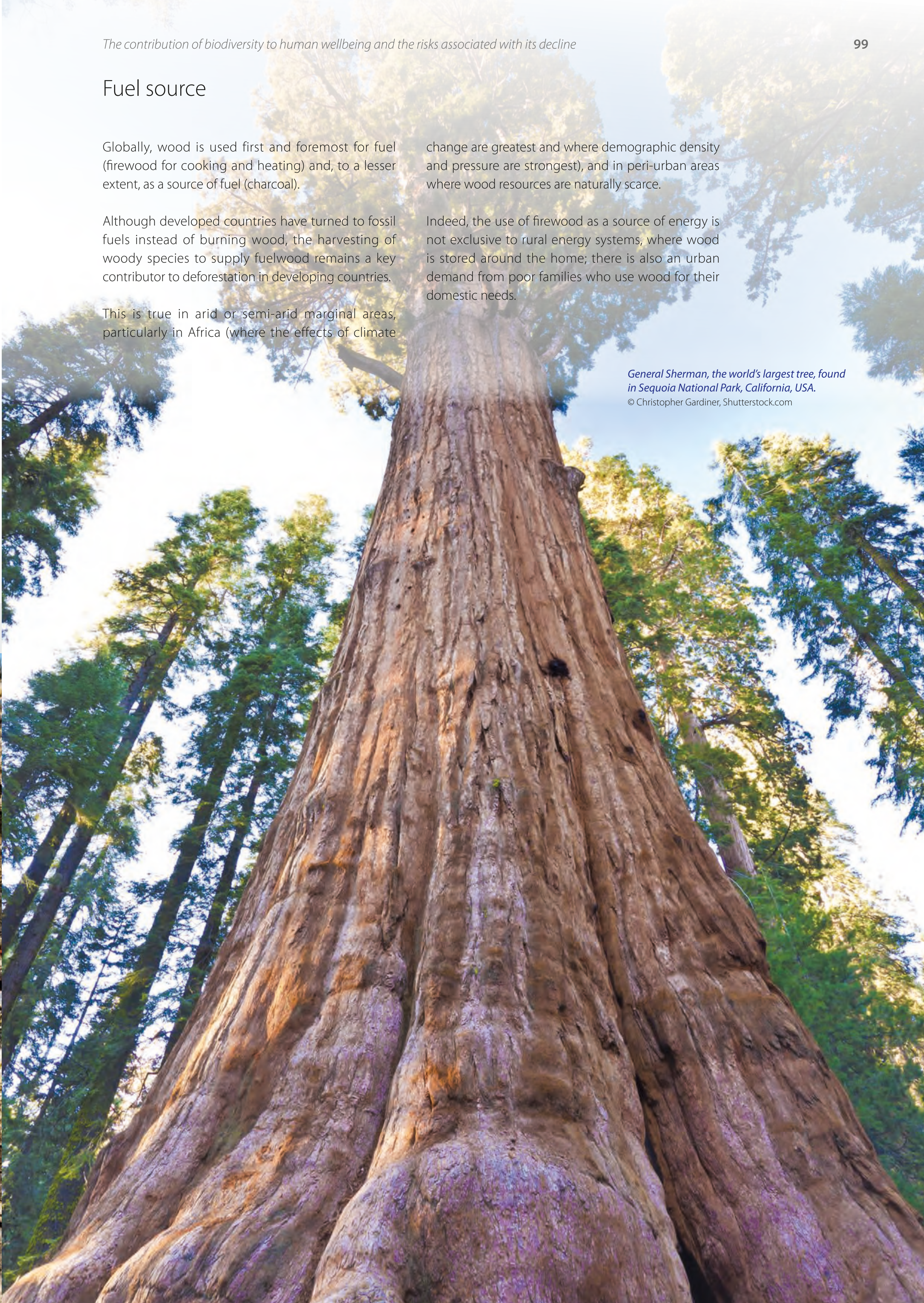
Fuel source

Globally, wood is used first and foremost for fuel (firewood for cooking and heating) and, to a lesser extent, as a source of fuel (charcoal).

Although developed countries have turned to fossil fuels instead of burning wood, the harvesting of woody species to supply fuelwood remains a key contributor to deforestation in developing countries.

This is true in arid or semi-arid marginal areas, particularly in Africa (where the effects of climate change are greatest and where demographic density and pressure are strongest), and in peri-urban areas where wood resources are naturally scarce.

Indeed, the use of firewood as a source of energy is not exclusive to rural energy systems, where wood is stored around the home; there is also an urban demand from poor families who use wood for their domestic needs.



General Sherman, the world's largest tree, found in Sequoia National Park, California, USA.
© Christopher Gardiner, Shutterstock.com

When demand increases and resources are less accessible, people in rural communities embark upon piecemeal, unmonitored initiatives to collect, transport and distribute firewood to urban areas. This leads to significant localized overexploitation of resources around towns and cities. If we take the example of Ouagadougou in Burkina Faso, the city's consumption of wood energy in in 2000 led to the clearing of 3,000 hectares of fuelwood which, according to FAO, corresponds to half its area and is by far the main cause of the depletion of timber resources in the peri-urban area.

There are similar cases in several regions including northern Côte d'Ivoire, which is highly urbanized.

Charcoal use is constantly increasing in urban areas of Africa because it is derived fuel that is easy to transport and store and which, in addition, emits no smoke.

The carbonization process, however, leads to a significant loss of the energy contained in the raw material.

It is therefore an expensive fuel in terms of the amount of wood used and contributes to a reduction in the populations of certain species that are recommended for use in manufacturing; these are often very dense woods that are valuable because they are used for timber, and which, because of repeated harvesting, are becoming endangered as species. These include African mahogany *Khaya senegalensis* and *Pterocarpus erinaceus* or Senegal rosewood; these two forage species also suffer from being pruned too often, and are consequently degraded and threatened due to extensive livestock farming.

But in addition to the focus on the use of certain species, thus leading to their depletion or extinction, the frantic search for wood energy in the above regions causes an overall reduction in species populations, a depletion of timber resources and a worrying decline in fuel supplies.

Traditionally, people are familiar with the high heat capacity species in their region, but heat capacity is becoming a less critical factor as resources become more scarce: after the high-density species, some more common species such as the shea tree *(Vitellaria paradoxa)* in Africa, a fruit specimen that is widely used for food and in industry, are being used for firewood.

The forest cover of dry forests is losing its density, turning into woodland and savannah woodland. Daily demand for wood energy increases along with population size, and cases of severe shortages have been recorded in southern Benin and in sub-Saharan Africa. Benin consumes annually its own estimated output of wood energy (nearly 6 billion cubic metres) and more besides.

Measures are urgently needed to combat the fuelwood crisis. A more rational management of logging can help to regenerate the species naturally, by observing a fallow period and through natural seeding.

The use of improved stoves and alternative energy sources such as gas is also recommended. Where there is no natural gas, wood gasification and the production of synthetic natural gas (SNG) from wood are some of the new technologies currently being developed and improved.

Wood burning in a fireplace.
© Olga Pink, Shutterstock.com

Burning charcoal.
© Pavel Hlystov, Shutterstock.com

Savannah woodland, Tarangire National Park in Tanzania.

Palm oil plantation.
© KYTan, Shutterstock.com

Rice fields in Mu Cang Chai, Vietnam.
© John Bill, Shutterstock.com

Indeed, conversion to gas makes it possible to obtain high yields with low emissions and it can be carried out in a decentralized manner. Indoor air pollution generated by fine particles from burning wood or charcoal is a public health problem in developing countries. These substances are emitted during combustion and are very harmful because they penetrate deep into the respiratory system of the inhabitants.

With the development of new technologies that make optimal use of wood energy, this resource could be an energy of the future.

In addition to its environmental credentials and the importance of wood energy for the conservation of biodiversity, it should be remembered that wood burning can be carbon neutral in terms of air emissions, as long as the wood is exploited on a renewable basis, i.e. if care is taken to compensate for or regenerate a clearcut, for example, or if felling is managed sustainably by doing it gradually or using a selection system.

Better management of sections of planted forests can sometimes prevent the destruction of precious parallel primary forests that are rich in biodiversity.

With regard to biofuels, the cellulosic ethanol industry could, under certain conditions, be a way forward.

Agrofuels generate large areas of crops that are cultivated for their oil (sunflower, rapeseed, palm oil) or for their sugar (corn, wheat, sugar cane, sugar beet), and which consume a huge amount of space that is often obtained at the price of the conversion of natural habitats. They have a balanced carbon footprint, the harvested crops being replanted or re-sown because the atmospheric carbon dioxide that accumulates as they grow is returned during combustion.

The cellulosic ethanol industry, once it has been developed, could yield better returns than agrofuels through efficient and economical processing of wood waste (chips, pellets) and straw (stubble) into sugar for ethanol production.

Lower quality forest species (poplar, birch, eucalyptus) can be used for cellulosic ethanol and wood gasification, thus enabling valuable species to be preserved and, crucially, providing for the organized recycling of wood waste, whether from the wood-processing industry, urban wood waste, household wood waste, and so on. For the phases involving the transformation of cellulose into sugars and the fermentation of sugars into ethanol, processes are currently being examined to curb emissions and use bacteria (present in termites), micro-algae, or a possible combination of these processes in paper pulp production.

As long as industrial forest plantations can reduce rather than increase the rate of deforestation; as long as they focus, for example, on small-scale ethanol production for local needs, using available biomass that is exploited sustainably or obtained without massive deforestation; and as long as this type of production can be used in conjunction with other energy sources, using (wood or plant) waste and without resorting to genetically modified organisms (GMOs), then it can also be considered an industry of the future in terms of maintaining biodiversity.

Algae fuel in a photobioreactor.

Ethanol manufacturing plant in São Paulo, Brazil.

Sources of medicines and genetic resources

In addition to providing traditional forest economy products such as timber, fibreboard, paper pulp and fuelwood, forest ecosystems also provide biological resources that are essential to communities and which could now be exploited much more sustainably, paving the way for a forest bio-economy that could provide numerous benefits for all stakeholders, whether local people, members of local authorities, policy-makers or international market players.

NTFPs (non-timber forest products) are a wide range of products that include medicinal plants, which provide many benefits and valuable resources: medicines and plant protection products, biochemicals, genetic resources, personal care products and essential oils, and so on.

Biodiversity is, first and foremost, a matter of life and it creates unexpected forms: living organisms, especially plants, develop molecules whose complexity and diversity are beyond our imagination. They make natural substances with remarkable properties.

In concentrating an impressive number of endemic species, tropical forest regions constitute a pool of natural bioactive substances that could potentially be used to create new drugs.

In the vast source of molecular diversity that the living environment represents, some 200,000 structures of secondary metabolites – chemical compounds or active substances with interesting pharmacological properties – have been described and can now

Tropical rainforests boast the highest biodiversity of any ecosystem and contain over half the earth's plant and animal species.

Tropical rainforest in the upper Amazon basin in Ecuador. © Dr Morley Read, Shutterstock.com

be used as a resource in biotechnology (medicine, pharmacy, cosmetics, agrochemicals, and so on).

However, biodiversity remains largely unexplored. It is estimated that only 3% of classified vascular plants have been studied for their pharmacological potential and only 2% of identified marine species have been analysed in this way.

Today, the massive and continuous degradation of natural forest habitats means that the disappearance of these as yet unexplored species may come faster than their discovery. With them we will lose an irreplaceable library of data, knowledge, genetic material and, most importantly, solutions, technological advances and cures for diseases.

Since time immemorial, the many indigenous peoples of the world have enjoyed the benefits of medicinal plants.

Over 200 plants, fungi and lichens have been identified as being used for various purposes by aboriginal Canadians living in various boreal or temperate forest regions, while in the Amazon over 1,300 medicinal species are used by indigenous peoples. The use of traditional plants is then still widespread – between 60% and 80% of people use them as medicines – and it can be assumed that for many of them, they form the basis of primary care.

Many forest species can be classified as pharmacological species. Depending on custom, religion, region and the nature of the illness, different parts of the tree are used: leaves, bark, roots, seeds and the same plant can have different uses. At all latitudes, people protect the local woody species.

In the Chilean forests, the boldo *(Peumus boldus)* sometimes produces majestic specimens and has long been recognized as a remedy for liver ailments;

Temperate rainforest in Olympic National Park, Washington, USA © Natalia Bratslavsky, Shutterstock.com

on Sumatra in Indonesia, local species of cinnamon are cultivated for their antifungal properties; in Africa, the precious wood specimens referred to above – the *Khaya senegalensis* and the *Milicia excelsa* – are used to treat dozens of diseases; in the rainforest of Panama, Embera women (known as *botanicas*) plant forest species in the gardens of their homes and use them to treat common childhood illnesses and as a remedy in gynaecology and obstetrics.

Custodians and users of medicinal genetic diversity

For the majority of people in developing countries, biodiversity and traditional healthcare are inseparable, as the fact that the distribution areas and fields for growing medicinal plants are protected by the local communities attests. They are sometimes known only to herbalists. They may be part of or even constitute entire areas that are considered holy by the community, such as the sacred forests of the Sherpas of the Himalayas, or the high-altitude Páramo for the Andeans. Medicinal plants often have a sacred dimension: they are directly associated with rituals or, growing as they do on sacred sites, they are venerated as an object of worship. It is common to find altars at the foot of forest species, such as a closely related species of the cade juniper in the forests of north-western Nepal. Biological diversity and cultural diversity are thus closely linked, and we will return to this cultural, recreational dimension that is a feature of forest ecosystems and their potential use for activities including contemplation, education, leisure and tourism.

Indigenous peoples are the custodians – *de facto* but not *de iure* – of medicinal biodiversity, but this is not always to their advantage. Measures taken by States have not always encouraged resource conservation because too often they provide subsidies for agricultural facilities and the implicit conversion of forest plots into farmland for crops or livestock.

Páramo is considered sacred by some Andean indigenous peoples.
Páramo landscape in Colombia near Nevado del Ruiz, dotted with espeletia plants. © Jess Kraft, Shutterstock.com

In addition, medicinal plant resources have been coveted, plundered, trafficked and traded illegally because they are valuable to and exploited by the international pharmaceutical industry, laboratories, and the cosmetics and the agrochemical industries.

For centuries, pharmacology has acknowledged the beneficial action of medicinal plants and therefore seeks to extract some of their active ingredients. At present, 40%-70% of approved drugs still come from natural substances. Before a plant-derived chemical compound can be exploited for therapeutic purposes, it has to be isolated. This takes a long time. It is estimated that for every 20,000 molecules isolated, only one molecule with drug potential is identified.

However, research continues to make progress. Once individual tests have been carried out, high throughput screening can now test in just a few weeks the action of almost 500,000 chemical compounds on a biological target.

On the other hand, where a chemical compound has only ever been used after being extracted from the plant (as with morphine from the poppy and digoxin from *digitalis lanata*), our understanding of the relationship between the structure of the molecules and their biological activity is now such that we can generally synthesize and improve them. And the biological activity of the new compounds has often proved better than that of the natural extracts.

However, most drugs are "semi-synthetic", i.e. they are a synthetic product whose starting point is a natural product. Taxol, for example, is an anticancer drug whose active ingredient is extracted from a rare molecule of the yew tree. This active ingredient is too rare, even on the plant, to be extracted in large quantities and still too complex to be synthesized by chemists at a lower cost, so it is synthesized from a more accessible part of the plant. Nature remains the starting and the reference point.

Dragon bridge in the Sacred Monkey Forest Sanctuary of Ubud in Bali, Indonesia.
© Elena Ermakova, Shutterstock.com

A young man preparing ayurvedic medicine in the traditional manner .
© Nila Newsom, Shutterstock.com

Shaman in Ecuadorian Amazonia during an ayahuasca ceremony.
© Ammit Jack, Shutterstock.com

Molecular diversity, genetic diversity and plant and animal diversity intersect and enrich each other in medicinal biodiversity. It is therefore essential to stress the importance of conserving local medicinal biodiversity.

In addition to enabling the industrial extraction of pure substances for major therapeutic purposes, medicinal forest plants provide chemical compounds that are used directly as simple family remedies that are very popular with people in developed countries in the form of powder, capsules, tinctures or extracts. The active ingredients of the plants are thus standardized and provide a lucrative range of authorised plant medicines. For the benefit of humanity as a whole and in addition to advances in chemistry, the botanical expertise and the pharmacopoeia of traditional societies are invaluable resources for exploring the bioactive substances that are present in abundance in nature. Moreover, a large part of the research carried out by Western institutions into the natural substances of the forests of Guyana, Panama, Congo and New Caledonia is devoted to traditional pharmacopoeia.

By pooling the tools of anthropology, ethnobotany and ethnopharmacology, the medicinal species indicated by traditional societies can be accurately identified, as can the parts of plants used to treat diseases and symptoms in a specific cultural context. This is a mine of information, knowledge and best practices that have been tested empirically for generations and that is extremely useful for research, particularly in order to avoid random exploration and for sorting potential species upstream of the laboratories.

In return, the knowledge of the traditional healers who constitute the living memory of the relationship between local ecosystem and herbal medicine can be improved, especially as regards recommended dosages, specific toxicities and the long-term adverse effects of certain plants; because consuming the plant whole, as traditional societies do, means that other substances contained in the plant are consumed along with the active ingredient and that it is impossible to know exactly how much active ingredient has been ingested.

The combination of modern and traditional pharmacopoeia should prove a highly productive collaboration and help to develop generally affordable medicines, herbal remedies and healthcare products. To this end, it is essential to recognize the rights of indigenous peoples and traditional healers, who should be able to benefit from the exploitation of medicinal plants in their forests.

Reference can be made here to the scope of the Nagoya Protocol adopted under the auspices of the Convention on Biological Diversity (CBD) at the last Conference of Parties (COP) in October 2010. The States Parties to the Convention adopted this international treaty on access to and benefit-sharing of genetic resources. The Treaty builds on the Convention negotiations for an international regime. The negotiations sought in particular to recognize the role of traditional medicine and medicinal biodiversity expertise in the provision of health care, and to consider integrating local healthcare systems into national healthcare systems. They also focused on issues surrounding the intellectual property rights of indigenous peoples.

The Nagoya Protocol takes account of the contribution of traditional knowledge used in conjunction with genetic resources in its definition of the rules and procedures required to ensure access and benefit-sharing in each contracting State.

Since 1998, the L'Oréal-UNESCO Awards have recognised more than 92 laureates from 30 countries, exceptional women who have made great advances in scientific research.
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Professor Quarraisha Abdool Karim, laureate of the For Women in Science prize for 2016, for her remarkable contribution to the prevention and treatment of HIV and associated infections, greatly improving the quality of life of women in Africa.
© Fondation L'Oréal

Biodiversity
and supply: aquatic ecosystems

Estuaries and deltas are meeting points between freshwater rivers and saltwater seas and oceans.

Irrawaddy Delta, Myanmar. © NASA

At the level of our biosphere, the water cycle allows the small percentage (about 1%) of available freshwater to continually renew itself. Without these slender resources, fields and forests would wither away and the living world would disappear. Water is therefore permanently on the move, circulating between sea, air and land in a complex cycle driven by the sun, which provides the energy necessary for evaporation.

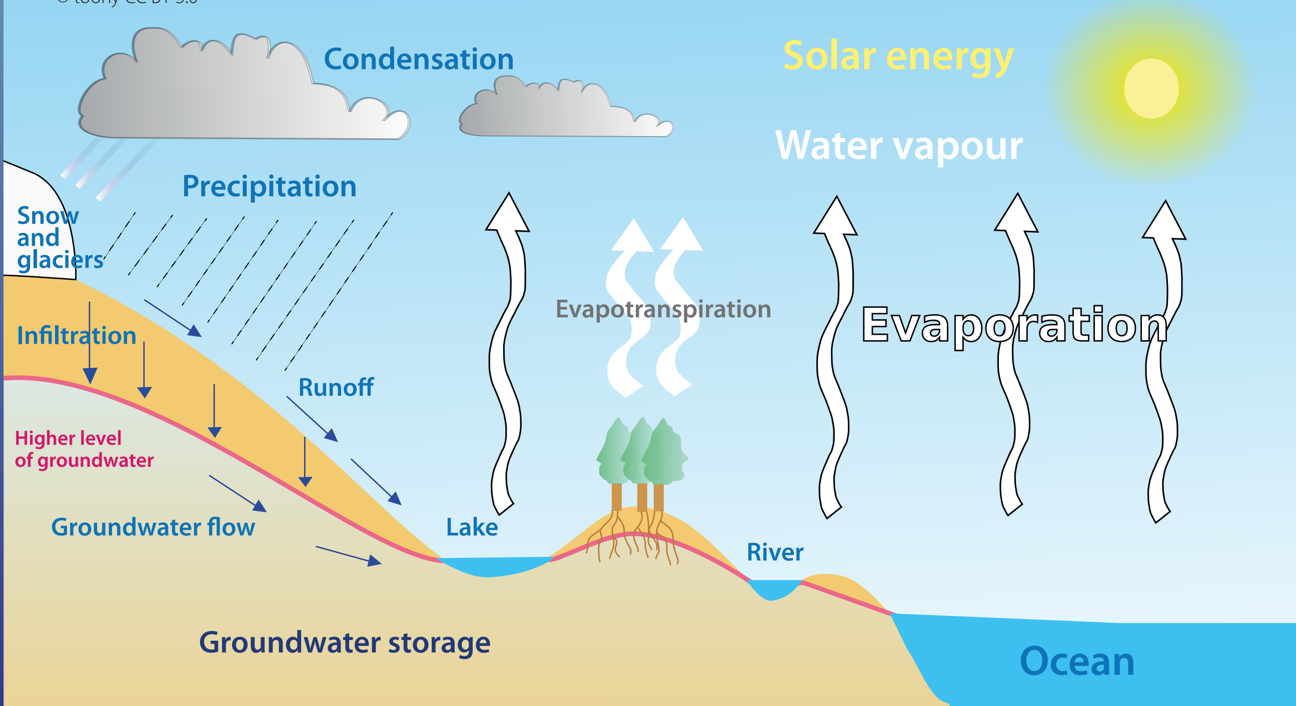
At every stage in this cycle, from condensed steam to glaciers, snowmelt to high-altitude springs, streams to lakes, rivers to deltas, and rocky coasts to oceans, water creates a wide variety of aquatic ecosystems, revealing different aspects of the interactions between land and water itself.

At the origin of the cycle is the surface water of oceans, a saline solution that nevertheless provides us with freshwater. This emanates from the vast expanses of sea that surround us, all the oceans forming a continuous whole that encircles our continents.

We still have much to learn about high-seas ecosystems and deep-sea habitats. We do know though that these environments sustain life, and that their integrity and health influence the biosphere's equilibrium. They affect, for instance, the availability of the Earth's surface water, which is indispensable to life. This very water, once it has evaporated, falls back to earth as precipitation and rejoins the ocean via rivers. When this water stays on the surface, we derive multiple goods and services from it. The same water also infiltrates into the ground, feeding plants through their roots or becoming groundwater, where it can be accessed via drilling to provide for our own drinking water needs.

The water cycle enables the small percentage of usable freshwater in our biosphere to be constantly renewed.

FIGURE 27: THE WATER CYCLE



In spite of this, the great river networks, the continental wetlands, and the coastal and marine ecosystems have all, in recent decades, been adversely affected, modified and frequently degraded. We have witnessed a considerable reduction in the extent of habitats and in the numbers of aquatic species, and a serious, sometimes irreversible, deterioration in environments that support life.

Before analysing the loss factors behind the degradation of aquatic ecosystems, it is essential to highlight the diversity of their characteristics and the wide range of services, especially provisioning services, they provide for us.

1. Coastal ecosystems

As floodplains, muddy deltas and estuaries fill with debris and sediment, free-flowing water becomes stagnant, generally shallow and covered with grassy plants.

Among the diversity of aquatic areas, it is in coastal areas where water seems to stagnate in shallow pools or where it spreads out in vast estuaries or endless deltas – giving the impression of dismal, lifeless landscapes – that we find a high concentration of biological life, the vitality and productivity of which is unrivalled.

As places where the land meets the sea, and where freshwater mingles with saltwater, coastal ecosystems have within their waters high concentrations of nutrients that come mainly from the sediment transported by rivers. This sediment is fertile, since the clay of which it is composed contains nutrients; and so, many indispensable minerals are washed down to the sea by rivers.

Other nutrients are carried to every part of the coastline, and are brought to the surface by vertical or upwelling currents, which lift them from the ocean depths.

This concentration of nutrient-rich matter gives rise to networks of food chains, which generate the most appreciated edible products in aquatic ecosystems – shellfish and other sea foods, especially fish. These are found in large quantities and many varieties in coastal areas, and form the basis of a staple diet for many human communities around the world.

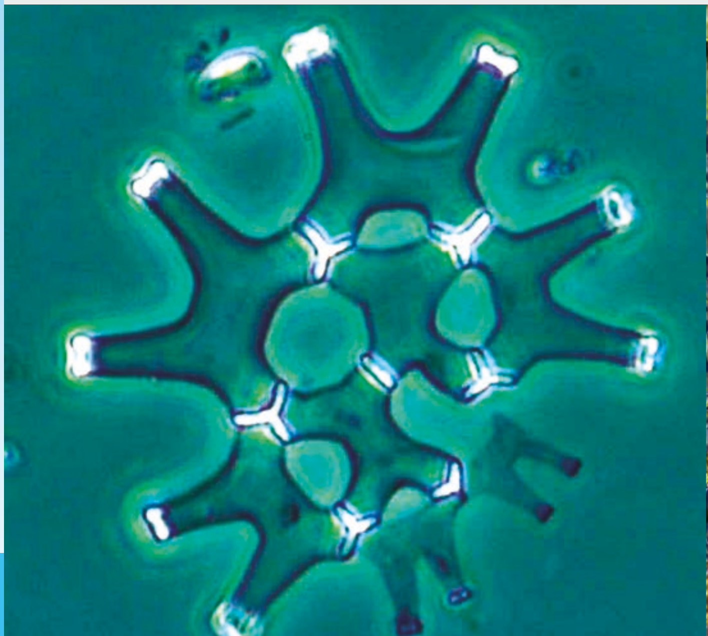
As in the case of terrestrial ecosystems, the numerous food chains that involve aquatic species rely on plants. From single-cell algae to the intertwined strands of kelp, and from beds of phanerogams (higher plants) on the sandy or muddy bottoms to floating flowering plants with submerged roots like water lilies, plants proliferate in coastal areas and provide food and habitats for different kinds of molluscs, gastropods and crustaceans, according to the individual environment. Coastal areas also support colonies of larvae, nymphs and insects, providing food for all the fauna – fish, marsh birds, coots and moorhens in Africa, waders including herons and egrets in Europe, and muskrats and racoons and so on.

Here we focus first on estuaries, each of which possesses a physical, ecological and dynamic system, formed through interaction with the land.

As with terrestrial ecosystems, the numerous food chains that involve aquatic species rely on plants.

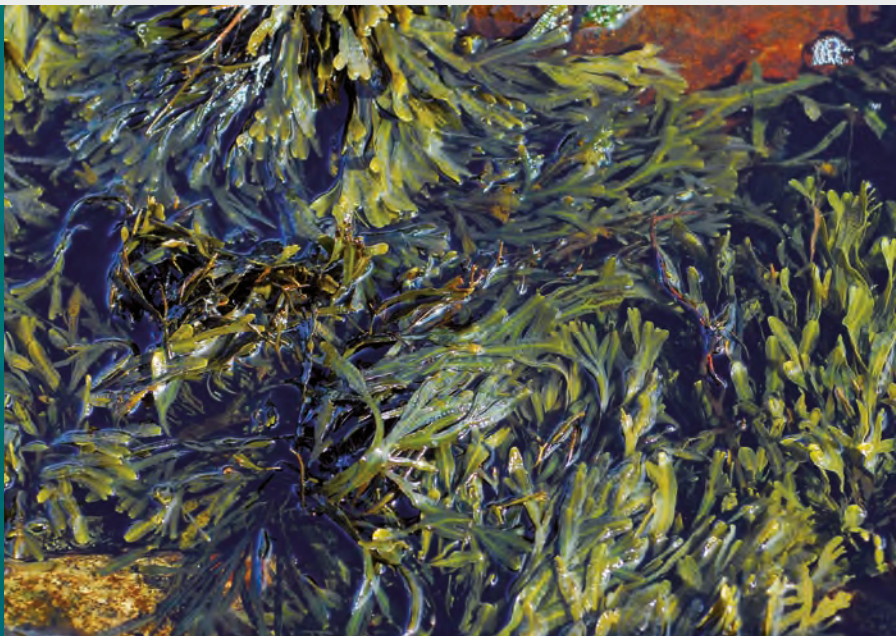
These plants are microscopic (such as unicellular algae and phytoplankton).

Unicellular algae. © J-C Druart, INRA



But they are also present in the form of underwater forests.

Brown algae. © Peter Prokosch UNEP Grid-Arendal



Marshes, salt marshes, salt ponds and sea-grass beds

As floodplains, muddy deltas and estuaries fill with debris and sediment, free-flowing water becomes stagnant, generally shallow and covered with grassy plants. These wet areas where the vegetation consists predominantly of Poaceae (reeds), Typhaceae (bulrushes), Juncaceae (rushes) and Cyperaceae (sedge) are what we call marshes.

Thanks to their creeping trunks, varieties of typha or bulrush propagate rapidly and stabilize waterlogged soil, forming a dense cover of high grasses. Such cover provides shelter for breeding birds – rails and bitterns – ducks and wild geese in the deltas of the Guadalquivir River in Spain and the Rhône in France.

This mass of emergent and submerged plant life of filamentous algae and plankton provides food for the teeming fauna of the marshes including insect and adult larvae (ephemera and water boatmen), tiny crustaceans and some 3,500 species of mosquito. The latter live near brackish water where they lay their eggs; the larvae and nymphs grow in the water and then serve as food for the fish. About 50 species of mosquito inhabit the coastal marshes of oceanic Europe.

Coastal marshes are natural areas for the growth of young fish or fry and other young sea animals, ranging from shrimp to the larvae of saltwater tarpons. In addition to providing food for the fauna, the vegetation mass of Poaceae and other macrophytes in the coastal marshes decomposes and enriches neighbouring seas by releasing nutrients and producing organic debris.

Another virtue of marshland vegetation is that it provides the local population with stems, leaves and roots for basketwork and furniture-making and, in the case of sturdy emergent plants, solid building materials.

For example, in the Lake Titicaca region of Latin America, as in numerous other coastal marshland areas, the local people weave local reeds (totora) to make boats (caballitos), houses, sails and a multitude of everyday objects.

Elsewhere, the common water hyacinth (Eichhornia crassipes) is an exotic invasive macrophyte in Southeast Asia, whose stems grow at an impressive rate. It is now widely harvested and used for making

The first wetlands declared 'of international importance' under the Ramsar Convention are located in Garig Gunak Barlu National Park in northern Australia on Aboriginal land. This satellite image shows different habitats of the Park: mangrove (dark green), sandy beaches and mudflats (white), sparse eucalyptus forest (ocher).

Garig Gunak Barlu National Park, Australia. © Landsat: data available from the United States Geological Survey (USGS)

In the Lake Titicaca region of Latin America, as in numerous coastal marshland areas, the local people weave local reeds (totora) to make boats (caballitos), houses, sails and a multitude of everyday objects.

Titicaca. © Thomas Quine, CC BY 2.0

Coastal marshes are natural growth areas for young fish or fry and other young sea animals, ranging from shrimp to the larvae of saltwater tarpons.

Freshwater shrimp. © Albertomeg, Public Domain

quality beds, chairs and sofas. Its roots, once they have been boiled and dried out, are gathered into cords and then woven around a bamboo frame. These traditional work methods offer several advantages: they visibly slow down the plant's progress (which in any case should not be assisted), boost the market by creating exports, and with the emergence of eco-design offer an alternative to leather and plastic furniture, the production of which causes pollution (CO_2, and the use of chemicals in the tanning and dyeing process).

Salt marshes occupy a special place among wetlands. They are found nested within shallow lagoons or along low-lying coastlines, locked behind sandbanks and islands.

The incoming and receding tides flood most of the marshland area twice a day. They contain numerous halophytic plants (adapted to saline conditions) such as glassworts, which excrete salt, rock samphire (*Crithmum maritimum*), a crassulescent plant, and common sea lavender (*Limonium vulgare*), which flourishes in salt meadows, as well as numerous organisms capable of withstanding periodic flooding at high tide.

Swept by the spray and the tides, these environments are constantly fed fresh nutrients and are among the most productive ecosystems in existence. Strewn with silt and organic debris, they very quickly become home to algae and plants. At low tide, the silted beds of the salt marshes are populated with infinite numbers of every species of crab, depending on the location, including fiddler crabs, edible crabs, stone crabs, hermit crabs, blue crabs and so on. They share this environment with numerous shellfish, ranging from fluted-shell mussels to razor shells, buried in the mud.

Seafood flesh is an indispensable source of protein for populations in coastal areas, who are sometimes very poor. According to the Ramsar Convention on Wetlands,* 75% of commercial fish stocks, and shellfish – a delicacy in many localities and cultures – depend on estuaries, especially mangroves and lagoons. These are themselves dependent on freshwater areas further upstream, such as rivers and lakes, which maintain water quality, thereby allowing food chains to develop, up to and including shellfish.

* **For more details see**
Part 3, Greater consistency of action and jurisdiction, The Ramsar Convention (p. 176).

Salt ponds are coastal basins of seawater from which salt is harvested by evaporation. This process occurs

Among the wetlands, salt marshes occupy a special position. They are found embedded in shallow lagoons along low-lying coasts, locked behind sandbars and islands.

Salt marsh. © F. Carreras, INRA

At low tide, the silted beds of the salt marshes are populated with infinite numbers of every species of crab, depending on the location, including fiddler crabs, edible crabs, stone crabs, hermit crabs, blue crabs and so on. They share this environment with numerous shellfish, ranging from fluted-shell mussels to razor shells, buried in the mud.

From top to bottom:

Raiatea crab. © Remi Jouan, CC BY SA 3.0
Cockles. © Benjamin Féron CC BY SA 3.0

through the combined action of sun and wind. These installations are linked to an agricultural style of farming practice: salt production. The skills of salt-marsh workers lie in the optimal exploitation of natural conditions in the regions where the marshes are located – increased salinity in the hot season or a higher rate of evaporation, depending on whether the ponds are located in Morocco, on the French Atlantic coast or in San Francisco Bay.

* **For more details see**
Part 2, Biodiversity and the cultural services of ecosystems (p. 148), and Vol. 2, Activity 6, People, landscapes and *terroirs* (p. 30).

This fine-grained and comprehensive knowledge and the accompanying vocabulary and imagery, confer on the salt ponds the special status of a *terroir*.*

Populations on the coast have often wrested from the sea the space needed for production. This includes grazing land for livestock, salt extraction, the maturation of oysters (oyster farming) and the farming of seawater fish (aquaculture). Traditionally, salt meadows were given over to extensive cattle-rearing, salt ponds to salt production, salt marshes to oyster farming and aquaculture, and brackish marshes to extensive fish-farming. Today, however, diversified commercial exploitation of these environments and the specialized techniques associated with them have been largely abandoned, and the different facets of the marshes seem to matter less and less.**

** **For more details see**
Part 2, Biodiversity and the cultural services of ecosystems (p. 148.

Sea-grass beds are underwater grasslands consisting of dense populations of flowering plants with long, narrow leaves, resembling pastureland. These 'beds' shelter a multitude of associated species, including numerous marine herbivores. Two of these animals, the dugong and the manatee, constitute important links in the sea-grass food chain. Both species are endangered and classified as vulnerable by the threat categories of the IUCN Red List (the extinction risk for these species is deemed to be greater in the wild).

By regularly eating enormous quantities of submerged plants from the beds, marine mammals help to maintain the high rate of primary productivity in these environments. These environments are extremely precious, since they constitute, along with mangroves and coral reefs (see below), unrivalled breeding grounds for fish.

Sea-grass ecosystems are in sharp decline globally, and are now recognized as areas that provide support to commercial fishing or, at the very least, enrich fishing areas. They also deliver considerable ecological services by capturing large amounts of carbon.

Sea-grass beds are underwater grasslands consisting of dense populations of flowering plants with long, narrow leaves, resembling pastureland.

Posidonia seagrass. © Gronk CC BY SA 3.0

Mangroves

In temperate regions, sandy shores and rocky coasts draw a clear boundary between land and sea.

In tropical and subtropical regions where the coastlines are very muddy and large amounts of sediment accumulate, water bodies become choked with vegetation and trees become established in grassy marshes, transforming them into wooded swamps.

In tropical regions, dense mangroves border the estuaries, extending the coastline further out to sea. These flooded forests incorporate populations of halophytic woody plants, which are adapted to the saline environment.

The Ramsar Convention guidelines define mangroves as 'wooded, inter-tidal ecosystems which are found in the tropical coastal environments, sheltered and rich in sediment, that are located between 32° N (Bermuda) and about 39° S (Victoria, Australia)'. They are found in Asia on the fringes of the Ganges and Mekong deltas, and along the south-eastern seaboard of the United States.

Characteristic examples include the bald cypress (*Taxodium distichum*) and the water tupelo (*Nyssa aquatica)* in North America, and the mangrove – a generic term denoting several genera including *Rhizophora*. Many are endowed with woody aerial roots called pneumatophores; these function both as respiratory organs for taking oxygen to submerged roots and anchoring systems that compensate for the instability of wet soils. In addition, a system of arch-shaped stilt roots gives mangroves secure moorings that keep them clear of the water, similar to a houses on piles.

Due to ecosystem productivity, these species with their ligneous excrescences produce a considerable quantity of lignin and wood.

The Ramsar Convention defines mangrove swamps as 'forested intertidal ecosystems that occupy sediment-rich sheltered tropical coastal environments, occurring from about 32° N (Bermuda Island) to almost 39° S (Victoria, Australia)'.

In tropical regions, the coasts are muddy and trees are located in grassy marshes. Estuaries in tropical regions are also lined with flooded forests and plants adapted to the salty environment. The largest of these forests is located in the Ganges Delta in the Sundarbans, which straddles India and Bangladesh.

Mangrove, Bali.

Tupelo wood is highly valued by cabinet-makers in the United States. The wood from *Rhizophora* species is less highly rated by carpenters and joiners, as it is extremely heavy, dense and difficult to work, although it is perfectly suitable for structural work. In Viet Nam, it is used for walls and floors, in Bangladesh for building houses – along with sundri (*Heritiera formes*), another tree typical of halophytic mangroves – and in Cuba it is utilized for making railway sleepers.

Mangrove wood is also prized in the form of charcoal, the main product produced from mangroves in Malaysia, Myanmar, Sumatra and Thailand. The bark of the red mangrove (*Rhizophora mangle*), in particular, produces excellent tannins highly suitable for dyeing leather.

Honey is harvested in many mangrove forests. The flowers of the various species of mangroves, as well as the large, compact inflorescences of the pandanus in Asia and the islands of the Pacific, are extremely melliferous. In Cuba, more than 30,000 hives have been displaced from the south to the north of the island to take advantage of the staggered flowering of the *Avicennia* mangrove.

Mangrove ecosystems support close to 2,000 species of fish, shellfish and crustaceans, including shrimps, crabs and oysters. These are among the animals most commonly found in the sediment retained by the tangled roots of mangrove trees. All are amphibious and represent a key output in the economies of tropical countries, providing fisheries with adequate subsistence for personal consumption and local markets, and communities with an indispensable source of food.

Mangrove ecosystems are home to nearly 2,000 species of fish, including mudskippers. This typical mangrove fish developed fins allowing it to leave the water and move on land.

Mudskipper.
© Self CC BY SA 3.0

Rocky coasts

Rock coasts are also home to ecosystems teeming with life, harbouring a wide range of plant and animal products, especially in their lower reaches where the rocks are only exposed to the lowest tides.

The two most common forms of adaptation among species of invertebrates on rocky coasts are the search for shelter under rocks and the development of a system of 'suckers' to enable them to attach themselves firmly to rocks and withstand backwash. Thus, coastal fishers often gather shellfish by turning over the mineral fragments that litter the seashore, although fishing still plays an important role. Specialized species are found in different parts of the world such

In subtidal areas, algae often grow in abundance and are home to multicoloured sea animals including starfish, sea urchins, sponges and sea anemones, which are often sought for their striking appearance

Sea anemone. © Parent Géry, Public domain

as periwinkles in oceanic Europe, small air-breathing gastropods concentrated on rocks just below the water surface.

In subtidal areas, algae often grow in abundance and are home to multicoloured sea animals including starfish, sea urchins, sponges and sea anemones, which are often sought for their striking appearance. These organisms, like those in coral reefs, are exploited commercially in tourist areas and sold as souvenirs or decorative objects. However, such exploitation is sometimes taken too far and can pose a threat to populations of species. Recently, these organisms have given rise to activities aimed at exploring species in their environment, such as coastal walks, school trips, snorkelling or diving in shallow waters. Lastly, their usefulness in identifying molecules important for our health or the improvement of industrial processes is becoming increasingly recognized. However, this also generates risks for the viability of populations of certain organisms, such as some species of sponge.

2. Ecosystems in inland waters

In recent decades, inland waters around the world have experienced severe damage. Fast-flowing mountain streams, meandering rivers and still water bodies alike have fragmented, drained and in some cases dried out completely. This trend has fundamentally affected their aquatic ecosystems.

From streams to rivers

Watercourses are, by definition, living entities. From the source to the sea, they go through different stages of development. In the mountains, where they start their lives, a stream is produced by the snowmelt from the glacier that feeds it; it then cascades down the steep slopes and hollows out a deep V-shaped valley. If the watercourse starts lower down the mountainside, it takes the form of a brook, either fed by natural springs or receiving its water from a watershed. It then becomes a river, propelled overland by the force of gravity and swelled by tributaries, until it flows into another, perhaps bigger, river. When a watercourse reaches maturity, it becomes a major river. Its valley widens out into a U-shape and it spreads out as it meanders towards its mouth, where it flows into the sea.

A hydrographic network consists of the river itself, all its upstream tributaries and the springs that feed it. A river is therefore fed, directly or indirectly, by a multitude

From the source to sea, waterways go through different phases of development. A torrent is born of snowmelt from the glacier that feeds it; it then cascades down the steep slopes, leaps into waterfalls and carves out a deep valley creating a watershed.
Tortuguero National Park, Costa Rica. © Peter Prokosch, UNEP Grid-Arendal

A river system consists of a river and all the tributaries that feed it, also referred to as a watershed. Here, the watershed of the Amazon is shown from its sources to its estuary in the Atlantic Ocean.

Basin of the Amazon River. © Image courtesy of NASA Earth Observatory

When a watercourse reaches maturity, it becomes a major river. Its valley widens out into a U-shape and it spreads out as it meanders towards its mouth, where it flows into the sea.

Volga, Russia. © UNESCO

of watercourses that converge in a tree-like structure. The land surface fed by the entire network constitutes the hydrographic basin. The term **watershed** denotes the part of the land surface bounded by the ridge lines (relief) from which the water drains naturally towards a common outlet, often the main waterway. The watershed is divided into a number of sub-watersheds, all of them feeding the watercourse and the tributaries that flow into the main waterway.

These explanations help us to understand that river basins are natural systems of drainage and storage (via natural channels), sometimes extending over wide areas, which regulate and distribute the planet's water throughout the different regions of the world.

When these systems are unimpeded they are said to be 'free-flowing'. The tree-like network of watercourses that makes up the watershed does not fragment; instead, the water moves around freely allowing water basins to provide us with the most essential of life-sustaining products: freshwater.

According to the AQUASTAT Main Database of FAO, the global sum of withdrawal ratios for agriculture is 70% of the available resource, the importance of agricultural water withdrawal depending on both climate and the place of agriculture in the economy (very important in Asia and Africa).

The role played by rivers is fundamental to our water supply. The water in river basins often covers permeable sediments above aquifers and, percolating down through the rocks, enables the underground water reserves on which we depend for direct consumption to be replenished and maintained at their proper level.

For example, the vast basin of the River Niger makes available considerable underground resources to the country of Niger, which is very dry. Conversely, over-exploitation of the Hai River basin in China has led to a significant lowering of the water table.

River basins are therefore roads, channels or thoroughfares that must be maintained in good condition or at least not disturbed for any length of time. This is in marked contrast to the current process of fragmentation affecting river basins. When we speak of 'wild rivers' we are refering to a river's ecological system in its integrity, which ensures the circulation of running water, and of the numerous species that divide their lives between freshwater and the sea.

Most salmon, for instance, need fast-flowing water to spawn, swimming upstream against the current to the higher reaches of mountain torrents. Other animals imitate this behaviour, in particular crabs, which swim upstream for hundreds of kilometres in order to breed. Eels, on the other hand, do the very opposite.

By sustaining populations of larger fish, such as sturgeon, carp, pike or barbell, river systems provide vital food resources for the poorest populations in isolated areas. As such, inland capture fishery from rivers and lakes is the dominant practice (90%) in both Asia and Africa.

Freshwater bodies: lakes, ponds, pools and bogs

A wide range of processes underlie the formation of lakes, ponds and pools. Lakes can result from a form of glaciation or from movements in the Earth's crust, as in the case of Lake Tanganyika and Lake Victoria in East Africa's Rift Valley. Some freshwater lakes, such as reservoirs, are the result of human efforts to control the discharge of water.

Likewise, ponds and pools can be either natural or artificial in origin.

In Africa and Asia, numerous ponds have been constructed with levies for the purpose of watering cattle, while some natural pools follow a temporary cycle that alternates between drying up and filling during the dry and wet seasons.

The gueltas of the Maghreb and the Sahel are natural water pockets that owe their existence to groundwater that has risen to the surface. Under the effect of seasonal precipitation, the water table just below the soil's surface increases and diminishes and its depth fluctuates.

In mountain areas, dams are often used to construct artificial reservoirs designed primarily to hold, treat and distribute the water needed for irrigation and domestic use. However, such reservoirs have little in common with vast, natural African lakes, located in tropical regions, which are characterized by highly developed and productive ecosystems.

Permanent tropical lakes and ponds often sustain rich plant life, dominated by flowering plants and broadleaf water lilies; the latter are equipped with stomata that allow them to breathe, while the top side of the leaves traps light. Many marshland animals (rails, coots and moorhens) have adapted to walk on the leaves of giant water lilies in the lakes of Kenya, the United Republic of Tanzania and Uganda.

These bodies of water are rich in fish, especially barbell and carp, usually introduced from elsewhere . As many as 500 different species of cichlids have been counted in Lake Tanganyika alone. The local populations practise subsistence fishing using boats, bailers or nets, and sometimes wading or diving just below the surface, to gather fish, brown shrimps, surface aquatic snails and crayfish from the muddy bottoms. However, these food resources can be endangered by the introduction of larger, carnivorous species.

Depending on the region and water quality (hard, alkaline or brackish), filamentous algae and plants with very fine leaves, such as watermilfoil and pondweed, can occur. These oxygenate and purify the water in the centre of the basin.

There are a wide variety of processes responsible for the formation of lakes, ponds and marshes, just as there are a variety of lake, ponds and marshes. These include Lake Baikal (Russia), the deepest in the world and the sixth largest in terms of area, Lake Titicaca (Bolivia), Lake Victoria (Kenya, Uganda) and Lake Michigan-Huron, among others.

High-altitude lake, Switzerland.

The edges of bodies of water are cloaked in vegetation typically found in the vicinity of freshwater wetlands including Poaceae, Typhaceae and Juncaceae. In Africa, bulrush shoots (*Typha latifolia L.*) can be harvested, while in Asia, water chestnut bulbs (*Eleocharis dulcis*) are gathered.

Trees are often found on belts of vegetation a little further from the water's edge. A common species is palm trees, which provides construction timber and firewood as well as vegetable oil and food products.

The African oil palm (*Elaeis guineensis* Jacq.) is typical of African freshwater areas. The pulp of its fruit is the source of palm oil – an indispensable product for cooking among local populations, and the second most widely produced vegetable oil in the world after soya oil. Palm kernel oil is extracted from the same plant and used exclusively for industrial purposes. Cultivation of this plant is highly profitable, however its introduction on a massive scale in Asia has become a major factor in the deforestation and deterioration of typical wetland ecosystems in the region.

In Asia, the true sago palm (*Metroxylon sagu*), which originated in the southeast, is a common sight around bodies of freshwater. Its trunk yields 'sago', a highly valued food flour used especially as an ingredient in cattle feed. In addition, many starches are extracted from palm trees: in Africa, 'moambe' is obtained by cooking the pulp of palm nuts (*Elaeis guineensis* Jacq.), while the Amerindians traditionally extract flour from the fruit of the desert fan palm (*Washingtonia filifera*), which is similar to Borneo's 'sago'. These extremely nutritional starches are invariably obtained from woody species that are typical of freshwater ecosystems.

Finally, tropical bodies of freshwater are indispensable for livestock farming. They act as natural watering places, but also encompass grazing areas and pasture land containing high concentrations of forage plants that can be harvested.

Peat bogs form in cold, wet environments, even in mountains, where inland lakes fill with sediment that accumulates along the edges. These lakes eventually fill up completely and end up supporting larger plants, which, in turn, decompose and form peat. Peat actually results from the compaction and gradual build-up of non-decomposed organic matter. Once dried, peat makes a good fuel, which is commercially exploited in regions where peat bogs are common. Because of its high organic matter content, peat is also valued in horticulture (compost).

The industrial exploitation of peat in Eastern Europe and in northern regions does, however, pose a threat to peat bog ecosystems, which play a major role in atmospheric carbon capture and storage, wherever they exist.

The Glaumbær peat farmhouse

3. Marine ecosystems

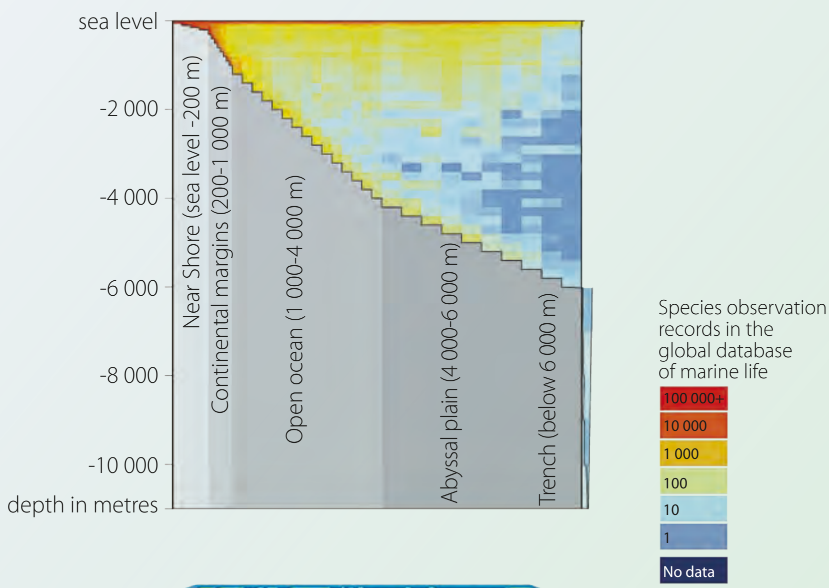
Ocean Biogeographic Information System

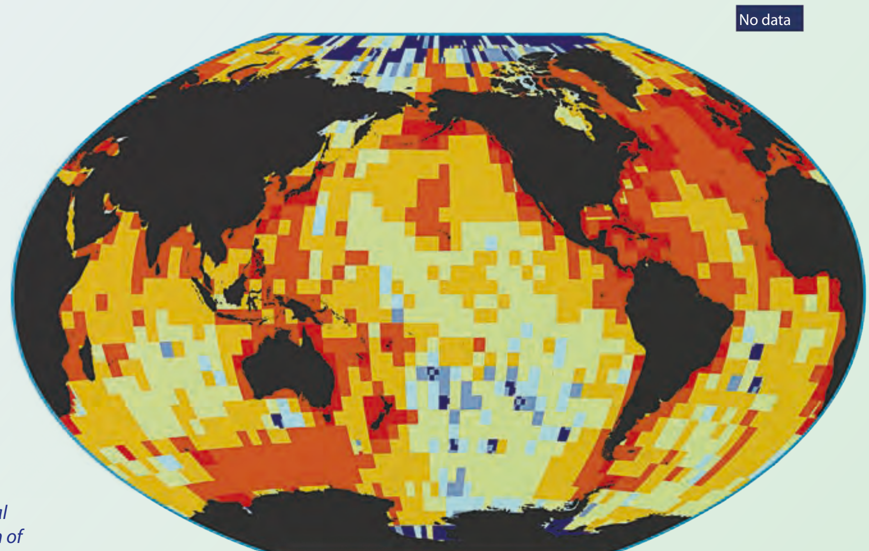
The Ocean Biogeographic Information System (OBIS) is the world's largest online system for recording, organizing and accessing data about life in the ocean. It provides open access to information on the diversity, distribution and abundance of marine species, and aims to assist decision-makers to sustainably manage the biological resources of our oceans. OBIS stems from the decade-long programme *Census of Marine Life* and is now integrated into the International Oceanographic Data and Information Exchange (IODE) programme of the **Intergovernmental Oceanic Commission** (IOC) of UNESCO.

On 8 January 2013, OBIS servers georeferenced 35 million observations covering 120,000 marine species from the Poles to the equator, the surface of the ocean to the deepest trenches, and from bacteria to whales. However, our knowledge of marine biodiversity is still incomplete. One-third to two-thirds of all marine species remain undiscovered, and the majority of known marine species have been observed only once. The median number of observations for a species in OBIS is four, with most data relating to vertebrates and other large animals (mostly fish, mammals and birds). However, it is known that the majority of species are

FIGURE 28: AN OVERVIEW OF SPECIES OBSERVATION RECORDS IN THE OCEAN BIOGEOGRAPHIC INFORMATION SYSTEM (OBIS)

Most of the open sea, as well as the depths, have barely been studied (www.iobis.org)





Source: Biodiversity's Big Wet Secret: The Global Distribution of Marine Biological Records Reveals Chronic Under-Exploration of the Deep Pelagic Ocean. © WEBB ET AL. (2010)

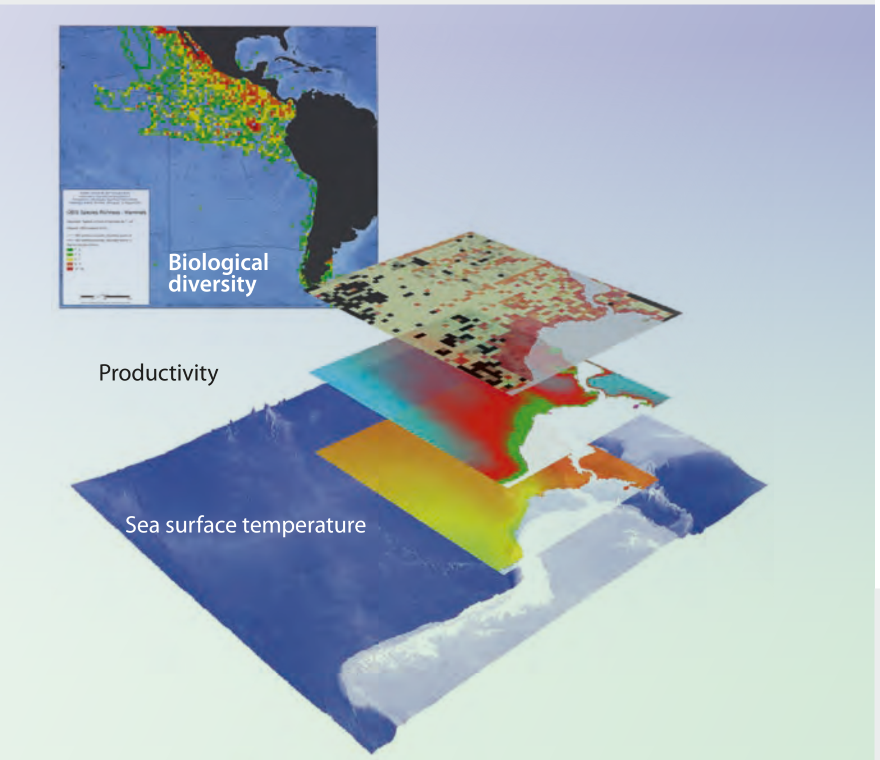
© IOBIS.ORG

smaller invertebrates (crustacea, worms and molluscs). The coastal waters in the Northern hemisphere are the best sampled, but around 95% of the vast midwaters of the open ocean (the Earth's largest habitat by volume) are mostly unexplored. In addition, historical records (most data stem from post-1960) and long-term time series (>10 years) are scarce.

Through OBIS, UNESCO contributes to the protection of marine ecosystems by assisting with the identification of marine biodiversity hotspots and large-scale ecological patterns.

OBIS data are used to support the identification of sites meeting the criteria of each EBSA regional workshop. OBIS data layers include species observations, indices for biodiversity and species of the IUCN Red List.

Eastern Tropical & Temperate Pacific EBSA Workshop, Galapagos, Ecuador, August 2012. © OBIS



The immense marine depths are home to many species. Some are widely known, such as sharks, dolphins, whales and rays, while others remain to be discovered.

Humpback whale and her young, Ha'apai, Tonga. © Glenn Edney UNEP Grid-Arendal

Coral reefs

Coral formations are living things. Coral reefs, which look like rocks, are in fact made up of skeletons or gorgonians of thousands of polyps, which live in colonies. Each polyp resembles a sea anemone, with a base shaped like a small bag and a crown of stinging tentacles. The base is the limestone envelope secreted by the polyp to protect its soft body. Coral is actually the result of a symbiotic relationship between cnidarians, animals related to sea anemones, and microscopic algae called zooxanthellae, which grow inside polyps. The algae produce nutrients by photosynthesis, some of which they pass on to the polyps. In this way, they help the animal organisms to construct their limestone skeletons, and the corals, in return, provide protection for the algae and food through their waste. The reefs are extended as a result of the corals building up their limestone skeletons and dying, then serving as a base for new individuals.

The algae contained in corals need light in order to survive. For this reason, coral reefs occur in very clear, shallow water that is directly exposed to sunlight and close to the shore.

The most important reefs are distributed around the equator in an area that stretches from Florida to Brazil, from the Red Sea to Madagascar and northwards to the Maldives, the northeast coast of Australia and the islands of the South Pacific.

There are several kinds of reef. The simplest are fringing reefs, which grow closest to the shore. These are submerged reef flats, accessible to visitors for tourist activities such as diving; however, it is important to control access. Barrier reefs also grow along coastlines but are separated from them by vast stretches of water. The Great Barrier Reef off the eastern coast of Australia is the largest of the coral reefs.

In what way is the formation of coral useful to populations in terms of provisioning?

Once polyps fix to the substrate, they produce 'buds', which remain attached to them. The buds multiply and the colony grows, eventually producing a gigantic 'one-organism ecosystem. It is fascinating to think that one individual can be the start of a whole reef.

Reefs are precious ecosystems. They are biological by definition and constitute life-sustaining environments. They unite every aspect of marine life: spawning, hatching, early and later growth, nutrition and

Coral formations are living things. Coral reefs, which look like rocks, are in fact made up of skeletons or gorgonians of thousands of polyps, which live in colonies. Algae from corals need light to live: coral reefs thus grow in shallow, clear waters exposed to direct sunlight.

Corals, Baa Atoll, Maldives. © UNESCO / Atoll Ecosystem Project Ministry of Housing & Environment

Coral reefs are particularly rich in biodiversity. All marine zoological groups are represented (crustaceans, molluscs, echinoderms, fish, octopus, etc.) and, according to the *GBO3*, coral reefs are home to 25% of all fish species. Similarly, coral reefs unite all aspects of marine life: spawning, hatching, early and later growth, nutrition and reproduction all take place within the reef for a very large number of saltwater species.

From top to bottom, left to right:

Moray, Baa Atoll, Maldives. © UNESCO / Atoll Ecosystem Project Ministry of Housing & Environment
Reef fish, Baa Atoll, Maldives. © UNESCO / Atoll Ecosystem Project Ministry of Housing & Environment
Reef fish, Baa Atoll, Maldives. © UNESCO / Atoll Ecosystem Project Ministry of Housing & Environment
Ray, Baa Atoll, Maldives. © UNESCO / Atoll Ecosystem Project Ministry of Housing & Environment

reproduction all take place within the reef for a very large number of saltwater species.

The reefs provide habitats for 1 million to 3 million species, representing 25% of all saltwater fish species. *GBO3* has calculated that about 700 million human beings are entirely dependent on reefs for their subsistence. The exploitation of reefs has given rise to local fishing on a significant scale, with over-fishing threatening their very survival.

However, since such fishing is profitable, local populations often develop customary laws to protect and maintain the reefs.

Few environments can compete with reefs in terms of their aesthetic qualities, especially their shape and colour. Their diversity embraces all the major zoological marine groups: crustaceans, echinoderms including sea urchins with very long spines (*Diadema palmeri*), starfish (Asteroidea), molluscs with various kinds of shells, octopuses, multicoloured sponges, sea anemones, gorgonians, shoals of small fish, coral bass, the bright blue and yellow Acanthuridae or surgeonfish (*Paracanthurus hepatus*, *Zebrazoma flavescens*), the ocelli (eyespots) of mandarinfish and the stripes of angelfish.

Such beauty gives rise to commercial activities that target fish-breeding, home decoration (aquariums), demand from collectors and the souvenir market. Such activities are often predatory, resorting to fishing practices that are destructive for the environment, including cyanide fishing to catch live fish, and dynamite fishing to bring fish to the surface in large numbers, alongside coral fragments.

Open-sea habitats and the fisheries issue

Although seas and oceans occupy about 71% of the planet's surface, these vast marine spaces account for only 15% of species known today, or a little more than 240,000 species. This is explained by the fact that marine life is still largely an unknown quantity, since accessing its biodiversity is no easy task.

Oceans and seas are populated by a large number of creatures that inhabit depths ranging from 0 m to 200 m.

From top to bottom, left to right:

Leafy seadragon. © UNESCO / Scripps Institution of Oceanography, UC San Diego
Anemone, Baa Atoll, Maldives. © UNESCO / Scripps Institution of Oceanography, UC San Diego
Whale. © UNESCO / Scripps Institution of Oceanography, UC San Diego

The ocean depths are populated, notwithstanding. Certainly, animals are less plentiful there than in the upper layers, where the energy from sunlight is used by plankton and the higher plants. It is very cold, water pressure is intense and there is little light. In the vicinity of hydrothermal springs, toxicity levels, due to significant concentrations of heavy metals, are high. Such conditions dictate that the biodiversity consist of species suited to great depths.

The animals that live there are adapted to a life of hunting . Examples include the conger eel, the abyssal squid and the dragonfish.

The base of the food webs in these lower depths is the uninterrupted plant and animal waste and debris that float down from the upper layers, and the chemical energy provided by hydrothermal springs. Scavengers feed on this material before being devoured themselves by predators. In recent decades, biological and pharmacological prospecting of deep-sea biodiversity especially around seamounts, which give rise to a high level of biodiversity, has led to the discovery of rare invertebrates and 'living fossils'. One of these, a crinoid (*Gymnochrinus richeri*), has enabled researchers to isolate active compounds in vitro against the dengue virus, a disease very common to tropical regions. In this regard, the exhibition *Biodiversity Humanity* noted that: 'Of the 18,000 substances that have come from marine organisms, 15% have allowed new active molecules to be isolated. To date, the chemical composition of just 1% of listed marine species has been analysed'. Researchers know from experience that deep-sea fauna are a potential source of new drugs. Accordingly, it is important to preserve these species and protect access to them with the support of local populations, and also to support research efforts.*

* **For more details see**
Part 3, The Nagoya Protocol on Access and Benefit-Sharing (p. 177).

For example, AZT, a synthetic drug used in the treatment of AIDS, was derived from molecules secreted by a sponge occurring in the Caribbean. This sponge is now an endangered species.

At a depth of between 0 and 200 metres, in the euphotic zone (characterized by the presence of sunlight) or continental shelf, the seas and oceans are populated by a very large number of marine animals: mammals (dolphins, porpoises and whales); squid and octopus; and fish, most of which are bony fishes, ranging from cod to emperor fish, with a small proportion of cartilaginous fishes such as sharks and rays. All are strong swimmers, since they need to remain mobile in the surface currents.

In the mesopelagic zone, between about 200 metres and 1,000 metres, the temperature drops and it gets progressively darker. Here, we only find communities of species adapted for living at this depth.

Phytoplankton (plant plankton) play a key role in all the chains of marine species. Composed of a multitude of diatoms and other single-cell algae and cyanobacteria, phytoplankton form the basis of oceanic trophic networks. In *Biodiversity, the Networks of Life*, published by the Scientific Council of Natural Heritage and Biodiversity (CSPBN), researchers for the French Ministry for the Environment estimate that: 'a millilitre of seawater might contain 100,000 micro-algae, 0.5 to 1 million bacteria and 10 million viruses'.

Phytoplankton provide food for zooplankton consisting of planktonic animals including copepods (crustaceans a few millimetres in length), krill and larvae, which in turn feed herring, anchovy and other small fish, themselves the prey of bigger organisms.

At the top of the chain are the biggest carnivores – killer whales, sharks and large tuna – which evade most of the other predators (with the exception of humans), but indirectly draw their energy from phytoplankton.

In recent decades, we have witnessed a decline in populations of several species of shark, owing to overfishing (shark meat, especially shark fin, has a strong gastronomic appeal) and to their eradication, which for a time was gratuitous, based on a false assessment of the largely imaginary threat they posed to humans. Their reduction in numbers has led to overpopulation of their prey, especially certain species of large rays and small sharks. This overpopulation has in turn caused populations of scallops and clams in North America to collapse, which proved disastrous for the shellfish trade, especially in 2003 (*Biodiversity, the Networks of Life*).

A millilitre of seawater might contain 100,000 micro-algae, 0.5 to 1 million bacteria and 10 million viruses

Maintaining the numbers of large predators is an important precondition for the equilibrium of oceanic ecosystems, and their elimination is an important factor in the degradation of these ecosystems.

The sea and its extraordinary biodiversity have, throughout history, fed human populations.

In many parts of Asia and Africa, fish still provide the biggest contribution to protein consumption. This is why fishing activity plays a primary role in ensuring the food security of humanity.

At the same time, over-exploitation of the oceans, as a result of modern fishing practices, places this vital resource at risk. Before we return to the issue of the degradation of oceanic ecosystems, it is therefore necessary to examine modern-day fisheries.

The amount of fish caught in 2004 totalled 95 million tonnes.

Fishmonger, Nepal. © Lawrence Hislop / UNEP Grid-Arendal

Fish selling, Greenland. © Peter Prokosch / UNEP Grid-Arendal

According to a report of the Food and Agriculture Organization of the United Nations (FAO), the amount of fish caught in 2012 totalled 158 million tonnes.

The potential for oceanic fishing has in many parts of the globe reached maximum capacity. It has become urgent to learn how to manage marine food resources with a view to ensuring the long-term viability of fishery activities.

To this end, two essential priorities can be identified.

1. Avoidance of the further decline of species that are currently being fished to maximum capacity (the volumes now being fished exceed annual production), short of which ecosystems cannot be maintained.

2. Learn to consume fish without decimating the oceans. This is indispensable, if we want to go on eating fish.

According to FAO, 75% of the world's reserves of wild fish species are at risk; this is the case for tuna and swordfish, as well as cod, hake, plaice, sole, turbot, and even eels and scallops. We must not persist in our demand for these wild species, but instead moderate our consumption and favour species that are not being over-fished or which benefit from being bred under carefully controlled conditions, such as brown shrimps, pollock, oysters and herring.*

* **For more details see**
Vol. 2, Activity 9, Agro-diversity: a sustainable production process? (p. 49).

4. Ecological services delivered by aquatic ecosystems and their state of degradation

Aquatic ecosystems not only supply our mineral, animal and vegetable products, they also provide us with a wide variety of valuable ecological services, encompassing the retention and transport of sediment and nutrients, flood control and water purification, among many others.

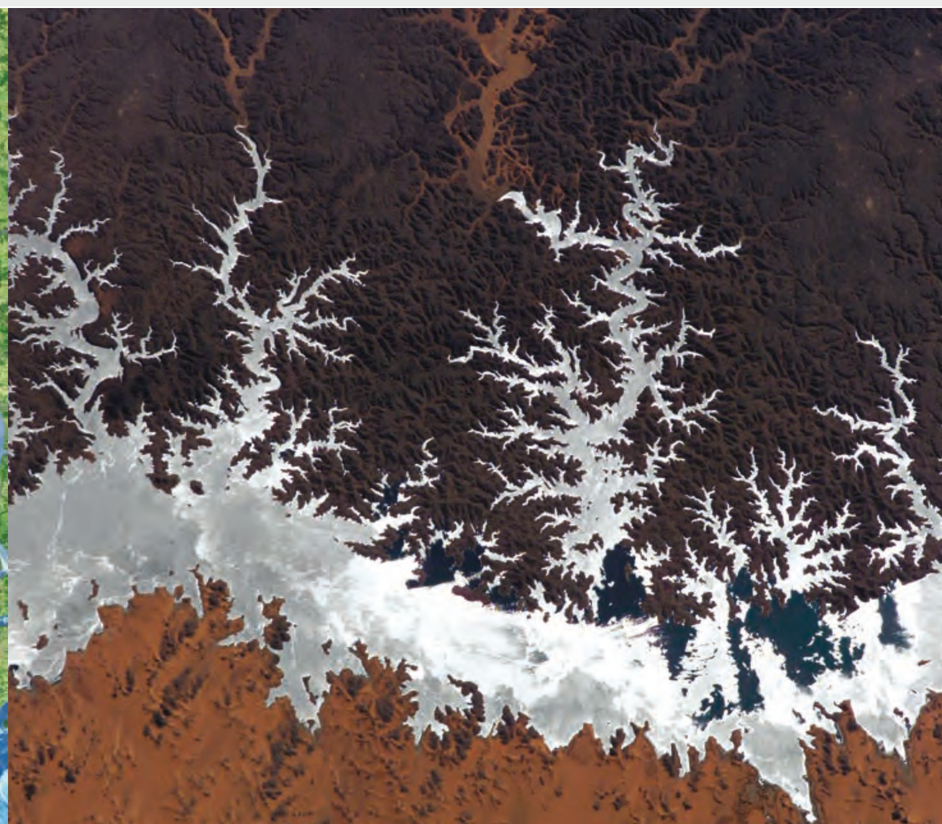
Today, we have a better understanding of the economic value of ecosystem services provided for different human societies by aquatic zones, thanks in part to the United Nations Millennium Ecosystem Assessment, which in 1997 set this value at US$15,000 billion. However, there are many worrying and repeated indications that aquatic ecosystems are disappearing at a much faster rate than other types of ecosystems.

By studying the contribution of aquatic and wetland areas to the functioning of natural systems, we are better able to identify the aspects of human activities (often motivated by short-term gain) most responsible for the destruction and degradation of these areas worldwide.

Through their multiple relationships and interactions, coastal ecosystems (including estuaries, deltas, swamps, flood meadows and wooded swamps) act as storage areas for the sediment carried by rivers.

River Hugli, India. © Image courtesy of NASA Earth Observatory

The River Nile feeds Lake Nasser. © Image courtesy of NASA Earth Observatory



Supporting and regulating services

Coastal ecosystems store sediment transported by rivers through multiple interconnections and interactions, including in the form of estuaries, deltas, marshland, flood-meadows and wooded swamps. Since sediment is naturally rich in nutrients, these areas are essential links in the nutrient cycle, allowing nutrients to accumulate and be absorbed into the chain of living organisms.

These places are the interface between land and sea and provide an essential support service for ecosystems, by offering natural habitats and food sources to a large proportion of marine and coastal aquatic organisms, regardless of whether they are adapted to brackish water or freshwater.

The plant formations linked to coastal ecosystems, including mangroves, often-dense forests that stretch across mudflats, and grassy marshes and coral reefs, perform a significant regulating service in terms of preventing natural disasters and protecting our coastlines.

By functioning as barriers against coastal storms and tidal waves, these formations help to control and regulate storms at sea. The Ramsar Convention makes clear reference to this in several of its information packs, stating that plant roots in coastal ecosystems 'bind the shore together, creating resistance to wind erosion and wave abrasion, and providing a physical barrier that lessens the impact of storm surges and tidal waves, by reducing their height and their destructive force'.

Following the violent tsunami that struck the Indian Ocean in December 2004, it was widely acknowledged that regions with coastal ecosystems least exposed to human-induced degradation were better protected from the surge of water.

Another feature of coastal ecosystems is that marshland plants spread (thanks to their underground rhizomes) and quickly form new clumps, storing carbon that builds up in the peaty sediment of salt marshes. These plant formations help to attenuate the effects of climate change by reducing general levels of greenhouse gases released into the atmosphere.

According to *GBO3*, salt marshes in the United States 'are estimated to account for more than one-fifth of the carbon absorbed by all ecosystems, despite covering a relatively small area'.

Broadly speaking, 'The quantity of carbon buried each year by vegetated coastal habitats such as mangroves, salt marshes and seagrass beds has been estimated at between 120 and 329 million tonnes. The higher estimate is almost equal to the annual greenhouse gas emissions of Japan'.

Among inland water ecosystems, rivers and their watershed naturally channel and store huge amounts of surface water. We saw earlier the extent to which the water of river basins, which percolates down through the soil and rocks, contributes to the replenishment of aquifer levels and our freshwater supplies.

Among inland water ecosystems, rivers and their watersheds naturally channel and store huge amounts of surface water.

Wetlands provide a flood control service, acting as retention basins and storage for runoff during floods.

Bukta Swamp, Lithuania. © UNESCO / Vytautas Knyva

Plant formations related to aquatic ecosystems, such as mangroves and grassy marshes, form a barrier against storms and tidal waves, thereby protecting inland areas.

Mangrove, Kenya. © Peter Prokosch / UNEP Grid-Arendal

* For more details see
Vol. 2, Activity 7, The interplay of species, services and products (p. 35).

Rivers must also meet rising demand from population growth and the unrelenting needs of irrigated farming. In addition, they form an ingenious system of natural channels that regulate water flow through the network. While it is common for surface runoff to overflow onto floodplains, rivers often contain these swollen, muddy waters and prevent flooding during heavy rains.

Rivers play a central role not only in the storage of sediment, but also in its transport. Streams and rivers join to form and carry large amounts of sediment through the landscape. We can say with confidence that the fertility status of estuaries and coastal ecosystems is dependent on the water quality in river ecosystems located further upstream. The diversity of species living in coastal environments depends on the connections that form between the different parts of the watershed, as the water, sediments and nutrients move downstream from the source of the river to the sea.

Any disruption in river flow affects sediment transport, the food supply of species, fish migration and the overall biodiversity of freshwater.

Wetlands and inland water bodies – lakes, ponds and pools – also act as effective retention and storage basins when surface runoff is produced, thereby providing important flood control services.*

In addition, inland wetlands play a role in controlling pollution by providing a natural water purification service.

Thanks to their plant life, which acts as a **biological filter**, these areas perform the role of natural water-treatment plants, by retaining the pollutants contained in sediment, soils and vegetation. In some cases, this may include the purifying power of **macrophyte** plants, such as reeds (*Phriagmytes*), hydrophytes or free-floating aquatic plants, and **microphyte** plants such as unicellular algae.

Most of these plants absorb phosphorus and nitrogen compounds as food, nutrients that when present in excess amounts act as pollutants. Absorption takes place through the cell walls of the stems and leaves.

These plants can also be used in **bioremediation**, a waste management technique that uses organisms to remove or neutralize pollutants. They support numerous microscopic organisms – including aerobic bacteria – in eliminating carbon compounds by using this organic matter as a source of carbon and energy.

In the late 1990s, New York City spent US$1.5 billion on the purchase of land and the protection of watershed wetlands for the purpose of purifying publicly owned water.

New York. © Derek Jensen, Public domain

The economic value of the purification function of inland wetlands can be significant, for example, as a means of treating urban and industrial wastewater by eliminating soluble organic pollutants (sugars, fats and proteins).

For example, in the late 1990s New York City spent US$1.5 billion on the purchase of land and the protection of watershed wetlands for the purpose of purifying publicly owned water.

Oceans and deepwater ecosystems deliver numerous ecosystem services. As we have seen, they provide a variety of food resources, valuable genetic resources for drug development, and mineral resources that open up new supply possibilities from stones rich in metals, such as manganese, copper, nickel and cobalt.

These ecosystems also interact with the atmosphere and, to this extent, are involved in climate regulation.

The ocean surface is the principal source of atmospheric water which, via evaporation and condensation, constantly maintains the water cycle driven by solar energy. In addition, the ocean warms the atmosphere through its ability to store heat and adds moisture through the evaporation cycle. The atmosphere contributes freshwater to the ocean through rain and is responsible for its motion through the action of the winds.

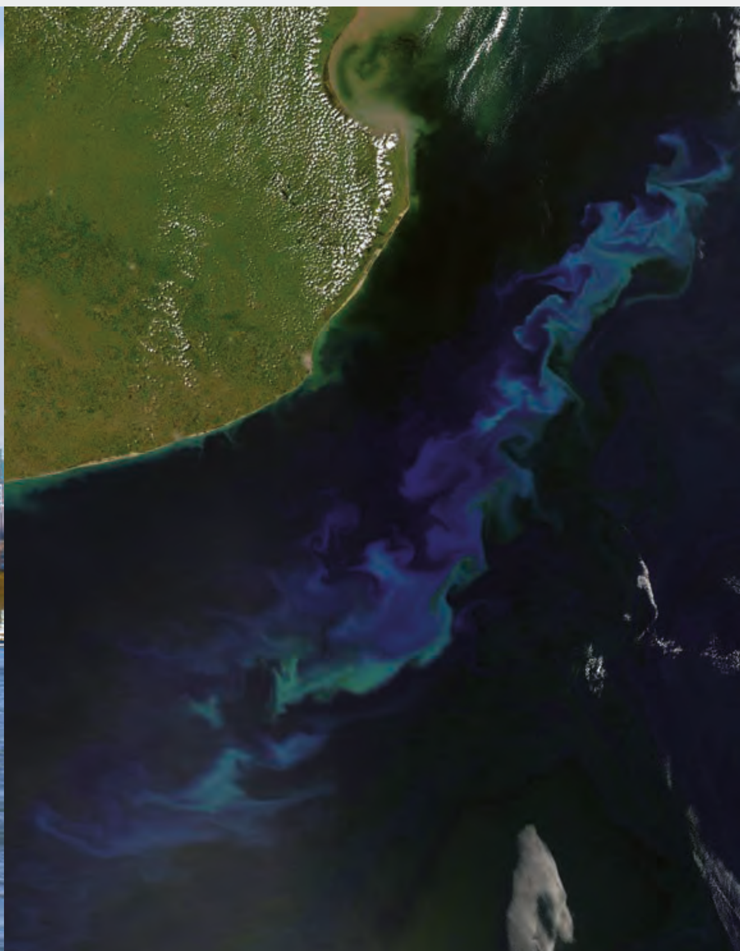
For many decades, the gases emitted by human activities (carbon dioxide and methane) have intercepted a proportion of the infrared rays emitted by the Earth. The heat that is trapped as a result has led to a rise in the air temperature and an increase in the overall land temperature. The ocean has the capacity to absorb much of the carbon dioxide in the atmosphere as well as some of the heat produced by the greenhouse effect.

Above all, though, oceans are precious natural carbon sinks. They assimilate carbon through plankton, corals and macrofauna, and subsequently convert it into sedimentary rocks (on the seabed) or into biogenic rocks, which form the basis of limestone skeletons and shells.

Like plants, marine phytoplankton use the process of photosynthesis to extract carbon from CO_2 and release enormous quantities of oxygen (O_2), since they cater for half the needs of heterotrophic organisms. Phytoplankton, as carbon autotrophic organisms, form the basis of oceanic food chains. More broadly, however, the process by which plankton and corals capture the carbon dissolved in water or taken from food is fundamental to the elimination of CO_2 at the level of the biosphere. This process is now under serious threat.

The oceans act as carbon sinks thanks to the presence of phytoplankton, which remove CO_2 through the process of photosynthesis.

Phytoplankton off the coast of Argentina (in light blue).



The oceans, which cover 71% of the surface of the planet, are valuable natural carbon sinks. They also maintain the water cycle and regulate the temperature of the atmosphere.

Earth, 'the blue planet'.

The alarming state of degradation of aquatic ecosystems

Over the last 50 years, inland water ecosystems worldwide have been disturbed or damaged to a greater extent than any other type of ecosystem. The state of marine ecosystems and deep-water habitats is also of concern; these have suffered damage resulting from fishing-related activities or the impacts of production systems (e.g. acidification of the oceans due to increased concentrations of human-induced CO_2 in the water).

Moreover, the conversion of wetlands, lakes, floodplains, marshes, swamps and mangroves for aquaculture purposes and coastline development, and their reclamation or drainage for agricultural purposes, has led to the break-up and destruction of the natural habitats associated with aquatic biodiversity.

The total area of wetlands located in coastal regions or inland has declined considerably. According to *GBO3*, between 56% and 65% of Europe's inland and wetland water systems, which were conducive to increased agricultural output, had dried up by 1985, including 73% of the swamps located in northern Greece and 60% of the original wetland areas in Spain.

The *Millennium Ecosystem Assessment* report summarizes the situation well: a swamp is still too often seen as wasted land, with its only value confined to the crops that could be grown on it if it were drained.

Intensive aquaculture, especially shrimp farming, has also led to the loss of precious coastal systems such as mangroves, of which 35% are thought to have been destroyed. More than a third of this destruction is blamed directly on intensive shrimp farming, especially in Thailand. This activity pollutes the environment, owing to the indiscriminate use of a combination of fertilizers, pesticides and antibiotics. Furthermore, it is unsustainable, since the prolonged use of a pond leads to the formation of a toxic slime on the basin floor, caused by unabsorbed body waste and food matter. Because this slime cannot be completely eliminated by emptying the basin, the ponds used for this intensive farming are often abandoned, leaving behind uncultivated areas.*

* **For more details see**
Vol. 2, Activity 9, Agro-diversity: a sustainable production process? (p. 49).

The introduction of farming is not the only factor accounting for the loss of natural coastal habitats. In France, for instance, the urban sprawl that blighted coastlines in the 1980s (car parks and concrete buildings) destroyed large percentages of pre-existing shorelines and wetlands.

Concerning coastal ecosystems, *GBO3* states that immense dams now intercept 40% of the discharge of rivers worldwide, so that a third of the sediment destined for coastal areas no longer reaches them. Thus, rivers such as the Nile in Africa, the Colorado River in North America and the Yellow River in China are periodically unable to reach the ocean.

Intensive aquaculture activities, especially shrimp farming, have resulted in the loss of valuable coastal ecosystems such as mangroves. An estimated 35% have been destroyed, threatening the survival of fauna that live in these ecosystems.

Shrimp breeders (blue plots), Ecuador.

These disturbances have a considerable impact on fish migration and the diversity of lifeforms and organisms in environments located at the interface between land and sea, since they are affected by the arrival of smaller quantities of natural nutrients.

Another example is the creation of a 'dead zone' of several thousand km^2 in the watershed of the Mississippi, at the level of the Gulf of Mexico. The environment is starved of oxygen and so incapable of sustaining animal life, because of the overload of nutrients deriving from the nitrogen compounds in industrial and agricultural effluent.

River basins have not been spared from this treatment elsewhere in the world.

The *Millennium Ecosystem Assessment* report also states that, since 1960, the amount of water held by dams has quadrupled, with more water now contained in artificial reservoirs than in naturally flowing rivers.

Watercourses have been diverted and their discharge has been substantially reduced (over the same period, the amount of water withdrawn for irrigation and to cater for industrial needs and the domestic needs of populations has doubled). In addition, both the watercourses and their natural habitats have been fragmented along the whole length of their basins. Only a small percentage of the 292 great river networks assessed are not affected by the impact of dams.

As noted in *GBO3*, the most fragmented rivers are located in industrial regions, such as the greater part of the United States and Europe, and in highly populated countries and regions (China and Egypt).

This fragmentation of ecosystems along watercourses is having a disastrous effect on biological life, impacting environments both upstream and downstream.

As a result, the stocks of inland freshwater species (sturgeon, eels, pike, salmon and amphibians) have fallen dramatically in Europe. While freshwater habitats cover less than 1% of the Earth's surface, they shelter a unique range of biodiversity including 25% of described vertebrates, more than 100,000 animal species and more than 2,000 macrophyte plants.

Another factor in the degradation of river basins is pollution.

Watercourses are affected by numerous sources of pollution, including contaminants from accidents, residues leached by heavy rain, industrial effluent – consisting mostly of heavy metals – hydrocarbons, agricultural effluent with residues of nitrates, phosphates, pesticides and nitrogenous fertilizers, and effluent from livestock farming. All of these can lead to bacteriological pollution of water right down to the water table.

Large dams now intercept 40% of river flows worldwide.

Emosson Dam, Switzerland.

According to *GBO3*, the treatment of wastewater and industrial effluent management have produced improvements in the water quality of many inland water ecosystems (including through the use of phytoremediation and the interactions between plants, soil and micro-organisms, which work very well on organic and inorganic compounds present in excess). However, agricultural pollution, sometimes caused by individuals, remains a serious problem in many parts of the world.

It is difficult to obtain reliable information on changes in the quality of water consumed in high population regions of developing countries, where water needs are considerable.

Thus, access to clean freshwater, which is already unevenly distributed and accessible worldwide, is becoming an increasingly critical problem for the survival of numerous species, including human populations.

In some regions of the world, such as the Middle East, the water withdrawn for irrigation exceeds the amount that river networks are able to supply. The extra water needed is therefore abstracted from non-renewable groundwater. This problem may be compounded by salinization (as a result of deforestation, irrigation and drainage) or water eutrophication (imbalance caused by an excess of phosphates and nitrates in the water). In such cases, water shortages can become a serious issue and many species experience water stress, in particular cattle.

The *GBO3* analysis is clear on this point: the exhaustion and pollution of economically significant water resources has reached the point of no return, and the prospect of a future deprived of reliable water resource systems has become a real possibility in some parts of the world.

Freshwater ecosystems are not alone in facing a growing pollution problem; human-induced impacts are increasingly creating challenges for the vast oceanic environments.

A key issue is the acidification of the oceans (a gradual decrease in their pH), due mainly to increased levels of carbon being dissolved then absorbed by the marine environment. The carbon comes from carbon dioxide emissions (CO_2) caused by the burning of fossil fuels, heating systems and various types of industrial combustion and fermentation.

This phenomenon is deeply harmful to ocean habitats and species. It makes the formation of calcium carbonate more difficult, which affects populations of crustaceans and molluscs, to the extent that they have to make their own limestone skeletons. Both molluscs and crustaceans play a vital role in filtering seawater.

Above all, the acidification of the oceans affects the primary production of phytoplankton (e.g. diatoms), the species responsible for the absorption of large quantities of CO_2 across the entire planet. It also affects corals, whose numbers continue to decrease at an alarming rate. This poses another problem, as coral

The main direct pressure on marine ecosystems is over-exploitation of resources.

Fishing. © C. Madzak, INRA

cover absorbs huge quantities of atmospheric CO_2. According to *GBO3*, hard coral cover in the Caribbean has declined by an average of between 50% and 10% over the last 30 years. Acidification results in coral bleaching caused by the coral's expulsion of zooxanthellae algae, with which it has a symbiotic relationship. The animal, no longer able to tolerate the acidic environment and the raised water temperatures, expels its symbiote, loses its colour and eventually dies. The decrease in calcification, mentioned above, is also equally harmful to coral.

However, the main direct pressure on marine ecosystems is over-exploitation of resources. From the 1950s to the late 1990s, the volume of fish catches increased fourfold. However, despite increased fishing activity, the total catch is now decreasing. This indicates that many marine fishery stocks no longer have the capacity to replenish themselves.

The main reason for the depletion of saltwater fish stocks is the destructive fishing methods practised by high-capacity fishing fleets tailored for profitability and quick returns. To this should be added modern techniques and materials such as bottom trawling and the use of mobile fishing equipment, whose effect on marine ecosystems is comparable to that of clear-cutting in forestry.

To a lesser extent, inland capture fishery is also characterized by the use of a wide range of fishing gear and tools that allow a large number of species to be caught simultaneously, leading to a steady increase in the size of catches (totalling 9.2 million tonnes in 2004, according to FAO's *The State of World Fisheries and Aquaculture 2006*). However, these fishing techniques also catch species with no commercial value, which are then returned dead to the environment without being used. Furthermore, the systematic targeting of species of particularly interest has led to population declines in species such as tilapia in African river basins.

Regarding open-sea ecosystems, over-fishing of targeted species such as large predators (sharks, swordfish and giant tuna) is a root cause of degradation. The *GBO3* states that, in 2007, 14% of all assessed fish stocks had collapsed, with 'stocks' referring to all the species of fish gathered in a fishing area. The decline in stocks is particularly prevalent in areas where large predators have been captured. Targeted capture of species leads to an imbalance in populations. Ecosystems that lose the integrity of its communities of species in this way become much less productive. In Mediterranean regions, such imbalances have led to the extension of fishing zones to areas where fish stocks have not been depleted by catches of large predators.

'Stocks' refer to all the species of fish gathered in a fishing area.

Recent studies on the conditions needed to rebuild stocks recommend radical changes to fleets and fishing equipment, and the creation of protected marine areas. Changes made to fisheries management in certain regions have already contributed to the development of sustainable practices.

From the 1950s to the late 1990s, the volume of fish catches increased fourfold.
Fishing. © C. Maitre, INRA

The contribution *of biodiversity to supporting services*

The supporting services provided by terrestrial and aquatic ecosystems are essential for the production of all other ecosystem services. They maintain the conditions for life on Earth through soil formation, the nutrient cycle, biomass production, provision of natural habitats, sediment retention and transport, production of atmospheric dioxygen, the water cycle and the carbon cycle.

Biodiversity has a constant influence on these key processes, primarily through soil formation.

It is useful to remember that the differences between biomes, in terms of ecosystem processes, are due mainly to variations in climate and the availability of resources, such as water, which determines the soil's moisture content and its natural fertility.

Biodiversity and especially its degradation can have a long-term impact on supporting services by reducing the capacity of the ecosystem to adapt to serious disturbances.

© Wonchai Patharakomol/FAO FO-6013

Soil formation begins with the minerals found in outcrops of bare rock, which are hard but biodegradable.

1. Soil formation

Soil formation begins with the minerals found in outcrops of bare rock, which are hard but biodegradable.

The initial transformation is brought about by the climate (through successive freezing/thawing and heat), water and the atmosphere, which interact with the rock and commence its degradation.

On rocky outcrops the first, and sometimes only, plants to take root are lichens, which are able to live without soil and produce acids capable of breaking up the surface rock.

The action of their roots, which work their way into the cracks and degrade the minerals with their secretions, is known as **biochemical erosion**.

The products of this mineral degradation combine with plant residues to form soil where before there was only bare rock. When the lichen dies, its remains are gradually incorporated into the mass of mineral particles, forming an environment where herbaceous species and, later, shrubs can grow.

This is a very slow process; it takes a considerable length of time for plants to become established amid the accumulated debris.

*** For more details see**
Vol. 2, Activity 10, Scenarios based on supporting and regulating services (p. 56).

2. Recycling dead organic matter

The soil is nevertheless a complex matrix.

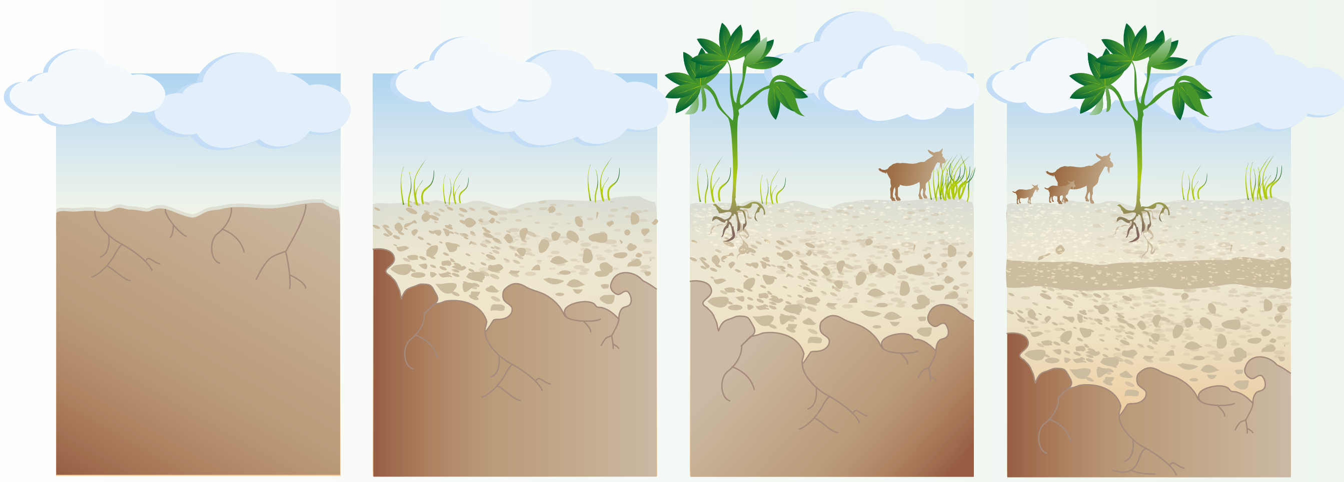
Plant debris forms a layer of organic material known as **plant litter** that is scattered over the ground and erodes the rock as it decays. But this litter is not made up solely of branches, leaves, fruits and roots of dead plants; it also consists of dead insects and animals, faeces, mucus and moulted material, and forms a layer of various types of waste from living organisms. This dead organic matter is known as **necromass** in contrast to biomass (living organic matter).

It is broken down and recycled by a chain of organisms (insects, fungi, microorganisms) that live in the soil or on its surface and thus produce humus, which is rich in minerals.*

Products from mineral degradation mix with vegetable waste to form a thick soil where there was only bare rock.

Ant.

FIGURE 29: SOIL FORMATION



1. Transformation of mineral matter by climate change
2. The first lichens produce acids capable of fragmenting surface rock
3. The products from mineral degradation are mixed with plant waste to form a dense soil
4. When the lichen dies, its remains are incorporated into mineral particles that form a suitable medium for plant species to develop

Examples of these **decomposers** include the fungus whose mycelial strands cover the dead bodies of crickets, or ants that dissect seeds or large pieces of twig. By burying detritus in the soil, carrion-eating insects such as the bluebottle fly, and dung-eating insects such as dung beetles, get rid of parasitic organisms and any other vectors of disease that it may contain.

Some decomposers, including fungi and a wide range of bacteria, refine dead matter and fully mineralize it, thus recycling nutrients in the soil.

In temperate forest regions, the absence of dead wood may indicate over-exploitation of the forest.

The World Wide Fund for Nature (WWF) has reported that nearly one-third of forest-dwelling animal, plant and fungi species in these regions depend on dead wood.

A dead tree can be a habitat and source of food for several hundred species over decades. Among these are saproxylophagous insects (feeding on dead wood) including coleoptera larvae and adults (scarab and longhorn beetles); brightly coloured fungi; various species of woodpecker, depending on the region (all climbing birds that build large nests); birds of prey, including owls such as the eagle owl; bats; squirrels and rodents such as dormice. Dead wood mobilizes a large number of wood-recycling organisms, which succeed each other in families and associated groups throughout the process of decay.

It is thus essential to conserve dead wood as both a pool of biodiversity and a factor in the vitality and quality of forest ecosystems, rather than trying to 'clean up' forests.

The necromass plays a major role in soil fertility and the nutrient cycle.

Dead leaves. © Florian Prischl, CC BY-SA 3.0

The necromass is an indicator of the biodiversity of an area.

Decomposition of organic matter. © Jörg Hempel, CC BY-SA 3.0

3. Humus production

As it decomposes, organic matter releases mineral compounds through a process known as **mineralization**; the and soft organic compounds then bind to each other and the clay to form **humus**.

Humus is a layer of dark topsoil that is naturally protective, retains water well and functions as a fertilizer whose chemistry varies according to its organic composition. It maintains the lower layers of soil, which are more or less permeable and aerated, by recharging them naturally with nutrients. This sustainable process makes the soil fertile.

Humus has difficulty forming in arid or desert regions where there is no plant cover. As a result, the soil is more vulnerable to erosion and may be destroyed.

Exposed land can be protected from winds and heavy showers by means of protective hedges or fast-growing plants that secure the soil.

Scavengers contribute to the elimination of waste and organic matter.

Beetle. © Dewet, CC BY-SA 2.0

4. Nutrient cycle

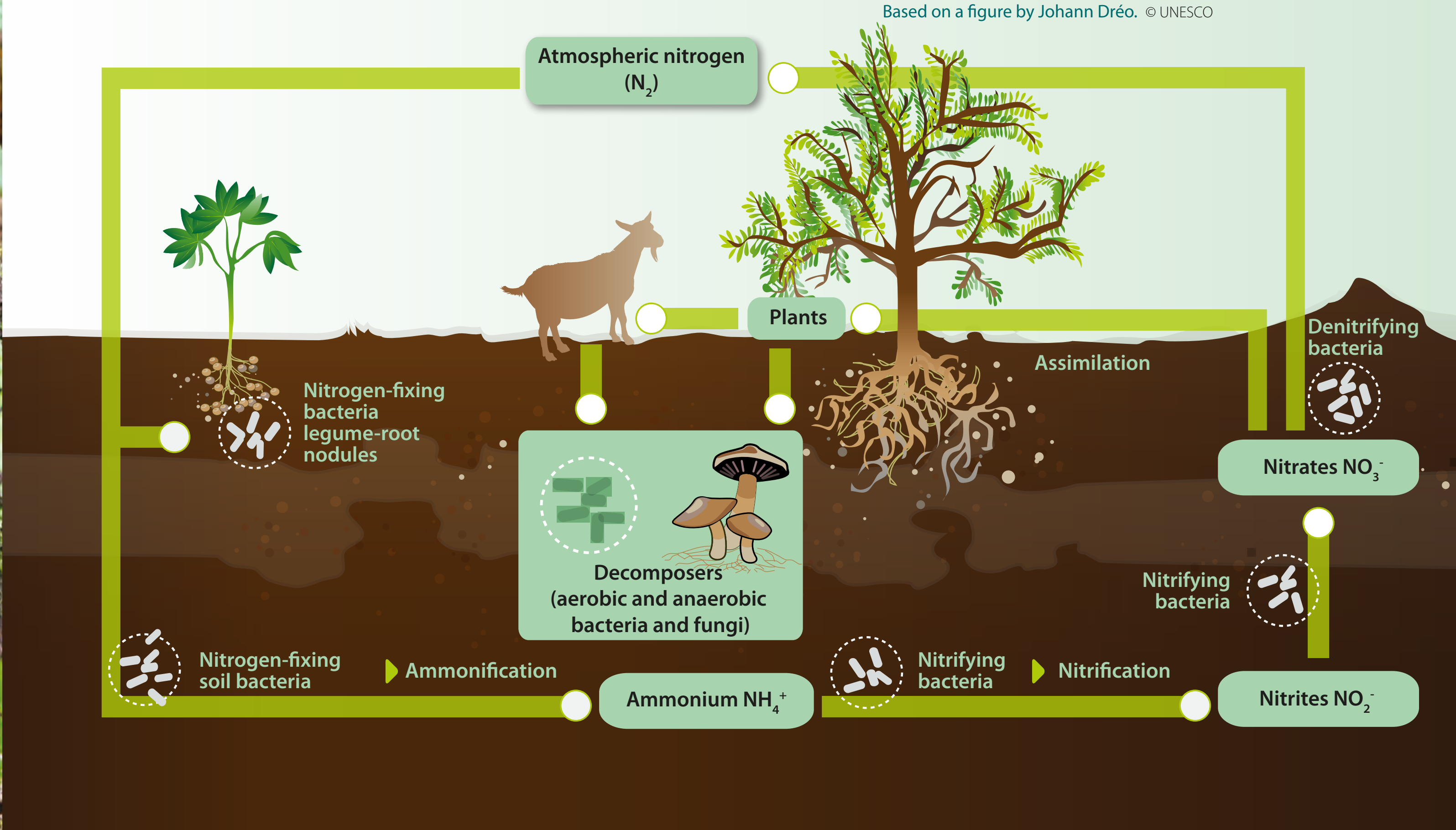
Nutrients (nitrogen, phosphorus, magnesium, potassium and copper) are essential to plant growth and therefore to building and maintaining ecosystems.

All living species share in the nutrient cycle. They absorb nutrients from their food or their environment (e.g. plants through their roots), store or transmit them (when plants are consumed by animals), and recycle them by breaking down dead organic matter. Finally, they release nutrients through decomposition. Thus, nutrients move constantly from living to non-living matter with biodiversity serving as the medium.

These nutrients include macronutrients such as carbon and nitrogen, which are used in large quantities by living organisms.

FIGURE 30: THE NITROGEN CYCLE

Based on a figure by Johann Dréo. © UNESCO



✱ **For more details see**
Vol. 2, Activity 10, Scenarios based on supporting and regulating services (p. 56).

Nitrogen occurs naturally in the atmosphere (which is 78% nitrogen), however human beings cannot harness it directly.

Like most species, we rely on the chain of life to meet our nitrogen requirements, by obtaining it from our food. Only certain groups of bacteria are able to use atmospheric nitrogen directly. These include bacteria of the genus *Rhizobium*, which attach to the roots of legumes (beans, clover, vetch or alfalfa, depending on the region) and form nitrogen-fixing nodules, which then produce ammonia.✱ The ammonia can then be used directly by plants and other bacteria.

The example of the nitrogen cycle, as with the carbon cycle or the phosphorus cycle, emphasizes the extent to which the global ecological cycles of macronutrients are interwoven with the chain of life. We ourselves are woven into this fabric as players (we release nitrogen compounds when we die), while being reliant on the active groups of bacteria and valuable plant families that drive these cycles to meet our metabolic requirements for pure nutrients.

5. Biomass production

The term 'biomass' refers to the total mass of living organisms measured in a given unit, a specific area or a population.

The production of biomass is an essential ecosystem support system for maintaining the conditions of life on Earth.

Biomass refers to the total mass of living organisms measured in a given unit, a specific area or a population.

The term usually refers to all vegetable matter, with plants accounting for up to 90% of biomass. This becomes evident when we look around our natural environment: the spatial structures of ecosystems are composed mostly of plants.

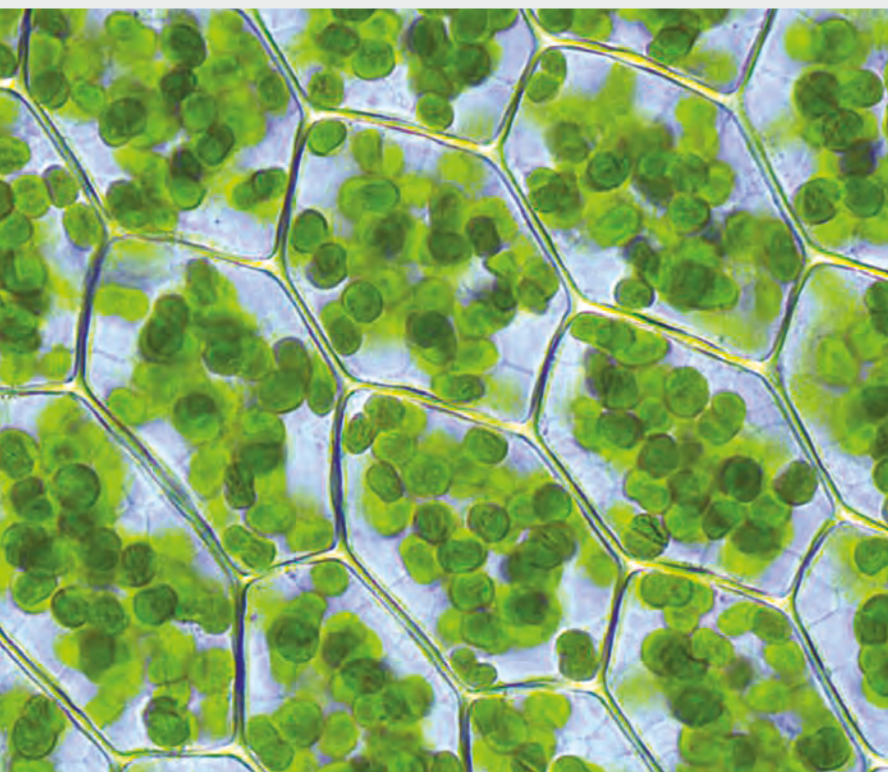
Plants exist at the bottom of the food chain, and as such are **autotrophs**: they use non-living matter (water, light and mineral salts) to grow and therefore to produce living matter (new stems, leaves, flowers and roots). Animals for their part are **heterotrophs**: they use organic material (meat, plants, etc.) to grow. This is why they are referred to as secondary producers (they produce life from other producers), while plants are primary producers.

Usually rooted in soil, plants absorb water and nutrients through their roots, together with carbon dioxide (CO_2) and oxygen (O_2) through the stomata in their leaves.

Plants harness solar energy, then through the chlorophyll in their leaf cells, use it to convert water and carbon dioxide into the simple sugars that make up their food. This phenomenon is known as **photosynthesis**: sugars are synthesized from photons, the particles that make up light.

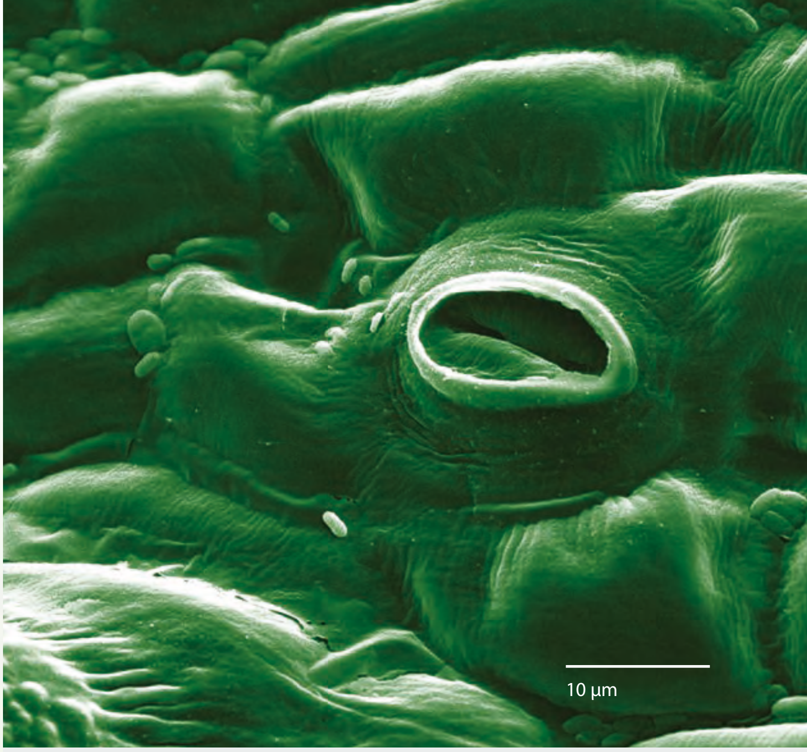
Fragment of a leaf observed under a microscope.

Photosynthesis. © Kristian Peters CC BY SA



Rhizobium bacteria attach to soybean roots where they form nitrogen-fixing nodules.

Microscopic image of a rizome. © United States Department of Agriculture, Public domain



Stomata are tiny pores on the leaf surface, which allow plants to absorb atmospheric gases, such as CO_2 for photosynthesis and O_2 to breathe.
Tomato stoma. © Vojtěch Dostál, Public domain

Angiosperms are plants that make use of pollinators to help them reproduce.
Bee. © José Reynaldo da Fonseca CC BY 2.5

Plants thus produce the vegetable matter that subsequently feeds other living organisms.

In addition to photosynthesis, biodiversity participates in the production of biomass in other ways. A large number of different organisms have colonized new ecosystems and thereby increased the overall quantity of living organisms and, therefore, the biomass.

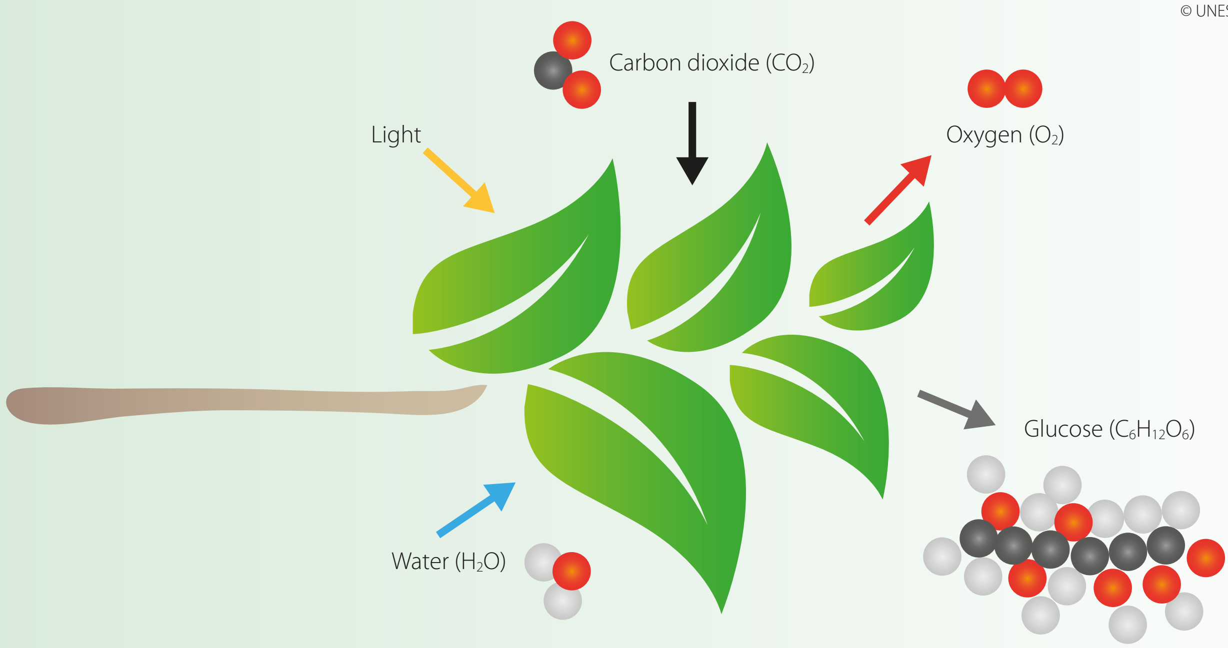
The success of flowering plants, or **angiosperms**, which appeared 150 million years ago, is partly responsible for this diversity.

The many families and species of flowering plants that make up the vast majority of today's plants reproduce sexually with the help of 'third parties' – other species including a variety of pollinators and dispersing agents that assist them at each stage of reproduction.

This strategy, unlike the asexual reproduction (cloning) of certain ferns, for example, allows flowering plants to employ genetic mixing to adapt faster to their environment and to any changes that occur in it. This selective advantage has enabled flowering

FIGURE 31: PHOTOSYNTHESIS

Based on a figure by TPE fotosíntesis artificial, CC BY SA 3.0
© UNESCO



A study in Ecological Economics by a team of French and German researchers puts the value of worldwide insect pollination at €153 billion in 2005, taking into account only the main crops consumed by humans.

plants to colonize new ecosystems more quickly than other plants.

Angiosperms often co-evolve with the species on which they depend for their reproduction. This has given rise to extraordinary diversity, such as particular corolla or organ arrangements for specific pollinators, particular seed capsules for specific dispersing agents, and particular proportions for companion plants needing just so much light.

This proliferation of new species has enabled the production of biomass across the planet.

However, it is important to understand that supporting services such as biomass production rely on vital links in the biological chain. Their preservation is crucial to the maintenance of this service.

However, a decline in the diversity of insect pollinators essential for plant reproduction has been observed. Atmospheric pollutants, including biocides, insecticides and fungicides, are damaging the molecules in flowers that produce their scent, thereby reducing the distance that their fragrances and other plant hormones will carry. This makes it harder for pollinators to locate the flowers, a fact that partly explains the diminishing populations of bees and nectar-eating birds and bats in many countries with large-scale industrial and agricultural systems.

A study in *Ecological Economics* by a team of French and German researchers puts the value of worldwide insect pollination at €153 billion in 2005, taking into account only the main crops consumed by humans.

The consequent value of the pollination service provided free of charge by biodiversity, which is responsible for maintaining not just crop production but also the supporting service of biomass production, is therefore colossal and probably incalculable.

In addition, it is important not to overlook the key role played by dispersing agents or 'germinating agents', such as the dispersal of seeds by animals (zoochory).

Seed-eating ants that live in the semi-desert ecosystems of Australia and feed on herbaceous plants eat the seed coats and discard the remainder, thus helping to disperse the seeds very uniformly. This explains the density of the magnificent floral carpets that appear as soon as the rains return in the spring.

The dung beetles in Central American rainforests provide another example of cooperative germination; they facilitate germination by burying seeds in the soil contained in the faeces of fruit-eating animals.

These examples of association highlight the sophistication of the biological interactions behind services such as biomass production.

The decline in pollinator numbers affects the reproductive rates of some species.

Epipactis palustris.

Another particularly notable association involves the spotted nutcracker and stone pine: the bird consumes large almonds contained in pine cones, and stores them in its oesophagus and under its tongue to be disgorged and buried in anticipation of winter. The forgotten seeds will germinate and ensure the spread of pine trees in even the most inaccessible areas.

Nucifraga caryocatactes, *Kotka, Finland.*

Human activities related to industry and infrastructures rely massively on the combustion of carbonaceous rocks (coal, oil and gas). When these fossil fuels are burned, carbon is released into the atmosphere.

Pollution moving from Beijing towards the Yangtze River.

6. Biodiversity and the carbon cycle

During photosynthesis, plants absorb carbon from the atmosphere in the form of carbon dioxide and convert it into organic molecules that contain energy (carbohydrates, proteins and lipids). Animals, for their part, absorb carbon the same way they do nitrogen, by eating plants or other animals.

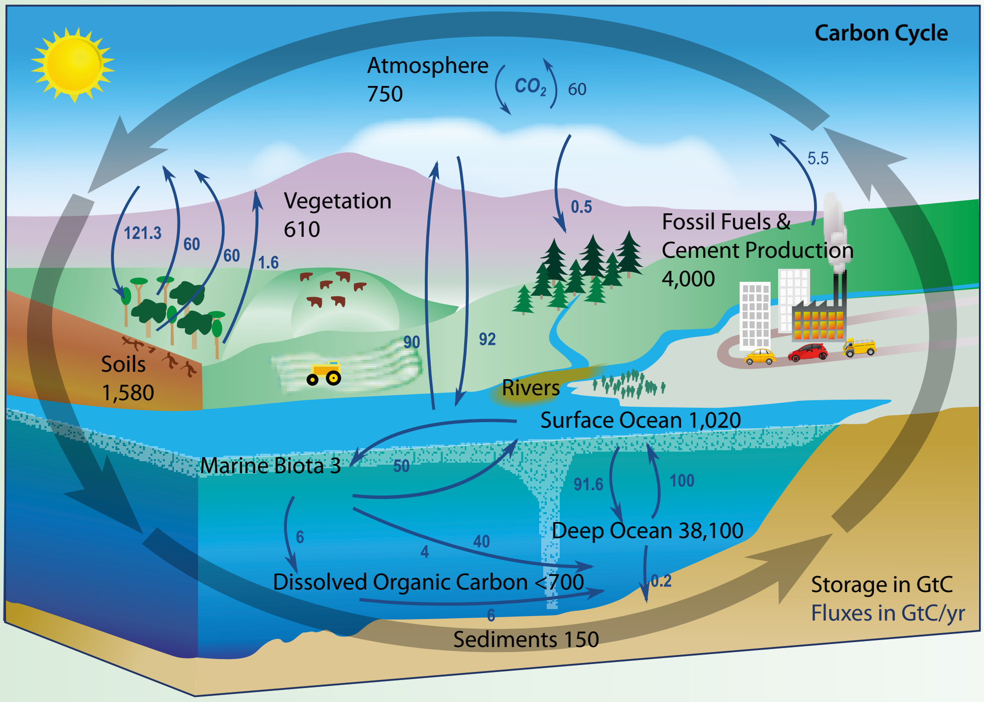
When living organisms die and are broken down by micro-organisms, most of their carbon returns to the atmosphere.

If there is not enough oxygen to generate any real microbial activity in the soil, micro-organisms cannot break down the carbonaceous remains, which stay trapped and accumulate beneath the ground. They will eventually turn into coal, oil or natural gas thereby becoming natural carbon reserves.

Our industry and transport depend heavily on the burning of carbonaceous rock (coal, oil and gas), which releases carbon into the atmosphere.

FIGURE 32: THE CARBON CYCLE

Like the nitrogen cycle, the carbon cycle is one of the major biogeochemical cycles of the planet. It refers to the complex exchange of carbon elements between the water, rocks, living matter, necromass and the Earth's atmosphere. Like nitrogen, it is a macroelement; all living things contain carbon.



Another significant source of human-induced carbon emissions is the extensive burning of organic matter as a result of deforestation.

Still widely used in tropical zones for reasons of economic development, deforestation often means the wholesale destruction of forests by fire in order to turn them into arable land. It is thus estimated that 750 million hectares of savannah are burnt annually, almost half of which are located in Africa.

The impact of human intervention on the changing carbon cycle can now be quantified: over the past two centuries, atmospheric CO_2 concentrations have increased by a third.

This imbalance is largely responsible for significant global warming, caused by the action of abnormally high concentrations of CO_2 and methane (greenhouse gases) in the atmosphere.

Given our current ability to quantify and understand the impact of human activity on climate change, it is essential to analyse and acknowledge the role of biodiversity in regulating the climate and the potential for storing carbon through photosynthesis, the main mechanism for carbon sequestration.

Photosynthesis does not reduce CO_2 emissions, but helps to extract carbon dioxide from the atmosphere by trapping or storing it in natural reservoirs such as forests.

While it is still difficult to gauge the carbon balance of a forest ecosystem, it is a recognized fact that tropical forests in their growth phase, and temperate forests not at risk of fire, are genuine **carbon sinks**, since they fix the gas in both wood and soil.

Every type of forest biomass stores carbon – cellulose, lignin, necromass, and animal, fungal and microbial biomass.

The radical changes in land use and forest cover worldwide that have affected biodiversity have also had an impact on regulation of the carbon cycle and on local, regional and global climate.

Imagine what would happen in terms of global warming if the Amazon forest were to evolve from being a carbon sink to being a source of carbon for the atmosphere.

Each year, the Amazon forest recycles 66 billion tonnes of carbon dioxide, largely as a result of recent plantations made during its growth phase. This amount corresponds to almost three times the emissions of fossil fuels burnt in the world.

The Amazon.

7. Biodiversity and other supporting services

Plants grow by converting carbon dioxide from the atmosphere through photosynthesis. At the same time they release oxygen, a gas essential to living organisms for cellular respiration.

Plants provide 21% of the dioxygen in the Earth's atmosphere – the oxygen that makes air breathable. The largest producers, well ahead of Earth's great forests, are cyanobacteria, algae and microscopic plants that make up phytoplankton (the plant component of plankton), since a substantial part of the marine oxygen that this produces is released into the atmosphere.

The level of oxygen in the atmosphere is steady, resulting from a dynamic balance between its production by photosynthesis and its consumption (through respiration and combustion).

However, a reduction in the oxygen content of the oceans has been observed, due in part to a lack of phytoplankton to regenerate the oxygen through photosynthesis. This phenomenon seems to be caused in part by acidification of the oceans.

Since the carbon and oxygen cycles are related, the oxygen-producing oceans also function as huge carbon sinks, with the carbon being absorbed by plankton, corals and fish before being transformed into sedimentary rock (biogenic limestone).

The increase in atmospheric carbon dioxide levels over a critical threshold, rising concentrations of CO_2 in the oceans, and the ammonia and nitric acid contained in acid rain are tending to acidify water and create conditions incompatible with biomineralization, coral growth and healthy phytoplankton.

If they become acid, the oceans could destroy the phytoplankton that trap carbon and supply the atmosphere with oxygen.

Forest and plant cover also provide vital supporting services. When water runs off the surface of the land, the action of roots penetrating deep into the soil is extremely important: firstly, they hold the soil in place, particularly on slopes, with the root divisions providing anchorage points to create a stable structure; and secondly, they allow the water to filter through natural

Coral reefs produce calcium carbonate, making them the most important oceanic and global carbon sinks.

Flynn Reef. © Toby Hudson, CC BY SA 3.0

Biodiversity also contributes to the production of freshwater. Even if the water cycle is essentially biochemical, living organisms including plants have a major influence on the cycle.

Spring. © Ana Eduarda Gonçalves de Barros, FAO FO-7404

cracks and percolate slowly through the ground to replenish the water table.

In regions with substantial deforestation as a result of steady population pressure (e.g. northern India, the Pamir Mountains and some areas of Southeast Asia), the forest cover no longer retains the heavy monsoon rains or the meltwater from the mountains. Runoff is increasing and the soil cannot absorb rainfall, since it lacks structure without humus.

In such cases, deforestation leads to flooding and deadly mudslides, while the leached soils are eroded and desiccated. One cumulative effect of a decline in plant cover is a reduction in **evapotranspiration**, a process by which water penetrating the soil is absorbed by the roots of plants, which draw it up and release some of it into the atmosphere through respiration. Atmospheric water is absorbed directly through contact with leaves, stems and epidermis. All the plants constituting plant cover retain water for the functioning of their cells.

Deforestation, if carried out intensively in a region, has the effect of reducing evapotranspiration, and the local water cycle may be substantially modified as a result, leading to disturbances such as flooding.

Habitat provision is another valuable supporting service provided by ecosystems, to which some species in the web of life make a very direct contribution.

These species are the cornerstones of communities; they often demonstrate considerable ecological 'engineering' qualities and are described as 'engineering organisms', since they build or themselves constitute habitats for other organisms.

For example, large trees in deciduous forests both living and dead support successive communities of species over time.

Coral reefs are another example; although they resemble carved rock, they are in fact coral skeletons, *corolla*, where thousands of coral polyps live in colonies. Microscopic algae live inside the polyps and produce food that they supply to the corals and to thousands of coral species, fish, turf algae and sea snails, which themselves are prey for reef predators.

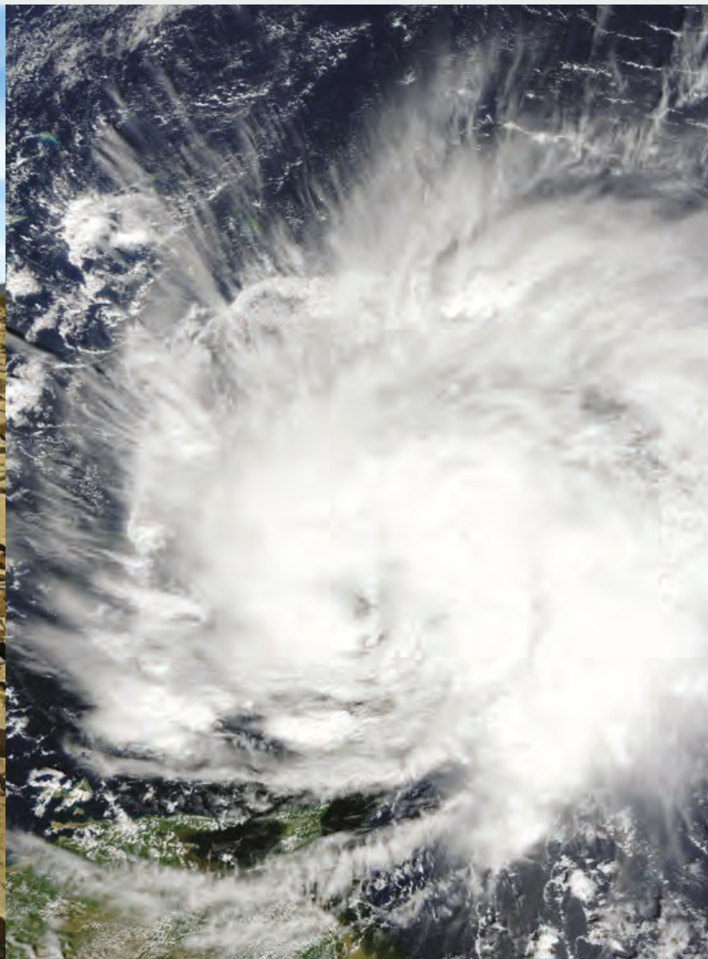
Beavers too cut wood and build and maintain dams that support communities of invertebrates and aquatic micro-organisms at the bottom of the food chain.

Finally, the introduction or increase of natural predators in ecosystems for the purposes of biological control requires multiple precautions, including a detailed analysis of their dispersal capacity and sensitivity to environmental conditions.

Consequences of drought in Mongolia.
© Asian Development Bank, CC BY NC ND 2.0

Hurricanes have an effect on the local hydrological cycle and its variability.

Hurricane Tomas, 2010. © NASA / MODIS Rapid Response System



Great Barrier Reef. © Sarah Ackerman, CC BY 2.0

Beaver dams. These examples of natural engineering remind us that beavers can be valuable partners in the restoration of endangered ecosystems or regulation.

Beaver dam. © Schmiebel, CC BY-SA 3.0

Among the species of natural engineers are earthworms, whose activities have a considerable impact: they aerate the soil, thus feeding it with oxygen, which allows the development of microbial activity. By focusing their resources they also create soil-borne concentrations of nutrients for flora and fauna, accelerating the growth of plants.

Lumbricus terrestris. © David Perez, CC BY 3.0

The tipping point is defined as 'as a situation in which an ecosystem experiences a shift to a new state, with significant changes to biodiversity ...'

Biodiversity *and the concept of the tipping point*

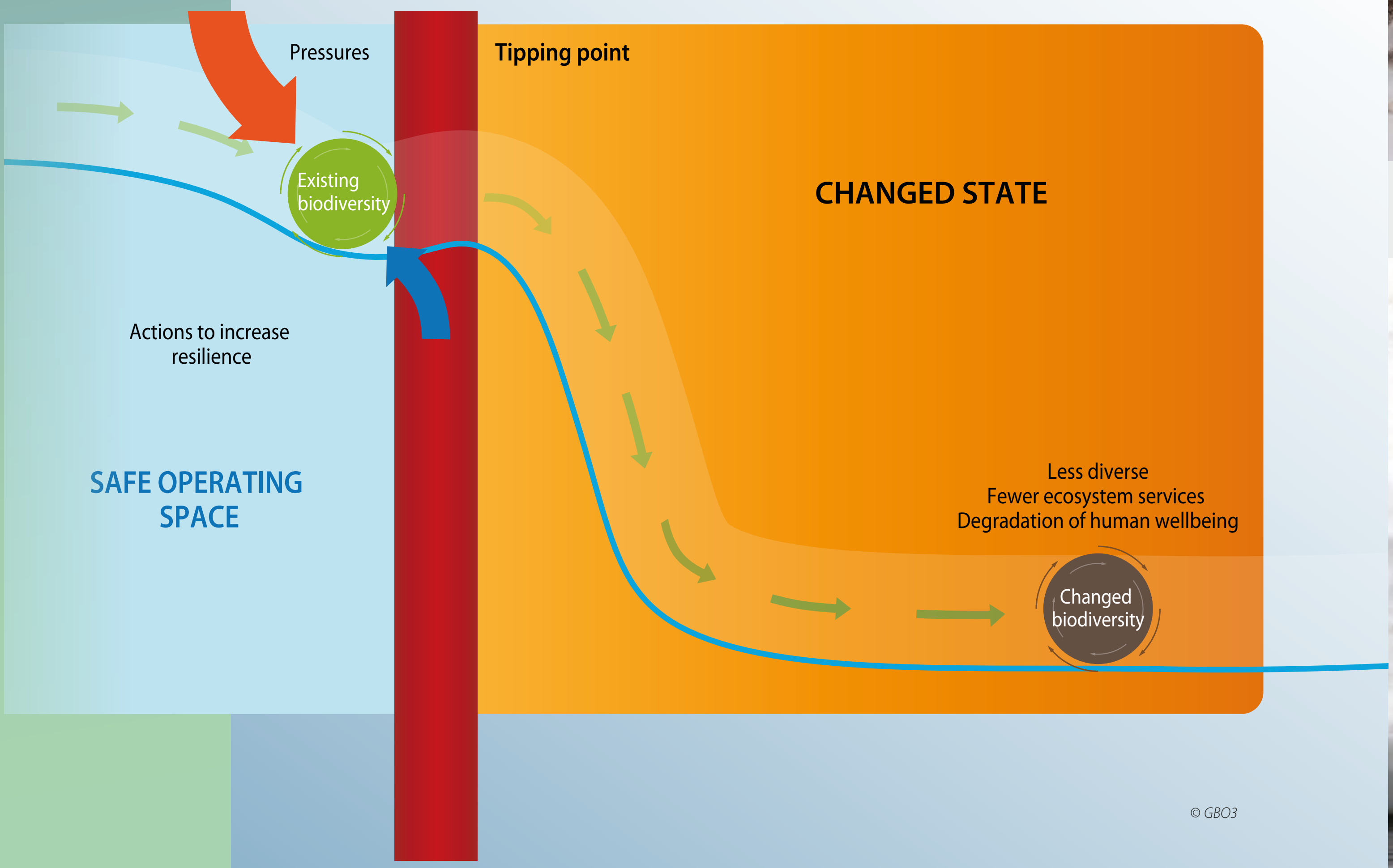
The *GBO3* defines a tipping point as 'as a situation in which an ecosystem experiences a shift to a new state, with significant changes to biodiversity and the services to people it underpins, at a regional or global scale.'

The report notes that 'tipping points also have at least one of the following characteristics:

- The change becomes self-perpetuating through so-called positive feedbacks, for example, deforestation reduces regional rainfall, which increases fire-risk, which causes forest dieback and further drying.
- There is a threshold beyond which an abrupt shift in the ecological states occurs, although the threshold point can rarely be predicted with precision.

FIGURE 33: TIPPING POINTS

The growing pressures on biological diversity could potentially lead some ecosystems into new states once tipping points are reached, with serious repercussions for human wellbeing. Although it is not easy to establish the exact location of tipping points, once an ecosystem passes into a new state, it can be very difficult, if not impossible, to return it to its former state.



- The changes are long-lasting and hard to reverse.
- There is a significant time lag between the pressures driving the change and the appearance of impacts, creating great difficulties in ecological management.

Tipping points are a major concern for scientists, managers and policy-makers, because of their potentially large impacts on biodiversity, ecosystem services and human wellbeing.'

In conclusion, the *GBO3* notes that 'it can be extremely difficult for societies to adapt to rapid and potentially irreversible shifts in the functioning and character of an ecosystem on which they depend. While it is almost certain that tipping points will occur in the future, the dynamics in most cases cannot yet be predicted with enough precision and advance warning to allow for specific and targeted approaches to avoid them, or to mitigate their impacts. Responsible risk management may therefore require a precautionary approach to human activities known to drive biodiversity loss.'*

* **For more details see**
Vol. 2, Activity 10, Scenarios based on supporting and regulating services (p. 56).

Reindeer. © Lawrence Hislop, UNEP Grid-Arendal

Polar bear, Svalbard. © Peter Prokosch, UNEP Grid-Arendal

Penguins. © Peter Prokosch, UNEP Grid-Arendal

Biodiversity *and the cultural services of ecosystems*

Our particular, distinctive uses of nature through hunting, fishing, gathering, agriculture and livestock farming, and consequently our lifestyles, have been shaped by the availability of natural resources and the constraints of the environment, especially climate.

1. Nature and culture at the universal level

In their history and construction, human societies have evolved in constant interaction with the surrounding environment. Our particular, distinctive uses of nature through hunting, fishing, gathering, agriculture and livestock farming, and consequently our lifestyles, have been shaped by the availability of natural resources and the constraints of the environment, especially climate. Every human community has thus invented and developed a complex set of solutions and responses to face the challenges of the natural environment.

The term **bio-cultural diversity** refers to these different approaches, found throughout the world, which have derived from the multiple ways in which humans interact with their natural environment. The co-evolution of human groups and natural environments has generated ecological knowledge and local customs, which constitute a vital reservoir of experience, methods and skills to help different societies manage their resources.

However, culture cannot be reduced to a set of interactions with the natural environment, as it derives equally from the influence of human and social factors.

Throughout history, human beings have managed to tame nature and develop uses for it, thanks to their specific capacity to perceive and reflect, and the combination of a complex psyche and a highly developed memory.

Perception for a human being is a physiological phenomenon that cannot be reduced to the action of an organ (i.e. the eye) or to the interpretation of a single individual: it is a complex mental process linked to our psyche as a whole.

Fishermen of Lake Patzcuaro, Mexico. © Fergar CC BY-SA 3.0

Materials used in harvesting palm vines. © Ji-Elle, Public domain

Throughout time, humans have perceived nature and conceived of the world through a powerful ideological determinism. Consequently, while human perception is universal, the way in which we perceive is not: we perceive primarily what we know of the world.

Culture therefore reflects the evolution of a human community with its own identity, determined by its ethnic origin, its history, its language, its religion and its artistic expressions.

In short, thanks to perception and memory, human beings in every region of the world have been able to recognize situations and experiences, and have developed distinct representations of nature and, more generally, systems and structures to cope with and learn to manage their natural and social environment.

These systems include languages, knowledge systems (acquisition of knowledge, practical skills and know-how), value systems (ethical, moral, spiritual), belief systems (religions, worldview), artistic expressions, economic systems (modes of production and exchange), social systems (institutions), legal systems, land tenure systems and so on.

All these systems have been built through interaction with the natural world. Human communities have not relied on natural processes not only in terms of satisfying their basic needs such as breathing, drinking or eating, but have also used natural processes to stimulate their need to develop intellectually, sensitively, spiritually and artistically. In evolutionary terms, this interface with nature has allowed us to develop and enrich our faculties.

Rock painting depicting buffalo, Covaciella Cave, Spain.
© José Manuel Benito, Public domain

Fresco showing scenes from everyday life with hieroglyphics, Egypt.
© Public domain.

The 'masquarade' of La Viajanera is a ritual celebrated in Cantabria, Spain, to honour nature.
© Cerofe CC BY-SA 3.0

The Milky Way. © BlaiseThirard CC BY-SA 3.0

Aurora Borealis. © Sennheiserz CC BY-SA 3.0

Cryolophosaurus elliot. © D. Gordon E.Robertson CC By-SA 3.0

Our development and experiences are rooted in the diversity of the biological world. The co-evolution of humans and their natural environments has enabled the emergence of increasingly complex representations of the world, plural and diverse worldviews, and numerous ethical ways of approaching life, with nature performing myriad crucial functions.

* **For more details see**
Vol. 2, Activity 7, The interplay of species, services and products (p. 35), and Activity 8, A notebook for studying nature as a source of inspiration (p. 42).

** **For more details see**
Vol. 2, Activity 8, A notebook for studying nature as a source of inspiration (p. 42).

Biodiversity and perception

The diversity of the living environment also plays a role in awakening individual sensitivity. We have all marvelled at the myriad forms of tropical plants, the contours of mountainous terrains, the brilliant colours of spring flowers, and at the beauty of land and seascapes?*

Biodiversity also plays a key role in developing our designation and classification systems. Indeed, our ability to classify and order, whether by scientific classification (in botany or palaeontology) or in art (nuances of colour) derives from the wealth of natural diversity. Our range of sensations thus has its origins, in part, in the diverse flavours of spice plants, fruit and vegetable species, and the many volatile components of the plants that surround us.**

Biodiversity and artistic expression

The living environment has always inspired us in terms of aesthetic experience and artistic expression.

In Western civilization, analogue representations of nature are extremely common in artistic production. The image is clearly a visual sign, an object that refers to another object, and which therefore exists by its representation. We have traditionally copied the visible world and, by extension, biodiversity, rendering it in frescos, painting, sculpture, drawing, photography and cinema among other forms.

Consider, for example, the infatuation of the Dutch and Spanish painters of the Golden Age (seventeenth century) with natural subjects, which they presented

Small horses in papier-mâché, Mexico.
© Tomascastelazo, CC BY SA 3.0

Still life. © Cornelis de Heem, public domain

Tree of life, Azerbaijan. © Urek Meniashvili CC BY SA 3.0

in a context of domestic utility. Among the species that make up the meals and the flowers that adorn kitchen walls, which are captured in a raw, almost decorative realism, can be found shellfish, open oysters, game, walnuts, pomegranates, quince, half-peeled lemons and lemon zest spirals, thistles and so on. Sometimes a lizard or butterfly will intrude, signifying impermanence, or a still life will portray perishables such as decomposing fish or a skull (suggesting that human life is precarious and meaningless). The same celebration of biological diversity is found in other contexts of cultural expression, for example, the bronze Lifestyle heads, discovered in southern Nigeria in 1938.

In the indigenous cultures of Africa and Australia, this reverence for nature is often expressed in a more ritualized, theatrical fashion, rooted in myths and beliefs in the borderland between art and religion that have shaped these societies.

The representations of the world transmitted by these myths enable these peoples to define their way of life in connection with nature, to establish coded performances and celebration rituals, and to establish rules for the use of natural resources.*

* **For more details see**
Vol. 2, Activity 8, A notebook for studying nature as a source of inspiration (p. 42).

The artistic representations produced include masks, paintings, totems, sculptures and dances performed during rituals and celebrations, which are often cathartic in character and linked to purification.

Analogous Western artwork represents a form of transcription, expressing an urge to render in various artistic forms the sensations and emotions experienced when we are confronted with nature.

In both cases, however, the artistic productions that depict the diversity of the living environment extend beyond the individuals and communities that produced them.

It is worth remembering, here, the definition of a work of art given by Ernst Gombrich in *The Story of Art:* 'What we call "works of art" are not the result of some mysterious activity, but objects made by human beings for human beings.'

Works of art can be described as offerings from artists that teach us to take a fresh look at new, unsuspected aspects of natural diversity.

Under their guidance, our eyes sharpen and discover the infinite in the finite, the fantastic nature of biological diversity in its apparent realism, and in the work of many contemporary artists, half-imaginary, half-visionary scenarios detailing the risks and consequences of current intense pressures on the natural environment.

Wawadit'la – home of Mungo Martin and his totems, Thunderbird Park, British Columbia. © Ryan Bushby CC BY SA 2.5

Harvest festival, Germany. © Eeignes Werk CC BY SA 3.0

2. Biodiversity and indigenous knowledge

Nature also offers other valuable cultural services in terms of training and technical expertise through the acquisition of indigenous knowledge and know-how.

Different human communities have developed their use of nature by adapting to the existing resources and constraints of the environment. Through their experience, they have been able to adjust and modify the natural environment to meet their needs, while learning from this interactive relationship.

Landscapes have been transformed with the introduction of agriculture. The terms **terroir** in Europe and **satoyama** in Japan refer to landscapes born from the union of nature and culture. They reflect a detailed knowledge of natural environments and their biodiversity, as well as often harmonious and sustainable management methods.*

UNESCO and the *Terroirs et Cultures* association define *terroir* as 'a delimited geographical area defined from a human community which builds along its history a set of distinctive features, knowledge and practices based on a system of interactions between the natural environment and human factors.'

Terroirs are therefore landscaped areas characterized by one or more farming activities, including terraces, palm groves, salt marshes, vineyards, landscapes marked by forestry-pastoralism or cattle farming, hedgerows and so on. They are also defined by the sets of knowledge and information they convey, such as thorough knowledge of local species and habitats, resources, seed management and crop rotation, supported by locally used indicators and diagnostic techniques.

Recognition of local knowledge in development processes and policies is one of the priorities of the LINKS (Local and Indigenous Knowledge Systems) programme launched by UNESCO in 2002. The programme treats local knowledge as being akin to 'traditional ecological knowledge', covering knowledge and interpretations accumulated by people with a long history of interaction with the natural environment. LINKS highlights the connections between these knowledge systems and local and indigenous rituals, spirituality and worldviews.

Important connections between artistic expression and spirituality, and between local knowledge and spirituality, exist in many indigenous societies.

Different human communities have exploited and developed nature according to the available resources and environmental constraints.

*** For more details see**
Vol. 2, Activity 6, A mural of terroirs (p. 30).

This empirical knowledge is based on the characteristics of the natural environment, which vary from one region to another. By maintaining the local ecosystems and their biodiversity, these knowledge systems can be built up and passed on from one generation to another.

Traditional agriculture, Kenya. © Neil Palmer (CIAT), CC BY SA 2.0

Vineyard, Cully-Lavaux, Switzerland. © Ricardo Hurtubia, CC BY 2.0

In the oral tradition of these societies, traditional ecological knowledge is taught, learned and passed on through action alone. When the Inuit, for example, teach a hunting technique, it is accompanied by a rite of passage to adulthood. In Morocco, when terraces are built in the Atlas Mountains, the women dance and sing on the sites once the rain has stopped. In trampling the soil, they tamp it down and make it waterproof, all the while invoking a form of divine protection for the terraces.

Traditional societies do not set rationality and spirituality against each other: the use and management of ecosystems and their biological community feed directly into local knowledge and are reflected in artistic expressions that depict the diversity of the living environment and act as the object of devotion.

Accordingly, some territories in remote areas, such as the Andean Páramo and the sacred forests of the Sherpas of the Himalayas, can be regarded as sanctuaries for ancestral worship. Other places, often with exceptional physical qualities (e.g. landforms and mineral qualities) bring together powerful religious and artistic associations, such as the Uluru-Kata Tjuta National Park for the Aboriginal community in Australia.

The UNESCO World Heritage Convention classifies these sites as **cultural landscapes**, indicating They show that nature and culture are inseparable in these societies.

More generally, even landscapes that play an active social and economic role can be charged with reverential, religious meaning. For example, the rice terraces of the Philippine Cordilleras were considered sacred by their founders, the Ifugao people, and are still considered so today.

Miao woman grinding corn, China. © Yves Picq, CC BY SA 3.0

Tuareg nomads. © Garrondo, CC BY SA 3.0

3. Erosion of biological diversity and cultural diversity

Although we all maintain a relationship with biodiversity we may appreciate it in different ways

Today, the majority of people are town and city dwellers and contact with nature is often indirect, or at least seems that way. Our physiological need to eat and enjoy healthy water and breathe fresher air makes us return periodically to the natural environment and, by extension, to the place it occupies in our lives and our societies. Paradoxically, nature is simultaneously retreating. Natural areas are being eroded, habitats are becoming fragmented and populations are increasingly isolated.

The massive decline in the populations of native and wild species is paralleled by an erosion of specific cultural features: every medicinal plant helps to preserve knowledge of traditional medicine, every woody species helps to preserve woodworking skills, and every aromatic species helps to safeguard the variety of flavours used in the local cuisine.

Species extinction thus results in the loss of precious indigenous knowledge on which cultural identities are based and developed. To lose one's identity or more generally to live in a state of identity drift is to lose access to a satisfactory intellectual, emotional, moral and spiritual existence.

The Report of the *International Conference on Biological and Cultural Diversity*, which was held in Montreal in June 2010, drew attention to this dual phenomenon of the erosion of biological and cultural diversity: '2010 raises the alarm over the unprecedented changes [the Earth's] main biological and cultural components are currently facing … In the current global change context, the loss of biological diversity, with the simultaneous loss of languages, knowledge systems, and specific ways of life, has resulted in new challenges for coupled social-ecological systems.'

The erosion of indigenous knowledge can contribute to a form of **acculturation** (i.e. a gradual abandonment of all or part of one's own cultural values in order to assimilate those of another group of people). This process constitutes a threat if it amounts to a form of alienation and disorientation, especially in young people. At present, the combined pressures of acculturation and the reduction in natural resources threaten many indigenous peoples.

In some contexts indicated by the *GBO3*, these pressures have been accompanied by economic choices that have proved harmful to the community.

Economic efficiency requirements have forced many small farms, forestries or fisheries to abandon traditional resource management methods, for example, by restricting collection of a bark popularly used in medicine or closing certain areas to fishing. Consequently, there is less regulation governing access to and use of resources and the latter can be looted, thus depriving local communities of precious assets of great cultural value.

For the same reasons, **polyculture** – cultivating multiple crops in the same space – is sometimes abandoned in favour of a single crop that is farmed

In developed countries, increasing social demand for access to nature has resulted in growth in the amount of time devoted to nature-related pursuits, including green tourism and outdoor activities.

Park in the city of Oslo.

intensively in order to make a quick profit. These choices, often driven by perfectly understandable short-term requirements, have disastrous consequences when crops fail or are over-exploited. They make local communities vulnerable to malnutrition, disease and even starvation.

4. Bio-cultural diversity and development

The maintenance of biodiversity (and associated indigenous knowledge) should be a priority for development and anti-poverty programmes and policies, as our food self-sufficiency and our health depend on the ecosystems around us and the goods and services that they guarantee.

It is therefore essential to consider biological and cultural diversity as a factor in socio-economic development. Stakeholders in every region must be able to protect and enhance traditional land use techniques, which are particularly well suited to the natural environment in which they were developed.

These are challenges for the future. Expertise such as local knowledge of how to improve seeding by using wild relative species has proved its usefulness and has already inspired modern technologies.

It is therefore important to strengthen communities' ability to assimilate exogenous and endogenous knowledge.

International institutions are working on this point to secure recognition of the intellectual property rights of indigenous peoples, as well as access to the benefits derived from the exploitation of their knowledge.

Tourism can also provide biodiversity-related development. In terms of investment and economic and social contributions, this can represent an enhancement of the educational, aesthetic, recreational and spiritual purposes of natural features for the people who come into contact with them or visit them. The educational aspect of the landscape is showcased, for example, through biodiversity observatories, botanical gardens and nature clubs.

Pomegranates, Istanbul market.

Xamã guarani.

The aim is to highlight the species contained in them – their botanical significance, their aesthetic features (colours, textures and scents), their genetic diversity, their history, the way they are currently managed and the different uses farmers make of them.

Highlighting the aesthetic features of a natural landscape through the history of art or the interaction between the natural and the built environment calls for targeted cultural tourism.

Ecotourism already enables people to discover a region through its products, production methods and local handicrafts. In Europe, gastronomic trips are organized across France, in southern Germany, in Wachau in Austria, in Tuscany, Campania and Sicily in Italy and so on.

UNESCO has recently inscribed the gastronomic meal of the French, traditional Mexican cuisine - ancestral, ongoing community culture, the Michoacán paradigm, and the Mediterranean diet on the Representative List of the Intangible Cultural Heritage; however, much remains to be done with regard to the culinary traditions of Asia and the Arab countries.

In addition, the specific ways in which land is occupied can provide inspiring opportunities for discovery and constructive cultural exchanges. Examples include learning about traditional navigation in the Pacific, the fishing methods of the Moken people (sea gypsies) in Thailand, and the lifestyles of Inuit hunter-fisher-trappers, reindeer herders in the Taiga, and Himalayan and Jordanian shepherds.

When emphasizing the value of cultural assets provided by biodiversity at the local level, it is important to develop a quality, targeted form of local tourism that combines respect for the environment with respect for local communities.

This is because these communities are, of necessity, an integral part and beneficiaries of this type of tourism. They must be asked for their input and should take part in initiatives and decision-making, and reap the benefit of these activities, while the organizers and operators act as intermediaries between local management and planning. In this way, tourism can help to justify the protection of local species.

Washoku is a social practice based on a set of skills, knowledge, practices and traditions associated with the production, processing, preparation and consumption of food. It was inscribed on the Representative List of the Intangible Cultural Heritage of Humanity in 2013.

Washoku is associated with a fundamental principle of respect for nature closely related to the sustainable use of natural resources. Basic knowledge as well as social and cultural characteristics associated with washoku are usually visible during New Year celebrations.

Washoku. © Ministry of Agriculture, Forestry and Fisheries, Japan

5. UNESCO and the links between biodiversity and cultural diversity

As noted in the Report of the Montreal 2010 *International Conference on Biological and Cultural Diversity*, UNESCO conventions and programmes on biological and cultural diversity are well placed to focus attention on the links between biological and cultural diversity at the international level.

The Local and Indigenous Knowledge Systems (LINKS) programme underlines, with regard to interdisciplinary research, 'the correlations between biodiversity and linguistic diversity'. It highlights the importance of valuing languages as a source of knowledge, practices and transfer of empirical nature-related expertise in predominantly oral cultures.

Although biodiversity constitutes the natural heritage of humanity, it is still undervalued.

However, in 1992, the UNESCO World Heritage Committee, during its sixteenth session, introduced the category 'cultural landscapes' as part of its Guidelines for the Implementation of the World Heritage Convention.

UNESCO has thus gained valuable experience in the identification, protection and management of cultural landscapes of outstanding universal value.

It has also become possible to increase international recognition of natural heritage sites by designating some as cultural landscapes.

Cultural landscapes are selected for their outstanding universal value, their representativeness in a clearly defined geo-cultural region, and their ability to illustrate the essential cultural elements of these regions. The emphasis is thus on the history of the region and the continuity of cultural traditions.

Living cultural landscapes fall under the category of 'evolving landscapes', and are classed as such insofar as they continue to play a social and economic role in contemporary society, while remaining closely associated with a traditional way of life.

Among the commonly cited examples of living cultural landscapes are the rice terraces of the Philippine Cordilleras, which reflect the indivisible link between nature and culture and reflect specific land – use techniques.

In choosing to classify and protect this type of landscape, the World Heritage Convention helps to enhance the natural values of landscape within the **cultural landscape** category; and by protecting

Macizo de Cajas Biosphere Reserve.
© UNESCO MAB / ETAPA EP

traditional forms of land use, it also simultaneously protects the diversity of the living environment. In addition to heritage protection, this also raises the question of the effective maintenance of biodiversity as a prerequisite to the maintenance of cultural diversity.

According to the summary of the state of research and policy work, drafted on the occasion of the *International Conference on Biological and Cultural Diversity,* there has recently been an increase in technical expertise in the development and application of integrated approaches to landscape management practices.

Parallel and complementary approaches to conservation, based on links between biodiversity and cultural diversity, are being developed or tested by the *Planète Terroirs* network, the Satoyama Initiative and the Biosphere Reserves network under UNESCO's Man and the Biosphere (MAB) Programme.

In conclusion, international agreements and UNESCO programmes relating to indigenous knowledge, land and landscapes, conversion of areas and sites into protected areas, and conservation of natural resources are highly useful tools that can help managers to protect ecosystems and biodiversity, maintain the cultural services they provide, and organize effective planning and management of the land, from the local to the international level.*

*** For more details see**
Part 1, Diversity of habitats, biomes and landscapes (p. 26), and Part 3, Towards concerted, wise management (p. 180).

Rice harvest in Nepal. © FAO Mountain Partnership / Jack D. Ives CC BY-NC 2.0

Mont-Viso Biosphere Reserve in the north-alpine region of Italy. © UNESCO MAB / Renzo Ribetto

Cherry trees in the Minami-Alps biosphere reserve, Japan. © UNESCO/Yamanashi Prefecture Minami-Alps

Part 3

The future of *biodiversity* and the conditions for its *conservation*

Left:
Elephant carrying logs in Thailand.
© J. Weber, INRA

Right, top to bottom:
Argan tree plantation.
© Luc Viatour, CC BY-SA 3.0
Cooperation for the conservation of the planet.
© Jürgen from Sandesneben CC BY 2.0
Polar bear on Wager Bay ice bank (Ukkusikaslik National Park, Nunavut, Canada).
© Ansgar Walk CC BY 2.5

Alternative *paths for terrestrial ecosystems*

It is vital to take into account the greenhouse gas emissions associated with large-scale conversion of forests.

1. Taking account of the combined effect of CO_2 emissions and the conversion of natural ecosystems

According to *GBO3*, 'alleviating pressure from land use changes in the tropics is essential, if the negative impacts of loss of terrestrial biodiversity and associated ecosystem services are to be minimized. This involves a combination of measures, including an increase in productivity from existing crop and pasture lands, reducing post-harvest losses, sustainable forest management and moderating excessive and wasteful meat consumption.'

It is also vital to take into account the greenhouse gas emissions associated with large-scale conversion of forests and other ecosystems into cropland.

Production of charcoal.
© CIFOR, Ollivier Girard

Landscape after deforestation, Madagascar.
© UNEP Grid-Arendal, Peter Prokosch

Significant research is being carried out on transforming lignin and cellulose plants (straw, wood) into alcohol or gas (lignocellulose-biofuel industry).

Prudhoe Bay oil field flare.
© UNEP Grid-Arendal

According to *GBO3*, this will limit the negative effects of incentives that reduce biodiversity by promoting large-scale deployment of biofuel crops in the name of climate change mitigation. For example, government policies and development programmes may in fact worsen the situation by providing direct and indirect subsidies to encourage large-scale production or monoculture of agrofuels. In Southeast Asia there has been considerable development of oil palm plantations as a result of support for biofuel demand.

Once we factor in emissions from land-use change, as well as energy emissions, we start to see the emergence of plausible development pathways that tackle climate change without widespread biofuel use.*

* For more details see
Vol. 2, Activity 11.3, Dialogue and action on sustainable forest husbandry (p. 71).

2. Payment for ecosystem services

Use of payments for ecosystem services, such as *Reducing Emissions from Deforestation and Degradation* (REDD) mechanisms, may help align the objectives of addressing biodiversity loss and tackling climate change.

Indeed, tipping points can more easily be avoided for certain terrestrial ecosystems if climate change mitigation to keep average temperature increases below 2° C is accompanied by measures to reduce the impact of other factors causing degradation of ecosystems, such as the conversion of natural habitats to cropland or for livestock farming.

For example, in some cases excessive expansion of grazing pastures in mountain areas has been reduced through the introduction of integrated ecosystem management procedures as part of regional projects, particularly in Latin America. Producers and farmers have received payment in the form of environmental services for adopting sustainable forest husbandry techniques (such as planting live fences around pastures) or, more broadly, for reducing grazing areas by improving pastures.**

** For more details see
Part 3, Forest management plans and the implementation of sustainable forest practices (p. 186).

Mountain forests north of Beijing, China.
© Peter Prokosch, UNEP GRID-Arendal

Improved agricultural techniques to promote sustainable practices. © Scott Bauer, USDA ARS

Monarch butterflies.

3. Management of highly threatened regions

In the Amazon rainforest, it is estimated that keeping the size of the deforested area below 20% of the original forest cover will greatly reduce the risk of widespread dieback. It is worth remembering that, while the relatively unfertile lands of the Amazon are not conducive to extensive farming, more could be made of the region's potential food resources and agricultural products if they were better exploited.

Better forest management options in the Mediterranean,* including the greater use of native broadleaf species in combination with improved spatial planning, could make the region less fire-prone.

* **For more details see**
Part 3, Forest management plans and the implementation of sustainable forest practices (p. 186).

In the Sahel, assistance with farming techniques to develop agricultural seeds and cultivars suited to local conditions, genuine poverty alleviation through the development of a viable food, agriculture and economic system, and – most importantly – better governance to improve management at all levels, could offer sub-Saharan Africa an alternative to the current cycles of poverty and land degradation.

National Bison Range, Montana.

4. Innovation in conservation

Finally, according to *GBO3*, innovative approaches to conservation should be adopted in order to prevent the loss of terrestrial biodiversity, both within and beyond protected areas. Indeed, species cannot survive in isolation. It is not enough to establish a reserve to conserve animal species that, for example, are constantly on the move in search of food and mating partners. In order to survive and thrive, it is essential for them to be able to move around.

In large preserved or restored areas, it is relatively easy to ensure continuity between the environments using natural elements or simple devices to facilitate animal movement. However, there needs to be a greater focus on biodiversity management in landscapes dominated by human activities, as climate change alters species distribution areas.

In many cases, species are clustered in fragmented ecosystems, and are increasingly vulnerable to disease and inbreeding. Accordingly, their movement should be facilitated through town and city centres, in major agricultural areas and around road infrastructure, because these areas of intense human presence are expected to play an increasing role as ecological corridors, as communities of species are forced to migrate to adapt to climate change.*

*** For more details see**

Part 3, Towards Concerted, Wise Management,Terrestrial protected areas (p. 180), and Marine Protected Areas (MPA) (p. 183).

Giraffe reserve, Masai Mara, Kenya. © Peter Prokosch, UNEP Grid-Arendal

The fight against poverty relies upon the development of a viable food, agriculture and economic system.

Women begin the process of making shea butter. © CIFOR / Ollivier Girard

Numerous elephants can be seen in the dense forest of the Special Reserve of Dzanga Sangha, Central African Republic. © Peter Prokosch, UNEP Grid-Arendal

Alternative *paths for aquatic ecosystems*

1. Promote remediation and wastewater treatment using biological processes

According to *GBO3*, it is possible to reduce the risk of eutrophication through better control of agricultural run-off, by restoring wetlands – which provide a free water treatment service thanks to the natural purifying power of their vegetation – and by investing in wastewater treatment.

The water quality of many inland water ecosystems has been greatly improved in developed countries thanks to treatment of sewage and industrial effluents through the organic chain. This can be extended to developing countries and applied to agricultural pollution control.

Phyto-purification systems offer a cost-effective and sustainable solution for wastewater treatment.

The main objective of wastewater recycling is to support the natural water purification cycle, in order to provide additional quantities of water for various uses or to help compensate for water shortages. This seems particularly necessary in countries with arid or semi-arid regions where reserves are dwindling. Mexico City has developed the largest urban wastewater reuse project by recycling nearly all the city's wastewater to irrigate almost 90,000 hectares of agricultural crops.

The widespread use of agrochemicals for cotton cultivation, inefficient irrigation systems and inadequate drainage systems are examples of conditions that encourage the absorption of saline waters and contaminated soil.

Water pollution, Amu Darya Delta, Uzbekistan. © Science and Analysis Laboratory, NASA-Johnson Space Center

Freshwater, Pakistan.

Wastewater is treated biologically to decontaminate the water of organic matter or various contaminants (heavy metals, hydrocarbons, pesticides and synthetic fertilizers). Depending on the case, a microphyte, macrophyte or hydrophyte finishing lagoon can be installed, but a combination of these systems makes for a better outcome.

Looking ahead, it is essential for us to conserve water reserves on a global scale and to use water more efficiently in the agricultural and industrial sectors, so as to meet the growing demand for freshwater. Many agencies, including FAO, issue regular communications on measures to improve the effectiveness of irrigation water by reducing direct evaporation, water loss during transport or by curbing run-off losses.

Excavation of a dried river in Kenya.

Cenotes are produced by a process of dissolution and collapse of limestone located above an underground network of caves and rivers. They are completely or partially filled with a surface layer of freshwater and sometimes a lower layer of seawater, if they communicate with the ocean through faults or other conduits. This illustrates the complexity of water availability for human uses.

Cenotes.

2. Restore or maintain river connections and connections between water sources

The environmental impact of river fragmentation can be reduced or even partially corrected if we reverse the trend of degradation. Encouraging the movement of species and sediment transport over waterways by restoring disrupted processes, for example, by reconnecting the tributaries of a river or the waters of a floodplain, is now a priority.

According to *GBO3*, more integrated management of freshwater ecosystems through policies targeting land management and protected area network, can help to address the specific problems of these ecosystems. This involves protecting the ecological integrity of a river, including its wildlife areas and fluvial dynamics; safeguarding the specific ecological processes of wetlands in their functional interactions with terrestrial and marine ecosystems; and supporting progress towards inland coastal ecosystems (marsh areas, swamps and mangroves) by maintaining existing connections with the water network upstream. This last point requires a review of dam installations to enable natural sediment flows and to ensure the safety of upstream activity.

As suggested by *GBO3*, payment could be made for environmental services to reward communities that maintain and ensure the proper functioning of all these ecological services to users throughout the watershed.

Congo River.
© Christina Bergey, CC BY SA 3.0

Fontfile Triple lock at Blomac, France. © Tournasol7, CC BY SA 3.0

Irrigation of rice fields in Viet Nam using a pedal system, Danang region. © INRA / J. Forneau

3. Promote the recovery of marine resources

The authorities responsible for fisheries and fish catches have an urgent responsibility to identify options for the sustainable management of marine resources for the long-term viability of fisheries.

Directly allocating to individual fishers, communities or cooperatives a certain percentage of the total allowable catch from the stock of a given species can provide an incentive to keep stocks healthy.

This provides an alternative to the negative incentives inherent in the conventional system of quota-setting, which express allocations in terms of tonnes of a particular stock, potentially encouraging short-term catch optimization.*

According to some recent fishery modelling studies, coordinated efforts to secure a modest reduction in catch volume, target larger fish and make stakeholders accountable for helping to maintain the integrity and productivity of the ecosystem, could lead to a significant improvement in the state of marine ecosystems, while simultaneously improving the profitability and viability of the sector.

The competent authorities must also improve their approach to illegal, unreported and unregulated fishing. Finally, we must work to promote a low-impact aquaculture that is less harmful for the environment and which deals with sustainability issues concerning the spreading of waste and feed for aquaculture species. This would help to meet the growing food demand for fish, while reducing pressure on wild stocks.

* **For more details see**
Part 3, Towards concerted, wise management, Individual Transferable Fishing Quotas (ITQ) (p. 185).

Salmon. © Earth's buddy, CC BY-SA 3.0

Inuit fishers. © Peter Prokosch, UNEP GRID-Arendal

Traditional cod drying, Norway. © Lawrence Hislop, UNEP GRID-Arendal

4. Reduce threats to coral reef systems

Although the challenge of arresting the degradation of reef ecosystems caused by the effects of climate change, namely ocean acidification, increasing ocean water temperatures and rising sea levels, is unlikely to be met in the short-term it is possible to implement urgent mitigation strategies at the international level.

In order to act on global warming and work to keep global temperature rises to a maximum of 2° C above pre-industrial values, there must be prompt action to limit global emissions of CO_2 and other greenhouse gases (methane and nitrous oxide), to ensure that they peak between 2015 and 2020 and then decrease rapidly. To this end, it is essential to fully implement the Paris Agreement on Climate Change so that feasible and robust mechanisms that enable all countries to adopt national measures are put in place.

Reduced pressure on coral reef systems from other factors, however, could make them less vulnerable to the impact of climate change. Almost 80% of marine pollution is land or human induced, and the huge quantities of toxic substances deposited in watersheds always flow into the ocean.

Easy access to hard data can help to drastically reduce ocean pollution from heavy metal, lead, mercury, arsenic and cadmium discharges from coastal or inland industrial activities, such as from smelters, waste incinerators or abandoned mining facilities in specific regions.

Avoiding the over-exploitation of herbivorous fish can help to maintain an equilibrium in the symbiosis between coral and the algae that inhabit it. The presence of herbivorous fish such as parrotfish *(Scaridae)* that grind the dead coral and eat the algae are indispensable for the renewal of coral reefs. A moratorium on fishing these species could help to avoid disruption to the reefs, as reductions in the number of herbivorous fish lead to harmful algal blooms. In such cases, the coral is invaded and soon replaced by algae, which reduces the resilience of the whole ecosystem.

Rainbow Reef, Fiji. © World Fish / David Burdick, CC BY NC ND 2.0

Coral reef, Solomon Islands. © World Fish / Sharon Suri, CC BY NC ND 2.0

Avoiding the over-exploitation of herbivorous fish can help to maintain the equilibrium in the symbiosis between coral and the algae that inhabit it.

Maldive anemonefish (Amphiprion nigripes).

Itajuru Channel, Brazil.

Actions of international institutions for the protection of biodiversity

1. Greater consistency of action and jurisdiction

The role of international institutions

The United Nations (UN) is perhaps the organization with the largest impact and power at the global level. It has 193 Member States, and conducts both regular and special meetings to address important environmental topics. Some of the most important summits include:

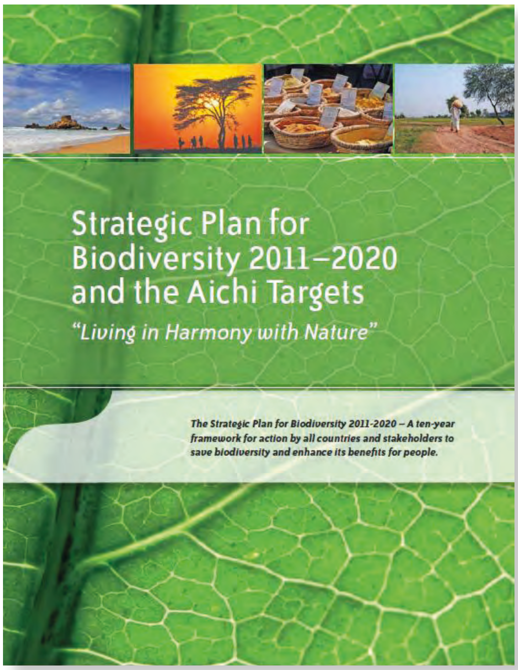
- The first **UN Environment Conference**, held in Stockholm in 1972, which led to the establishment of the UN Environment Programme (UNEP), headquartered in Nairobi;
- The **UN Conference on Environment and Development** (or the 'Rio Earth Summit'), held in Rio de Janeiro, Brazil in 1992, which brought together over 179 world leaders and over 2 400 NGO representatives. It was the largest inter-governmental gathering in history, resulting in Agenda 21 (a plan of action for sustainable development), the Rio Declaration on Environment and Development, the Statement of Forest Principles, the UN Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD);
- The **Millennium Summit** held in New York, in 2000, where the Millennium Declaration was adopted, which includes as one of its targets reduction of biodiversity loss. In addition to working with nations around the world, the UN system supports partnerships with the public and private sectors and with civil society. The UN consults NGOs and CSOs on policy and programme matters and hosts briefings, meetings and conferences for NGO representatives.
- The **Rio+20 Conference** in 2012, which laid the basis for the Sustainable Development Goals for the period 2015-2030.

Adelie Penguin, Antarctica.
© Peter Prokosch, UNEP Grid-Arendal

The Convention on Biological Diversity and the new Strategic Plan 2011-2020

Since its adoption in 1992 at the Earth Summit in Rio de Janeiro, the objective of the *Convention on Biological Diversity* has been to develop national strategies, plans and programmes to help ensure the conservation and sustainable use of biological diversity.

The text of this Convention recognizes for the first time in international law that the conservation of biological diversity is a 'common concern of humankind'. Firstly, the provisions of the Convention



Strategic Plan for Biodiversity 2011-2020. © CBD / UNEP

are expressed in terms of objectives and policy sets, while the implementing measures are developed in accordance with the specific situation and capabilities of each Party or signatory. Their application requires coordinated efforts between State Parties and international institutions.

Implementation of the Convention requires the mobilization of information and resources at the national level. For this purpose, the Convention states that the Parties should develop national strategies, plans or programmes to help ensure the conservation and sustainable use of biological diversity. Each party is therefore required to provide an annual report.

In practice, implementation of the Convention is supported by organizations and working groups that report to the governing body of the Convention, the **Conference of the Parties (COP)**, which assesses progress towards implementation and adopts new programmes to achieve the objectives, and the **Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA)**.

The work of the Convention Secretariat (SCBD) includes preparing and servicing the meetings of the COP and the subsidiary bodies of the Convention, and coordinating with other international agencies.

The tenth meeting of the Conference of the Parties, held in Nagoya in October 2010, was historic from the perspective of its achievements: a revised and updated Strategic Plan for Biodiversity and a new international general framework for all biodiversity-related conventions of the United Nations system.

The plan incorporates the Aichi biodiversity targets, which cover the period 2011-2020 and include the following actions:

- Work to reduce the rate of loss of natural habitats, including forests, by at least half, and where feasible bring the rate close to zero;
- Establish a conservation target of 17% of terrestrial and inland water and 10% of coastal and marine areas;
- Restore at least 15% of degraded ecosystems through conservation and restoration;
- Make a special effort to reduce pressure on coral reefs.

The Plan was drawn up based on the conclusions of *GBO3*. Its targets must be converted quickly into national strategies and action plans that lead to effective and urgent measures, in order to secure the intended objectives of reducing biodiversity loss by 2020.

This plan is supported by the *Protocol on Access and Benefit-sharing Arising from the Utilization of Genetic Resources*, which is considered a major legal instrument for protecting biodiversity. According to Ahmed Djoghlaf, former Executive Secretary of the Convention, 'the Protocol will allow us now to fully implement the Convention' and to lay the foundations for 'a new international economic and ecological order based on respect of nature in its diversity'.

In this way, the achievements of the Nagoya Conference and the International Year of Biodiversity, celebrated during 2010, created an opportunity for mainstreaming biodiversity in decision-making.

To improve policy coherence at the international level for the conservation of biodiversity, the Convention on Biological Diversity promotes cooperation and partnership with a range of other conventions, institutions and mechanisms.

Family of crabs, Sri Lanka. © Bernd Thaller, CC BY NC ND 2.0

The Biodiversity Liaison Group boosted by the Convention on Biological Diversity

The Secretariat has established a formal liaison group between the secretariats of biodiversity-related conventions: the Biodiversity Liaison Group. It brings together the following:

- Convention on Biological Diversity (CBD)
- Convention on International Trade in Endangered Species of Fauna and Flora (CITES)
- Convention on Migratory Species (CMS)
- International Treaty on Plant Genetic Resources for Food and Agriculture (FAO)
- Convention on Wetlands (also known as the Ramsar Convention)
- World Heritage Convention (WHC).

Memoranda of cooperation have been signed between the conventions and joint work programmes describing the activities, and agreed targets have been formally adopted.

Case studies on migratory species and their habitats have been disseminated through the clearing-house mechanism (CHM) to facilitate scientific and technical cooperation between CBD/CMS and CBD/Ramsar.

The secretariats of CBD and CITES are working together to implement the *Global Strategy for Plant Conservation* and, more specifically, to achieve Target 11 of the Convention on Biological Diversity: 'No species of wild flora endangered by international trade'.

The role of CITES

CITES aims to ensure that the international trade in specimens of wild animals and plants does not threaten the survival of species to which they belong.

Since trade in wild plants and animals extends beyond national frontiers, it must be regulated by international cooperation in order to safeguard certain species from over-exploitation. States that ratify CITES, known as the Parties to the Convention, must adopt legislation to ensure compliance with the Convention at the national level.

Many traded species are not endangered, but the existence of an agreement to ensure sustainable trade is important in order to preserve these resources over the long term.

Yellow-billed Kite, Nakuru National Park, Kenya. © Peter Prokosch, UNEP Grid-Arendal

Rock hyrax, Lake Nakuru, Kenya. © Peter Prokosch, UNEP Grid-Arendal

Orphan gorilla, Congo. © Tim Freccia UNEP GRID-Arendal

To date, CITES provides protection for more than 30,000 wild species, which are listed in one of the three Appendices to the Convention according to the degree of protection they require. Any import, export or introduction of species covered by the Convention must be authorized through a licensing system.

The annual reports submitted by Parties to the Convention constitute the ultimate resource for applying the Convention to international trade in specimens of listed species (they list the number and type of permits and certificates issued).

Export quotas have proved to be effective. In signatory countries, the quotas are established unilaterally at the national level, but the Conference of the Parties can itself establish certain quotas in the case of species such as the African elephant *(Loxodonta africana)*, the leopard *(Panthera pardus)* or spurred tortoise *(Geochelone sulcata)*.

The role of the FAO International Treaty on Plant Genetic Resources for Food and Agriculture

According to its own definition, the prime objective of the ***International Treaty on Plant Genetic Resources for Food and Agriculture*** is to recognize the enormous contribution farmers make to the diversity of crops that feed the world. It aims to establish a global system to provide farmers, plant breeders and scientists with access to plant genetic material and, in particular, to ensure that they share the benefits they derive from the use of these genetic materials with the countries from which they originate.

What is original and innovative about the Treaty in terms of access and benefit sharing is that it declares that the major crop plants (64 species producing 80% of human consumption) must be included in a universally accessible genetic resources pool. Signatory countries must therefore agree to make available to the international agricultural community the genetic diversity of the species they cultivate, as well as any related information.

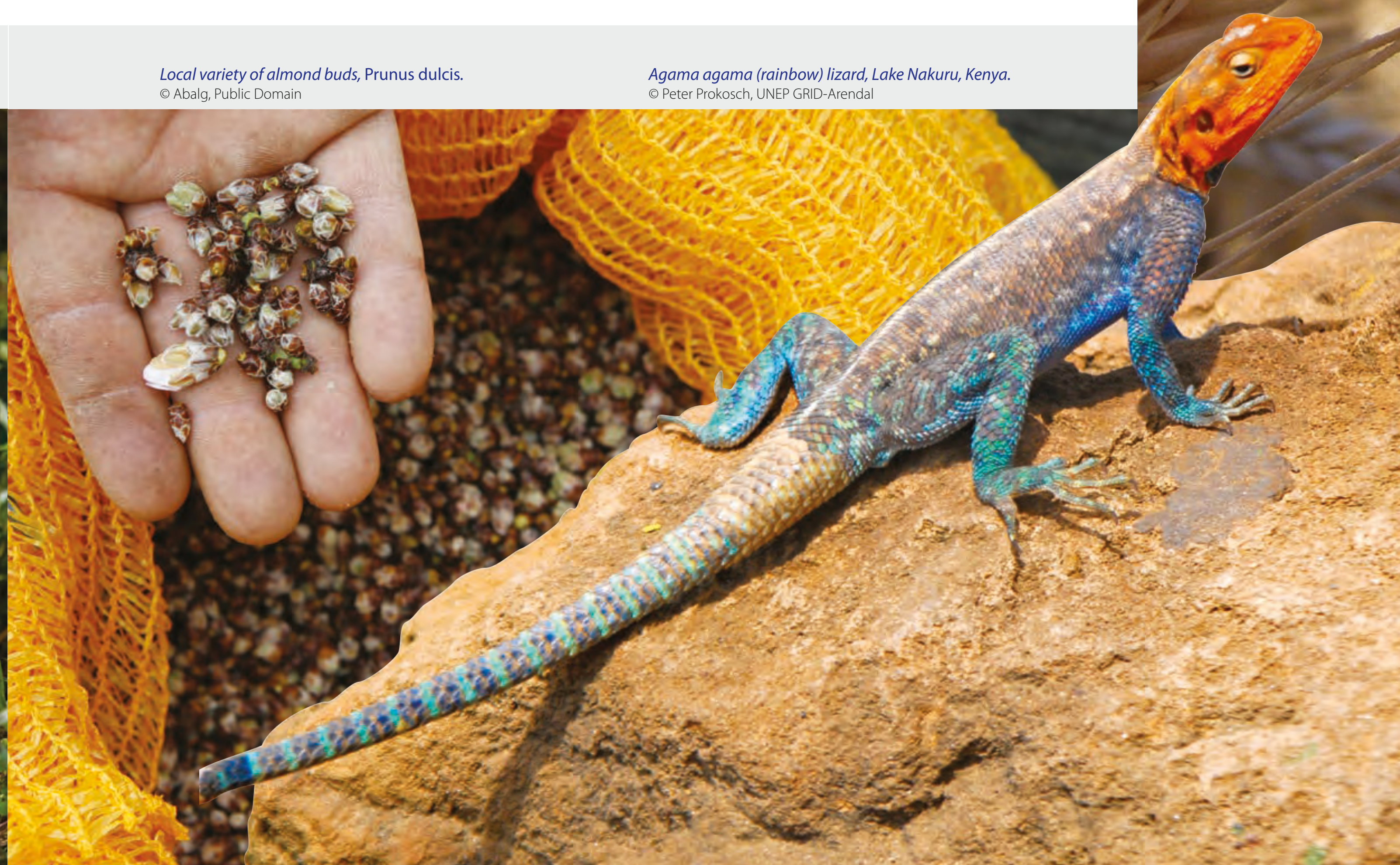
The stored materials can thus be improved and laboratories in developed countries can avail themselves of an established framework to bring their technical expertise to farmers in developing countries, in order to extend or develop work they have undertaken on their own land.

Above all, the Treaty recognizes the contribution of local communities in the conservation and development of plant genetic resources and encourages governments to take action to protect the rights of farmers, whether in terms of protecting traditional knowledge, the right to benefit-sharing or the right to participate in decision-making at the national level.

Epi triticale wheat, France.

Local variety of almond buds, Prunus dulcis.

Agama agama (rainbow) lizard, Lake Nakuru, Kenya.



The RAMSAR Convention

The Convention on Wetlands, known as the **Ramsar Convention**, after the Iranian city where it was adopted, is an intergovernmental treaty that entered into force in 1975 and provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.

The wise use of wetlands is defined as 'the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development'. In other words, at the heart of this concept is the idea of conservation and sustainable use of wetlands for the benefit of human communities all over the planet. Indeed, these areas provide essential ecological services by regulating hydrological regimes, playing a vital role in climate change mitigation and forming reservoirs of biodiversity. They are in themselves a valuable economic, scientific, cultural and recreational resource for the whole of humanity.

The Convention has taken a broad approach to determining the types of wetlands covered by its mission: they include swamps and marshes, lakes and rivers, wet grasslands and peatlands, oases, estuaries, deltas and tidal areas, marine coastal areas, mangroves, coral reefs and artificial wetlands such as fish ponds, rice paddies, reservoirs and salt marshes.

The role of the signatory countries is to maintain the ecological character of their wetlands of international importance and designate suitable wetlands for the *List of Wetlands of International Importance* ('Ramsar List') and ensure their effective management.

As of September 2016, more than 2,240 wetlands were included in the Ramsar List.

The creation of IPBES (the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services)

At its plenary session on 21 December 2010, the General Assembly of the United Nations approved the creation of an intergovernmental science-policy platform on biodiversity and ecosystem services (IPBES).

The platform aims to improve the interface between the scientific community and policy-makers on biodiversity issues and, in particular, to provide capacity-building for better use of science in policy-making.

As with the Intergovernmental Panel on Climate Change (IPCC), which has a mandate to regularly

Downstream water-dependent crop fields.
© Lawrence Hislop, UNEP GRID-Arendal

review the state of knowledge on climate change and publish assessment reports providing 'expert' scientific information to decision-makers without making recommendations ('relevant but non-prescriptive information'), the role of IPBES is to inform governments and provide them with the best available scientific knowledge on biodiversity and ecosystem services, to enable them to take the necessary decisions.

A key function of IPBES is thus to assist indirectly in the framing and implementation of policies by identifying tools and methodologies that can be used to develop them.

Following the resolution of the United Nations General Assembly and the report of the third intergovernmental meeting in Busan, South Korea, UNESCO and its international partner organizations (UNEP, FAO and UNDP) agreed to make IPBES operational as soon as possible. Two IPBES plenary sessions were thus scheduled for late 2011 and early 2012 to agree upon the governance structure of the platform.

To prepare for discussions on the operating procedures for IPBES and the institutional arrangements required for its organization, UNESCO examined the potential requirements for the platform to act as a knowledge-producer. The Organization suggested that the scientific community could develop a strategy for knowledge production, in order to provide a strategic response to the need for new knowledge in the field of biodiversity and ecosystem services.

The Nagoya Protocol on Access and Benefit-Sharing

The Conference of the Parties to the Convention on Biological Diversity (COP), held regularly since its inception, has sought to implement thematic programmes corresponding to the major biomes of the planet (forest biodiversity, dry and sub-humid lands biodiversity, etc.). It has also initiated work on crosscutting issues relevant to the thematic programmes.

One such issue is access to resources, notably genetic resources, and benefit sharing.

With regard to ecosystem management, according to the Convention it is essential to continue to develop knowledge about functional biodiversity and to manage ecosystems as part of an 'ecosystem approach' based on understanding and analysis of the contribution of biodiversity to ecosystem services.

The ecosystem approach seeks to better define and maintain or restore any benefits arising from ecosystem services, especially the benefits ensuing from their production and management.

The first ever deliverable of IPBES is an assessment on the contribution of pollination to food security and other ecosystem services.

Flower. © Flower's lover CC BY 2.0

Agroforestry products at Lubuk Beringin. © CIFOR / Tri Saputro

The ecosystem approach seeks to better define, and maintain or restore the benefits resulting from ecosystem services, especially those arising from their production and management.

To this end, it is essential to study the ecological role of biodiversity in the production of ecosystem services, in order to better preserve the structure and overall dynamics of the ecosystem and maintain the various services that it provides.

The functioning and resilience of an ecosystem depends on biodiversity at all levels. It includes the dynamic relationships within species, from one species to another, between species and their abiotic environment, and the physical and chemical interactions within the environment to which biodiversity contributes.

The conservation and, where appropriate, regeneration of these relationships and processes is more important for the long-term conservation of biodiversity and the ecosystem, and the maintenance of ecosystem services, than species protection alone.

Indigenous peoples and other local communities living on the land are central to this work, and as important stakeholders their rights and interests should be recognized.

Given the potential benefits of ecosystem services management, it is appropriate that the benefits of these services are shared, especially among those who encourage grassroots conservation, such as local populations and the stakeholders responsible for production and services management (in many cases, representatives of industries in developed countries that have access to the natural resources of a third country). In the final analysis, all ecosystems should be managed for the benefit of humans, regardless of whether this benefit is related to consumption.

At its last meeting in Japan in October 2010, the Conference of the Parties to the Convention adopted the **Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization**.

The objective of the Protocol is to ensure that developing countries that are rich in biodiversity obtain a fair and equitable share of the benefits arising from the use of genetic resources from their lands.

To this end, the Protocol establishes obligations for States Parties to the Convention. They are required to adopt measures on access to genetic resources, benefit sharing and compliance. For example, a permit or its equivalent must be issued when access to a resource is granted. In addition, the Contracting Parties must ensure that indigenous and local communities have given their prior consent for access to genetic resources for which the communities have a recognized right to grant access.

In terms of benefits, the States Parties must adopt measures to ensure the fair and equitable sharing of benefits arising from the use and commercialization of genetic resources. Thus, benefit sharing will be subject to the mutual agreement of the Contracting Party

Ecosystem services in Tintilou and in Boromo, Burkina Faso

Tintilou, Burkina Faso.

Boromo, Burkina Faso.

using the resources (in the context of research and development, essentially in genetics or biochemistry) and the Contracting Party providing the resources. This clearly establishes the rules by which a company, such as a pharmaceutical or cosmetic company, can use a molecule taken from a medicinal plant from a third country, and market it while sharing the profits with the country of origin.

However, the benefits derived from genetic resources are not necessarily monetary; they include the results of R&D programmes applied to certain genetic resources, transfer of technologies using these resources, participation in biotechnology research programmes and the financial benefits associated with marketing the products derived from genetic resources.

Examples of benefit sharing include:

- Research exchanges where a researcher from a genetic resources supplier country works with a member of the user country research team;
- Payment of royalties generated by the exploitation of genetic resources, which are shared between the provider and the user of the genetic resources and the associated traditional knowledge holders;
- Preferential access for supplier countries to all types of medicines derived from the genetic resources or associated traditional knowledge they have provided (e.g. a preferential purchase rate for the medicines in question);
- Shared ownership rights to intellectual property to be secured for the user and the provider of genetic resources for the patented products arising from the genetic resources that have been made available.

The Protocol seeks to provide consistent answers to all these aspects. The Protocol's implementation tools and mechanisms include provision for the establishment of a fund known as the Multilateral benefit-sharing mechanism. It applies in particular to capacity-building to help countries negotiate framework agreements and develop national legislation for their implementation, to perform targeted management of traditional knowledge associated with the use of genetic resources, and so on. Financial support is provided through the Global Environment Facility (GEF).

The United Nations Decade on Biodiversity (UNDB) 2011-2020

At its 65th session in December 2010, the General Assembly of the United Nations proclaimed the period 2011-2020 as the **United Nations Decade on Biodiversity** (UNDB), with a view to contributing to the implementation of the Strategic Plan for Biodiversity for the period 2011-2020.

Vendor of corn ears, Nepal. © Subash S.P./CIMMYT

Eucalyptus globulus. © Forest & Kim Starr, CC BY 3.0

The Decade is intended to serve primarily as a vehicle to support the implementation of the objectives of the Strategic Plan for Biodiversity, and strives in particular to promote the involvement of various stakeholders in order to mainstream biodiversity into economic activities and development plans.

As such, it can support action to address the underlying causes of biodiversity loss, such as production and consumption patterns, or promote initiatives to overcome barriers linked to lack of public awareness of the importance of biodiversity.

The United Nations resolution also perceives the coordination of activities during the Decade as a way to enhance synergies between the various conventions on biodiversity.

According to the Strategic Objectives for the Decade, the aim is to provide a flexible framework for the implementation of the Strategic Plan, to provide guidance in this regard to regional and international organizations, and – above all – to continue to raise public awareness of biodiversity issues. To this end, the implementation plan will deliver key messages about biodiversity and its importance, along with communication guidelines so that they can be adapted into local cultures. It will also build partnerships with communication organizations worldwide in order to disseminate these messages and adapt them to the local level. Finally, it will develop principles for mainstreaming biodiversity into 'national curriculums' with an emphasis on the principles of education for sustainable development (ESD).

2. Towards concerted, wise management

The creation of protected areas is the main instrument for conserving biodiversity.

Terrestrial protected areas

The creation of protected areas is the main instrument for conserving biodiversity.

According to the latest figures, protected areas now cover 17% of the Earth's surface area.

The objective the international community set itself, in 2002, to protect at least 10% of each of the world's ecological regions (ecoregions) has not been achieved and consequently many sites key to conserving biodiversity are presently located outside protected areas. The 20-point strategic plan adopted at the Conference of the Parties (COP) in October 2010,

designed to curb the massive erosion of biodiversity by 2020, envisaged extending terrestrial protected areas to 17% of the Earth's surface. This target has been achieved, and new targets have been proposed under SDG 15, which deals with protecting, restoring and promoting sustainable use of terrestrial ecosystems and halting biodiversity loss.

Out of all the protected areas whose management effectiveness the Convention was able to measure via national reports, it is estimated that 13% are genuinely satisfactorily managed, 5% are managed effectively and the remaining percentage is managed barely adequately. Some of these protected areas still lack the administrative capital and staff needed to ensure proper management.

The **Alliance for Zero Extinction** network aims to identify critical sites for the conservation of biodiversity, whose protection is a priority to prevent the extinction of endangered or critically endangered species. It would appear that many of these sites currently have no legal protection.

In order to achieve the objectives of the Convention on Biological Diversity, protected areas have striven to manage their natural resources using the ecosystem approach advocated by the Convention, and to engage all sectors of society in biodiversity conservation and management. In addition to becoming instruments for ecosystem protection and biodiversity conservation, in general, some also provide instruments for social and economic development and have thus made a major contribution towards shaping the concept of conservation over recent decades.

- This primarily involves conserving, in the true sense of the word, endangered species and natural areas, using ex-situ conservation if necessary; for example, by establishing conservation stands where in-situ conservation is not possible, thus maintaining the genetic heritage of highly endangered species (although reintroducing them into their natural habitat remains the priority).

- It also increasingly involves restoring ecosystems, reintroducing hedges and natural connections into landscapes, treating polluted waterways, and improving over-exploited rangelands and pasture. In addition, ecological restoration can provide for the large-scale involvement of local communities, combining scientific innovation and new conservation approaches and technologies with the re-evaluation of traditional knowledge.

In addition to these actions, protected areas necessitate consideration of biodiversity as a natural life and development partner and the provision of support for the naturally productive and diverse dimension of ecosystems. Protected areas, particularly those belonging to the **World Network of Biosphere Reserves** under UNESCO's **Man and the Biosphere (MAB)** Programme (currently 669 sites in 120 countries), are increasingly integrated into the local

Alaska landscapes. © Peter Prokosch, UNEP Grid-Arendal

Royal crane (Balearica regulorum). © Peter Prokosch, UNEP Grid-Arendal

economy and their work makes an active contribution towards implementing the ecosystem approach by seeking to simultaneously promote conservation, the sustainable management of resources, and the fair and equitable sharing of benefits arising from the utilization of genetic resources.

This involves addressing new challenges:

- Identify and assess the functional role of biodiversity in the production of ecosystem services, especially regulatory and supporting services. Indeed, while many species provide valuable provisioning services (food, wood) it is crucial to consider the species that enable this supply to take place. These include keystone species with functional characteristic traits that enable them to play a more active part than others in essential ecological functions such as biomass production, the nutrient cycle, recycling of nutrients, pollination systems, seed dispersal systems, biological control systems and so on.

- Better quantify and generally assess the supporting and regulatory services of ecosystems and the contributions they make, and identify the people and actions that maintain them.

- Focus on the regeneration and maintenance of relationships and processes between species, and between species and their environment, that constitute the source of these services, in order to maintain the structure and dynamics of the ecosystem (temporal structure, vertical structure, horizontal structure, trophic structure and so on).

- Use combined study of the component roles of biological diversity and the ecological functions of biodiversity, to understand which factors of local biological diversity will determine management decisions (with reference to Principle 5 of the ecosystem approach).

- Provide practical support for local conservation stakeholders, who possess a considerable knowledge of traditional agriculture, by harmonizing incentives (eliminating distorting subsidies, paying for environmental services) and promoting capacity-building (helping to develop local knowledge in a context of scientific and technological progress and integrated management of ecosystems).

- Move increasingly towards community management of biological resources by encouraging people to take part in management to secure economic development. Some countries such as Namibia have also handed over responsibility for wildlife protection to volunteer village communities.

Young stakeholders in the Mont-Viso Biosphere Reserve, Italy. © UNESCO-MAB

Bashkirskiyi horse as part of conservation measures of local varieties. © L.A. Sultangareeva

- Encourage progress in public policy-making and the adoption of biodiversity legislation at the international level through collaborative decision-making between States, as well as at the national level and at the grass-roots level, through the allocation of public subsidies for biodiversity-friendly practices such as the development of organic farming, the use of permanent grassland and zero-till crops, and the maintenance of soil cover in winter.

- Conduct policy and conservation work in an eco-regional context, on a scale that is compatible with ecological processes, and thus encourage participation in management initiatives and cross-border cooperation.

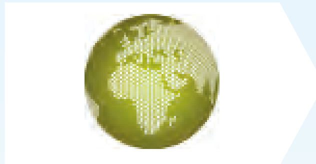
Marine Protected Areas (MPA)

Protection of marine and coastal areas lags far behind that provided by terrestrial protected areas. Accounting for less than 1% of the total ocean surface – 0.6% to be exact and 5.9% of territorial waters (near baseline) – aquatic ecosystems too often seem left to their own devices in terms of conservation, although this situation is changing rapidly.

The Strategic Plan for Biodiversity 2011-2020 envisages increasing the global area of marine and coastal reserves by 10% of the area of the existing 238 marine ecoregions. As pointed out in *GBO3*, the high seas are barely represented in the protected areas network,

BIOSPHERE RESERVES
SOME STATISTICS*

There are **669 biosphere reserves** in **120** countries, including **16** transboundary sites.



70 in **28** countries in **Africa**

30 in **11** countries in the **Arab States**

142 in **24** countries in **Asia and the Pacific**

302 in **36** countries in **Europe and North America**

125 in **21** countries in **Latin America and the Caribbean.**

The total area covered by biosphere reserves around the world amounts to over **1.045 billion** hectares.

*as of April 2016

Rhodiola rosea, *Minami-Alps Biosphere Reserve, Japan.*
© UNESCO/Yamanashi Prefecture Minami-Alps

which illustrates the inherent difficulties in creating protected areas outside established economic areas.

An area of water is difficult to define in terms of space as an ecosystem, as aquatic biomes correspond less to the zonation criteria of a terrestrial biome owing to the large currents that traverse the oceans. Accordingly, **marine protected areas** are designated areas of sea with one or more long-term preservation objectives.

They often encompass several conservation objectives such as protecting or restoring fish stocks, protecting endemic species or rare habitats that are endangered, protecting biodiversity in general or preserving a range of remarkable habitats.

The International Programme on Protected Areas under the Convention on Biological Diversity embodies the characteristic interlocking of components of marine protected areas, which often play a role, locally and internationally, in providing an area for migrating birds, spawning grounds for fish and breeding grounds for many different species. In this respect, the Programme references the need to establish coherent national and regional networks that are both representative and effectively managed.

The success of a marine protected area depends largely on its implementation context. This includes identification of the project and the support of the local population; significant involvement of local people in decision-making; implementation of the management plan and application of the management rules. The Soufrière Marine Management Area (SMMA) in Saint Lucia is a good example of a successful marine conservation project, which was created to address a reduction in biodiversity and coastal fish stocks. A result of the establishment of the MPA, fish biomass has increased significantly. All families of species, including commercial species of parrotfish and surgeonfish have quadrupled in biomass across the whole site. The results are clear in terms of recovery of populations of species and fish stocks, while conflicts between traditional users (fishers) and tourist industry stakeholders (hoteliers, pleasure boat operators) have diminished thanks to an increase in the incomes of fishers, who also derive additional benefits from the growth in tourism. Jobs have been created and the population in the region feels involved. It is worth noting that the project has largely been financed through flexible funding arrangements such as the French Global Environment Facility (*Fonds Français pour l'Environnement Mondial* – FFEM), which can sometimes function as a useful complement to the national contributions made to the Global Environment Facility (GEF) and the work it undertakes.

Locally Managed Marine Areas (LMMA)

According to *GBO3*, in recent years more than 12,000 km^2 of the South Pacific region have been managed through a network of **locally managed marine areas (LMMA)**, a community system for managing marine resources.

Cormorans, South Africa. © Peter Prokosch / UNEP GRID-Arendal

Somateria is a genus that groups highly migratory ducks commonly known as Eider. © Peter Prokosch / UNEP GRID-Arendal

The initiative involved almost 500 communities in the South Pacific island States. The communities and their local leaders worked together with their governments, NGOs and international institutions to develop management plans for fisheries and conservation objectives to address their resource depletion problem, using traditional management systems.

These systems rely heavily on indigenous knowledge and the customary tenure regime, which imposes seasonal bans and temporary closures of fishing areas. These aspects have been incorporated into a more modern technical and scientific management system.

Economic and conservation objectives have been achieved in Fiji, for example. Fish catch is up threefold, household incomes are up by 35% to 45%, and there has been an increase in populations of exploited species.

Human populations are aware of these initiatives thanks to the benefits obtained. These include the restoration of fish stocks, food security, refuge for heritage species threatened by fishing, ecosystem restoration following major disturbances, forms of cultural regeneration and stronger community organization.

Individual Transferable Fishing Quotas (ITQ)

One fishery management method that has emerged in recent years is **Individual Transferable Quotas**.

Artisanal fisheries. © FAO / Filipe Branquinho

Coconut crab of Henderson Island. © UNESCO / Ron Van Oers

Under this system, the total allowable catches by species and fishing areas are directly allocated to fishers in the form of transferable quotas. This allows them to rent or sell their quotas to others, spread their catch over the year or buy new quotas when they have exhausted their own. In fact, the system can allocate a specific percentage of the total catch of a given fish stock to individuals, fishing groups (communities) or cooperatives. The specifications can relate to the species, fishing area or size of catch. Thus, while fishing companies are only allowed to catch and sell more fish if more fish are available, they have the security of being guaranteed a set amount of fish.

As a result of these quotats, fishers become more involved, as they have a direct incentive to know about stocks, maintain them in good condition and protect fishery resources.

This leads to a decrease in round-the-year fishing, short-term catch optimization and unbridled competition.

According to *GBO3*, a study of approximately 120 fisheries regulated by ITQs in 2008 showed that the risk of collapse was halved, compared to fisheries using other management methods.

However, before ITQs can be seen as a viable and sustainable management option, some potential drawbacks need to be addressed. In particular, the system seems 'skewed' towards the most developed and economically viable companies, who can easily purchase quotas, and seems to neglect small businesses.

Forest management plans and the implementation of sustainable forestry practices

The implementation of forest management plans is a positive step towards a more rational and ecological exploitation of forests. They make it possible to calculate the amount of wood that can be taken without jeopardizing forest regeneration. They enable the long-term planning of logging and forestry operations, managed in tandem with measures to

Artisanal fisheries, Malaysia.

School of tuna.

promote the environment and local populations. They are particularly useful in tropical regions.

The planning stages involve a number of diagnoses of the area concerned, followed by drafting of the management plan. The marketable resource must then be assessed and management parameters determined, based on stand reconnaissance. Among the key questions are: What should be the minimum operating diameter? What should be the stand recovery rate? What are the objectives by species? Should certain species, examples of species, or representative samples of stands of associated species be automatically protected?

Ambient biodiversity and the natural environment also need to be assessed. Following a flora inventory, a decision should be taken regarding whether to set aside specific sensitive areas.

Finally, it is essential to assess the socio-economic environment of the site and analyse the infrastructure, the local economy, the impact on residents, and the living and working conditions of the staff required under the management plan. Once these stages have been addressed, the plan can be drafted and operational planning can get underway.

Encouraging the management of forestry concessions by integrating biodiversity issues and taking into account and involving local people is a management method applied over more than 5 million hectares of forest in the six forest countries of Central Africa and the Congo Basin. However, this approach requires time and significant human and financial resources – parameters that could be improved through capacity-building (logging company establishment and efficiency, company security, partnerships facilitated with institutions or NGOs specializing in conservation, legislative compliance and so on).

The fight against illegal logging and the use of reduced impact logging techniques (which local communities are often familiar with) should be undertaken in parallel, and progress confirmed to ensure sustainability.

However, even with these management methods and operational practices, it is unlikely that logging will be able to meet the increasing needs of a rapidly growing

Planning steps consist of producing a number of diagnoses from the area concerned and then writing a management plan.

Dordogne Basin, the Dordogne at Tremolat, France.
© F. Ehrhardt-EPIDOR

A botanical strain is the base of a tree trunk and its roots. In forest husbandry, it is what remains after cutting down a tree. © Lawrence Hislop, UNEP GRID-Arendal

The Orange-breasted sunbird (Anthobaphes violacea) is a species of passerine birds belonging to the Nectariniidae family. © Peter Prokosch, UNEP GRID-Arendal

population. The planning system must take greater account of the latest research advances – especially in the field of forestry and forest biology – relating in particular to the behavioural aspects and ecological dynamics of specific species. In other words, the results of research must be exploited to the full.

The Forest Stewardship Council (FSC)

The Forest Stewardship Council (FSC) is an internationally recognized eco-label which ensures that a wood-based product has been manufactured in compliance with procedures intended to ensure sustainable forest management.

In terms of its structure, the FSC is a council with its origins in an NGO established in 1993, following the Earth Summit.

According to the FSC, the concept of forest management is not restricted to the commercial exploitation of the wood resources of a forest. To ensure the sustainable management of forests, the manufacture of a product must meet certain criteria in terms of quality and environmental performance. However, it must also comply with social and economic criteria.

There are two parts to the FSC certification system: forest management certification and chain of custody certification. The latter guarantees every stage of the product throughout the supply chain, from the certified forest management unit level, through to processing and, where appropriate, its origin and recycling potential (waste wood and paper).

The Forest Stewardship Council logo helps us to opt for responsible consumption by making the maintenance and conservation of biodiversity a factor in the manufactured goods and consumer items on offer, while providing accountability for certain sectors such as wood industry and market players, and – more broadly – ensuring greater public awareness of our relationship with nature and natural resources.

The Marine Stewardship Council (MSC)

As with the Forest Stewardship Council, the **Marine Stewardship Council** supports an awareness-raising policy that encourages sustainable fishing practices. It assures consumers that the certified product at the end of the chain comes from a management system

Marine Stewardship Council awareness-raising campaign. © MSC / Sandra Mies CC BY-NC-ND 2.0

that respects the long-term sustainability of resources and the health of marine ecosystems.

The consumer can thus choose whether to buy a product that has made no (or minimal) contribution to the degradation or over-exploitation of natural resources.

In addition, seafood that meets the certification criteria can provide benefits for the fishers concerned in terms of market share gains. The MSC is thus able to assist and protect small-scale fisheries that do not engage in overfishing.

Organic farming labels

The *Biogarantie* label in Belgium, *AB* in France, *OF&G* in the United Kingdom, *Bourgeon* in Switzerland, *Canada Organic* in Canada and the *China Green Food Development Center* in China are organic farming labels that provide certification worldwide for the production modes of organic farming produce.

These product labels enable us to make an informed decision and choose commodities – essentially food – that are produced in a farming system based on respect for the living environment and natural cycles, which promotes biodiversity, prohibits the use of chemical fertilizers and biocides, and whose main concern is to respect the soil and preserve its fertility.*

* For more details see
Vol. 2, Activity 11.1, Dialogue and action on sustainable agriculture (p. 62).

Sustainable wood harvest in Lukolela, Democratic Republic of the Congo.

Sustainable agriculture practice in the Himalayas.

3. Our ecological footprint

An ecological footprint is a tool for measuring the pressure exerted by humanity on nature. The unit used corresponds to the biologically productive area of land or water required to produce the resources that an individual, a population (or an activity) consumes, and to absorb the waste they generate.

Today, we have the means to assess the food and wood we consume per capita or population, the equipment we use, and the productive land area required to absorb the CO_2 produced by fossil fuels we consume.

The system for calculating an ecological footprint enables us to compare the footprint of a population in relation to the local or global bio-productive area estimated to be available.

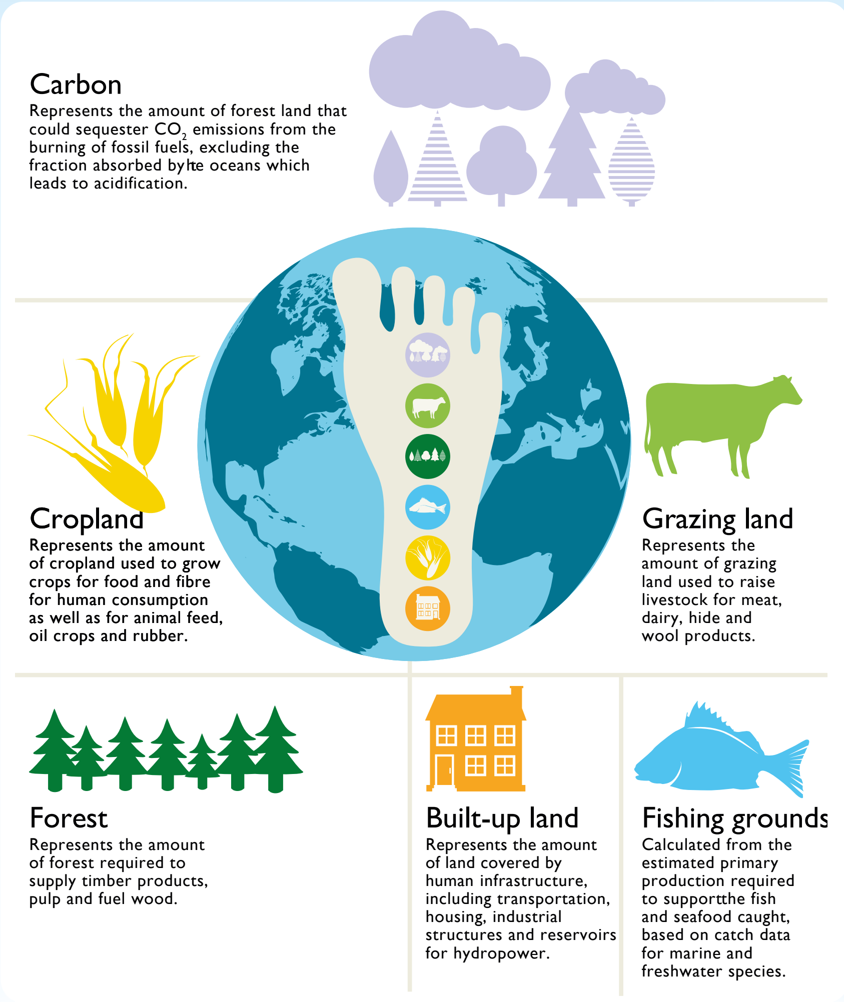
It starts from the assumption that the Earth's regenerative capacity may be the major constraint on our global economy, if the latter continues to over-exploit the resources that our biosphere is able to supply and renew.

The average ecological footprint on the Earth's surface is 2.2 global hectares per person (although there is a significant disparity between the ecological footprint, for example, of a citizen of the United States and an inhabitant of Malawi). However, there are only 1.8 hectares of biologically productive area available for each person. This form of over-consumption is termed an 'overshoot'. If we wish to maintain this lifestyle in the future we will need several planets. However, the finite nature of our world's ecology is undeniable, and the extraordinary way it operates within a natural system that sets its own limits is a reality.

In the long run, exceeding the ecological limits of our biosphere leads to the destruction of ecological services and ecosystems, and wholesale depletion of the biodiversity on which our economy unquestionably depends.

It is still possible for each and every one of us to be vigilant as human beings, and commit to live a life of our own choosing within the ecological constraints of the biosphere.

Arctic Expedition. © Bjorn Alfthan, UNEP GRID-Arendal



Decoding the ecological footprint.
© WWF

Salt marshes and freshwater habitats, West Coast National Park, South Africa.
© Peter Prokosch UNEP Grid-Arendal

*** For more details see**
All activities proposed in Vol. 2.

We have the option to act in our classrooms, our businesses and our institutions. We can calculate our own environmental footprint with the help of teachers and educators during sustainable development campaigns run by schools as part of the United Nations Decade of Education for Sustainable Development. We can participate in NGO efforts to conserve species and resources, and we can encourage our towns and cities, our decision-makers and local governments to justify our consumption of natural resources. We can become active planners who incorporate the ecological footprint into sustainable development indicators and reporting systems, and we can contribute to international efforts by developing and implementing grass-roots action plans for a sustainable local development that maintains, preserves and uses biodiversity sustainably.*

Swedish dogwood (Cornus suecica) *is a perennial herbaceous plant of the Cornaceae family.* © Peter Prokosch, UNEP GRID-Arendal

Biodiversity Learning Kit – Volume 1

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Education for Sustainable Development

UNESCO
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Schools

United Nations
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Cultural Organization

Japan
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