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EC Cooperation:

Responding to climate change

Sector Script for Ecosystems & Bio-diversity Management

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This document was developed by EuropeAid in cooperation with DG RELEX, DG DEV and DG ENV with the support of the "environmental integration advisory services" project. It was designed to provide practical guidance on the links between climate change and a specific sector, together with possible responses to climate-related challenges. The purpose of this "script" is to support political dialogue on climate change implications between the European Commission, partner governments and other national partners involved in EC development and external cooperation activities, as well as to facilitate strengthened climate change integration in ongoing and future cooperation programmes and projects, with a focus on developmental benefits for the partner countries.

This sector script is one of a series prepared in a standard format. Scripts are available for the following topics:

- Introduction and Key Concepts
- Agriculture & Rural Development (incl. forestry, fisheries and food security)
- Ecosystems & Biodiversity Management
- Education
- Energy Supply
- Health
- Infrastructure (incl. transport)
- Solid Waste Management
- Trade & Investment (incl. technological development, employment and private sector development)
- Water Supply & Sanitation

Note that the script is not country or region-specific, and has been prepared to cover a wide range of possible effects and responses. Users are invited to appreciate which elements, among those proposed, are relevant to their specific needs and circumstances.

Note: This sector script was written with a focus on the management of ecosystems and biodiversity in general. Forestry, agricultural systems as well as fisheries are addressed specifically in the sector script dedicated to Agriculture & Rural Development, and water in the script dedicated to Water & Sanitation. The text makes references to other related and complementary scripts.

Users of this script are advised to read it in conjunction with the Introduction and Key Concepts information note, which introduces the series and puts things in context.

Comments are welcome and can be addressed to the following e-mail:
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These documents can also be downloaded on the EuropeAid/E6 Intranet Pages.

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Climate change impacts on ecosystems and biodiversity

Substantial changes in the structure and functioning of terrestrial, marine and freshwater ecosystems are expected to be triggered by warming of 2-3°C above pre-industrial levels, and by changes in rainfall patterns. In many cases, climate change will exacerbate the ecosystem degradation that already prevails due to multiple anthropogenic pressures. Typical impacts already observed over a wide range of ecosystems and likely to increase in future include changes in the geographical distribution of species, changes in population sizes, changes in lifecycle events, and increased frequency of pest and disease outbreak.

Changes in ecosystems and ecosystem degradation do in turn affect the provision of ecosystem services, with potentially significant consequences for agriculture, forestry, fisheries, energy production, health, infrastructure, the livelihoods of rural populations and urban dwellers, and quality of life. Overall, climate change is expected to accelerate the degradation of ecosystems and therefore reduce their capacity to deliver ecosystem services. Such degradation, which may take the form of changes in the quantity, quality and/or timing of services, is already under way in most regions of the world as a result of multiple human pressures. Valuable services are likely to be further threatened by the additional stress caused by changing climatic conditions. The degradation of ecosystem services matters because:

- it may severely affect human wellbeing;
- it tends to affect primarily the poor and the most vulnerable, and also to aggravate inequalities – and poor and vulnerable people are usually the least equipped to cope with the degradation of the natural environment;
- it impairs chances of meeting or sustaining some of the Millennium Development Goals (MDGs);
- ecosystem degradation represents a destruction of natural capital assets, which for many developing countries represent a sizeable share of the productive asset base on which to build their development.

Ecosystem changes and degradation are inextricably associated with changes in biodiversity, biodiversity losses and higher rates of species extinction. In the 21st century climate change is expected to become the dominant driver of biodiversity loss. The loss of biodiversity (and notably of species diversity within specific ecosystems) reduces the overall resilience of ecosystems, including their capacity to recover from climatic shocks. It also threatens food security, directly affects the livelihoods of the rural poor and indigenous peoples, deprives humanity of a potentially wide range of future options to exploit biodiversity as a source of goods and services, and causes a loss of "non-use values".

Finally, climate change is expected to reduce the productivity of agriculture and food production systems in most regions of the world – at a time when policies supporting the production of biofuels increase demand for arable land. It may also force the relocation of large human settlements and some infrastructure. Pressures for the conversion of the shrinking supply of natural ecosystems to agricultural, industrial and settlement uses are thus likely to get worse.

Reducing vulnerability and enhancing adaptive capacity through ecosystems and biodiversity management

The resilience of ecosystems, and thus their capacity to keep providing essential ecosystem services on a sustained basis in spite of potentially disrupting short-term variation and long-term changes in climate, will play a significant role in reducing human vulnerability to the effects of climate change and enhancing adaptive capacity. Greater biodiversity is deemed to enhance ecosystems' capacity to withstand shocks, including climatic ones. Therefore, preserving biodiversity and protecting ecosystems to support and enhance their resilience to the effects of climate change should be considered an essential and high-priority component of any adaptation strategy.

The "green infrastructure" approach, which emphasizes network and systemic aspects and the need to plan land use in a comprehensive and strategic manner, provides a framework within which all new developments should ideally be planned, with environmental, social and economic sustainability as the ultimate goal. It has the potential to decisively support efforts to reduce vulnerability and adapt to climate change.

The maintenance of natural ecosystem services is generally much cheaper than either attempts to restore them after they have been degraded or investments in man-made infrastructure to provide equivalent services. This is an important consideration at a time when climate change adaptation and mitigation are expected to require the mobilisation of significant financial resources.

Adapting to climate change in ecosystems and biodiversity management

Some specific measures can be taken to actively restore ecosystems and enhance their resilience to the effects of climate change – but they will not be effective without a comprehensive action plan aimed at addressing both the direct and indirect drivers of ecosystem degradation and biodiversity loss (including, in a medium- to long-term perspective, the stabilisation of greenhouse gases in the atmosphere).

Active human interventions and the use of "environmental engineering" techniques can be used to directly enhance the resilience of ecosystems and biodiversity and/or restore damaged ecosystems. Besides protection- and restoration-oriented approaches, technological innovation and development oriented towards the alleviation of existing pressures on the environment is also part of the response. It is useful, for instance, to support the development and dissemination of agricultural techniques and technologies that increase crop yields and livestock productivity without significant adverse impacts on the environment; technologies that promote energy efficiency, water efficiency and efficiency in the use of materials; low-carbon and "clean" sources of energy, as long as they cause minimal disruption to the functioning of ecosystems; and industrial processes that minimise GHG emissions as well as all other forms of pollution.

Finally, in the field of natural resource governance and the mainstreaming of biodiversity, measures to support biodiversity and ecosystem resilience should also include a mix of:

- changes in institutional and environmental governance frameworks (e.g. mainstreaming of ecosystem management, biodiversity protection and sustainability objectives in national development and poverty reduction strategies, and improved land use planning and management);
- knowledge-based responses (e.g. more systematic consideration of the total economic value of biodiversity and ecosystem services in the economic analysis of development strategies and interventions, enhancement of institutional capacity to monitor ecosystem change and biodiversity loss and to assess their impacts on human wellbeing);
- modification of economic incentives (e.g. payments for environmental services, cap-and-trade schemes);
- social and behavioural responses (in support of changes in consumption patterns and lifestyles).

Contributing to climate change mitigation: opportunities for storing carbon and reducing GHG emissions in biodiversity and terrestrial ecosystems management

While ecosystems and biodiversity are threatened by climate change but can, if adequately protected, enhance societies' resilience and adaptive capacity, they are also an essential element in the mitigation response. Their management offers a variety of possibilities to contribute to climate change mitigation efforts through reduced emissions and through carbon sequestration in natural and semi-natural ecosystems. In many cases, these possibilities are congruent with adaptation options: carbon management in ecosystems involves significant potential co-benefits, notably in terms of biodiversity and ecosystem service protection. Furthermore, it is often a very cost-effective approach – and one that allows the contribution of developing and emerging countries to the global mitigation effort.

Globally, it is estimated that terrestrial ecosystems store approx. 2,100 Gt of carbon (i.e. almost three times as much as the atmosphere) in biomass and soil organic matter. The potential for carbon management is related to forests, peatlands, cultivated ecosystems and, to a lesser extent, grasslands; it is more significant in some types of biomes than in others. The processes involved in ecosystem-based climate mitigation are characterised by complexity as well as considerable uncertainties. There is no universally applicable list of good practices, and scientific advice should be sought before choosing a mitigation strategy. It is essential to keep financing research in this field, so that policy makers can base their decisions on an increasingly sound scientific foundation. Another important aspect to keep in mind is the necessary balance to be achieved between carbon management policies, rural livelihoods and the need to feed the population: there are potential synergies but also tradeoffs between these objectives.

Forests have significant potential as carbon sinks, and generally store carbon more permanently than, for instance, croplands. Curbing deforestation is considered one of the most cost-effective ways of reducing GHG emissions: avoiding deforestation could achieve significant emission reductions in the short term, without requiring new technology, and at a low cost in comparison with other mitigation options – even if compensation is offered to cover the opportunity costs of not exploiting forests. Other possible options include reforestation and afforestation. They may play a role in mitigation strategies but the protection and restoration of existing forests is a more sustainable and, from the point of view of long-term mitigation potential, a more effective option.

Peatlands are the largest and most efficient terrestrial store of biomass carbon. The conservation and restoration of peatlands, in particular in tropical regions, is also deemed to be an extremely cost-effective carbon sequestration technique. Possible measures to contribute to climate change mitigation by fixing carbon in peatlands include protecting still intact peatlands, reducing the loss of carbon from cultivated and grazed peat soils, and restoring degraded peatlands.

Grasslands are also net carbon sinks, at least as long as they are not degraded or subject to intensive production practices involving excessive nitrogen fertiliser applications. Where grasslands are used as grazing lands, management practices can significantly influence the capacity of these lands to store carbon. Limiting grazing pressure is key for maintaining carbon storage capacity.

Cultivated systems are both a sink and a source of GHGs. Agricultural lands have the potential to store large amounts of carbon dioxide (CO_2), depending on how soils are managed: the richer the soil is in organic matter, the more carbon it stores. Natural decomposition processes lead to the release of some CO_2. Agriculture is also a source of two other powerful GHGs: nitrous oxide (N_2O) and methane (CH_4). Currently, the agricultural sector is deemed to contribute to approx. 13.5% of global annual GHG emissions; however, in a recent UNEP report, experts consider that making agriculture carbon-neutral by 2030 is a “challenging but achievable goal”. Minimum tillage, “conservation tillage”, improved manure management and more efficient use of fertilisers are examples of measures that could contribute to this objective.

Finally, it should be noted that biodiversity influences the carbon storage potential of terrestrial ecosystems and their contribution to climate regulation at the local, regional and global levels.

u HOW CLIMATE CHANGE MIGHT AFFECT ECOSYSTEMS AND BIODIVERSITY

Climate change will affect ecosystems and biodiversity both directly and indirectly, through a range of biophysical and socio-economic impacts. The table below summarises the main impact pathways.

Ecosystems are defined as "a dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit" (MEA 2005c:894). As for ecosystem services, they are "the benefits people obtain from ecosystems", which come in the form of "provisioning services such as food and water; regulating services such as food and water , regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth" (MEA 2005c:895).

	Ecosystems & biodiversity
Biophysical effects	
Changes in temperature and rainfall patterns	•
Shifts in seasons	•
Increase in extreme weather events / natural disasters	•
Raised sea level and increased coastal erosion	•
Increased river bank erosion	•
Desertification, soil erosion	•
Reduction in the availability of freshwater	•
Reduction in the quality of water	•
Changes in hydrological flows, in permafrost	•
Increase in disease and pest outbreaks	•
Socio-economic impacts	
Economic and social disruption, loss of livelihoods	•
Increased malnutrition	•
Increased probability and intensity of conflicts	•
Population displacement and human migrations	•

Biodiversity is defined as "the variability among living organisms from all sources"; it includes "diversity within species, between species, and between ecosystems" (MEA 2005c:893), and can be considered at various scales (local, regional, global). Biodiversity and ecosystems are closely intertwined: ecosystems host biodiversity, biodiversity plays a significant role in the functioning of ecosystems and underpins the provision of many ecosystem services. By threatening or altering the functioning of key ecosystems, climate change exacerbates existing threats to biodiversity – which to a large extent already result from other human pressures.

In the sections below, we review how climate change might affect the structure and functioning of ecosystems, how impacts on ecosystems might affect the provision of a wide range of ecosystem services, how climate change is expected to become a driver of biodiversity loss, and why this matters.

1.1. Changes in ecosystems

Substantial changes in the structure and functioning of terrestrial, marine and freshwater ecosystems are expected to be triggered by warming of 2-3°C above pre-industrial levels, and by changes in rainfall patterns. Shifting seasons, exposure to flooding and extreme weather events, changes in water quality and availability and raised sea levels are also likely to put some ecosystems under stress and trigger changes. Predicting ecosystem changes as a result of climate change is a complex undertaking – especially as climate-related pressures are only one of the multiple pressures to which ecosystems are exposed as a result of human activities and the relentless quest for food, water, energy and materials.[1] Indeed, in many cases, climate change may exacerbate ecosystem degradation without necessarily being its main driver. This does not mean that climate change is unimportant, however:

- On the one hand, climate change is a driver of ecosystem degradation that is expected to increase sharply in all types of ecosystems in the coming decades, so that "by the end of the century, climate change and its impacts may be the dominant direct driver of biodiversity loss and changes in ecosystem services globally" (MEA 2005c:17).
- On the other hand, given the already significant existing stresses, there is an increasing probability of non-linear changes (e.g. accelerating, abrupt and/or irreversible changes not directly proportional to changes in external conditions) in ecosystems. This means that any "marginal" pressure exercised by climate change may have disproportionate impacts on ecosystems and their capacity to provide services, including the risk of crossing some irreversible "thresholds" or "tipping points".[2]

Climate change already has observable impacts on ecosystems, and these impacts are likely to increase significantly over the coming decades. Typical impacts observed over a wide range of ecosystems include:

- changes in the geographical distribution of species: for instance, vegetation zones are typically expected to move towards higher latitudes or altitudes;
- changes in population sizes;
- changes in lifecycle events such as the timing of reproduction or migration events, or the timing of budburst and blooming;
- increased frequency of pest and disease outbreak (MEA 2005a:17).

Here are some observed or anticipated impacts of climate change in relation to specific types of ecosystems:

- Marine fisheries systems: Changes in sea surface temperature, in salinity and oxygen levels, in oceanic circulation patterns, in the acidity of oceans – all of which may be triggered by climate change – may affect marine ecosystems and the fisheries that depend on them. The ranges of many fish species have already changed and may change further, as planktonic growth is affected by changing conditions. The composition and phenology (i.e. life cycle

[1] The Millennium Ecosystem Assessment identifies *habitat change* (resulting from land use change and in particular the conversion of natural ecosystems to croplands and other economic uses, the physical modification of rivers and excessive water withdrawal from rivers), *overexploitation of resources* (including overfishing and timber exploitation), *invasive alien species* (deliberate and accidental, linked to trade and globalisation), *pollution* (from agriculture, industry, waste, etc.) and *climate change* as the main **direct drivers** of ecosystem changes. They often act in synergy. These direct drivers, in turn, are caused by various **indirect drivers**, of which the most important are *population change* (incl. demographic growth and migrations), *economic activity* (incl. economic growth and the globalisation of trade), *socio-political factors* (incl. the level of public participation in decision making, the level of development and influence of civil society, the existence of conflicts), *cultural factors* (which influence mankind's relation to nature) and *technological change* (a source of both threats and opportunities).

[2] **Threshold effects** are "abrupt or non-linear changes or regime shifts in a system in response to a gradual or linear change in single or multiple drivers" (MEA 2005b:6). They characterise phenomena such as the collapse of fisheries, regional climate change linked to the loss of forest cover, eutrophication, or the switch from savannah to desert. In the current state of knowledge, quite often science can predict the existence of thresholds but not their exact level.

events) of fish stocks is also affected, and in some areas the development of invasive new species is facilitated by new climatic conditions. Ocean acidification is also expected to have negative impacts on the growth of shell-forming organisms and coral reefs.

- Coastal systems: The salinity of estuaries, coastal wetlands and coastal waters may change as a result of changes in stream flows. Lower river flows result in increased salinity in estuaries and the lower parts of rivers; conversely, higher flows such as those triggered by heavy rainfall reduce salinity. Annual fluctuations in salinity levels are normal but may be amplified, with important consequences for the composition of flora and fauna and for coastal fisheries. Increased salinity, especially if combined with excessive underground water abstraction, may lead to salinity intrusions in coastal aquifers, with impacts on freshwater supply, and in wetlands, with impacts on migratory birds and other species which may lose their traditional habitats in deltas and estuaries. The quantity of sediment and nutrients transported by rivers to coastal areas could also be affected by changes in rainfall patterns in upper river basins, with consequences for water quality, fauna and flora (e.g. increased incidence of – sometimes toxic – algal blooms and "dead zones"[3] in coastal areas as a result of higher concentrations in nutrients). Coral reefs are quite sensitive to changes in temperature as well as acidification, which reduces calcification rates; under the combined impacts of higher water temperature and other pressures, they are bleaching and dying in many parts of the world, with adverse consequences for biodiversity and coastal fisheries. Mangroves may shrink as they become increasingly squeezed between a rising sea and inland settlements and agricultural systems; they may also be damaged by more frequent and severe storms, or suffer from changes in the hydrological balance of estuarine systems. As for land-based coastal ecosystems, they are particularly exposed to storms and storm surges, sea level rise and floods.

- Lakes and rivers: The water cycle is likely to be affected, potentially significantly, by changes in rainfall patterns and temperatures. Some lakes may recede or even disappear as a result of higher evaporation and lower intake of surface and groundwater, while new lakes are formed as a result of glacier melting. Riverine ecosystem productivity may be affected by the recession of aquatic habitats during prolonged drought periods (possibly alternating with devastating floods), as well as deteriorating water quality. The range of many fish species is likely to change, with cold-water fish suffering restrictions in their range while the range of cool and warm-water fish expands. Aquatic insects may see their range expand. The range of invasive aquatic weeds may expand as a result of higher water temperatures or changes in water flows. Increased surface water temperature in the summer may cause a decrease in oxygen levels and changes in the water mixing regime, particularly in deep lakes, with consequences for the growth, reproduction and distribution of fauna and flora. Heavy rainfall episodes may result in increased levels of sediments being transported to surface water bodies, with impacts on fauna and flora from increased turbidity and the deposition of sediments in river beds and lake bottoms.

- Freshwater wetlands: These ecosystems, which are already among the most threatened due to other pressures, are likely to be affected by changes in precipitation patterns and the increased frequency or severity of disturbances such as droughts, floods and storms. In some regions, higher temperatures (leading to increased evaporation) combined with decreased precipitation and recharge of aquifers may result in the partial or total drying out of wetlands, threatening many amphibian and migratory bird species.[4] In other regions, however, the opposite happens: for instance, the thawing of the permafrost results in the formation of new wetlands (although this may be only temporary). The carbon sink potential of peatlands is expected to be reduced by the thawing of the permafrost in upper latitudes, and by more frequent droughts in lower latitudes – which will increase the risk of fire and peatland degradation. Migratory and nomadic bird populations are expected to be particularly affected by changes in their wetland habitats, especially if their fragmentation gets worse.

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[3] **Algal blooms** are a manifestation of **eutrophication** (i.e. the sudden proliferation and then decay of aquatic plants or phytoplankton under conditions of excessive nutrient loads) in coastal waters. They create **dead zones** (areas characterised by **hypoxia** i.e. low levels of dissolved oxygen, in which life is impossible for most plant and fish species), inflicting significant damage to fisheries and sometimes also to health (through the contamination of marine food chains by the toxic substances produced by some algae species).

[4] Freshwater ecosystems are generally considered to have the highest proportion of endangered species.

- Forest and woodland systems: Climate change is expected to have significant (although different) impacts on forests all over the globe. In high latitudes, significant temperature increases (which lengthen the growing season) coupled with the "CO_2 fertilisation effect" induced by higher atmospheric CO_2 concentrations are generally expected to boost forest productivity, at least in the short term and if temperature increases remain reasonable; winter precipitation is also expected to increase. Reduced summer precipitation is generally expected in regions of dry forests, resulting in lower productivity, land degradation and species impoverishment as soil moisture decreases. Tropical mountain forests (cloud forests) may dry out and experience significant changes in their species composition (including invasion by non-mountain species). In many regions, forests are at risk of degradation or even destruction as a result of higher temperatures and more severe and prolonged droughts; damage may result from more frequent and destructive fires[5], as well as pest and disease outbreaks in stressed ecosystems. Changes in temperature and rainfall patterns are already causing changes in the altitudinal and latitudinal range of individual forest species and vegetation zones (e.g. expansion of boreal forest in Arctic regions).

- Dryland systems: Drylands, which are characterised by scarcity of water, include a diverse range of sub-humid, semi-arid and arid regions encompassing deserts, savannahs, grasslands and scrublands which are used as rangelands, croplands and also host some dry forests and urban areas. Primary production in these ecosystems is very dependent on rainfall patterns. In most dryland regions, climate change is expected to exacerbate already observable trends towards higher temperatures and lower precipitation, with increased water stress, reduced biological production, a shift in vegetation zones, loss of grassland and arable land, salinisation and increased rate of desertification among the possible consequences.

- Island systems: Low-lying and small islands are those most at risk in the context of climate change, as they are threatened by sea level rise, storm surges and coastal floods and the associated consequences: salinity intrusions in aquifers (which may significantly reduce freshwater supply), soil salinisation, shoreline erosion, and the destruction of important ecosystems such as mangroves, coral reefs and wetlands. Some low-lying islands (e.g. the Maldives, Tuvalu, some archipelagos in the Philippines and Indonesia) may disappear altogether; other islands may lose part of their land surface and as a result experience higher pressures on remaining land areas. Island ecosystems' biodiversity is considered particularly fragile because of their isolation, which restricts or prevents exchanges of genes and individuals with neighbouring ecosystems; endemic species may become extinct as a result of climate-induced stresses.

- Mountain systems: Mountain ecosystems are also considered particularly fragile, because the species that populate them often only tolerate relatively narrow ranges of temperature and precipitation, and the combination of steep slopes and thin soils makes the recovery from disturbances slower than in other systems. The zonation of ecosystems is driven by temperature and soil moisture conditions. The nature of precipitations (rain or snow), and the duration and depth of snow cover, also influence the type of ecosystem that prevails in a given area. Climate change affects all these parameters, and may for instance lead to the invasion of alpine meadows by forests. Shifts in the range of some plants are already being observed as a result of higher temperatures, and this trend is likely to increase – but not all species are expected to adapt well or fast enough, and those living at the highest altitudes may not have anywhere to migrate to; some endemic mountain species are thus considered at high risk of extinction.

- Polar systems: Polar ecosystems are probably those undergoing the fastest changes as a result of climate change, because the rise in temperatures is more significant in polar regions (especially the Antarctic) than elsewhere. Significant changes in vegetation cover (e.g. recession of tundra areas in favour of forests) and in the range of fauna are already being observed; the contraction of the habitat of some species threatens entire populations. Invasive alien species are making fast progress. The recession of sea ice and the thawing of the permafrost induce significant changes in the structure of ecosystems (e.g. formation of new wetlands) and the services they provide, such as traditional food supply (e.g. reduced access to marine mammals,

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[5] Forest fires are a natural phenomenon and may cause no lasting damage; they even contribute to the balance of some forest ecosystems, for instance in savannahs and boreal regions. However, in other types of ecosystems they can become very destructive, especially if their intensity exceeds "normal" thresholds (for instance as a result of abnormally dry conditions).

collapse in polar bear populations) and climate regulation services.

- Cultivated systems: Cultivated systems, like natural ones, are sensitive to changes in temperature and rainfall patterns, and are very dependent on the availability and quality of water, soils and nutrients. This makes them quite vulnerable to changes in climatic conditions, directly and indirectly. The dependence of cultivated systems on natural ecosystems should also be highlighted: degradation of natural or semi-natural systems may lead to adverse consequences for cultivated ones, in the form of increased risk of pest and disease outbreak and reduced availability of ecosystem services such as hydrological flow regulation and balanced nutrient cycling. For more details on possible impacts on cultivated systems, please refer to the script dedicated to Agriculture & Rural Development.

- Urban systems: Climate change is expected to exacerbate some of the environmental issues that affect urban areas locally, in particular floods, poor air quality and the health and ecological issues associated with inadequate sanitation and waste management (please refer to the scripts dedicated to Infrastructure, Solid Waste Management and Water Supply & Sanitation for further details). Furthermore, it will disrupt the provision of ecosystem services (e.g. food and water supply, energy supply, regulation of air pollution) that originate outside urban areas but are indispensable to the wellbeing of urban populations.

1.2. Changes in ecosystem services

Changes in ecosystems and ecosystem degradation do in turn affect the provision of ecosystem services, with potentially significant consequences for human activities, livelihoods and quality of life. Overall, climate change is expected to accelerate the degradation of ecosystems and therefore reduce their capacity to deliver ecosystem services. [6] Such degradation, which may take the form of changes in the quantity, quality and/or timing of services, is already under way in most regions of the world as a result of multiple human pressures. Valuable services are likely to be further threatened by the additional stress caused by changing climatic conditions.

Here are a few examples of how climate change might affect the provision of ecosystem services:

- Freshwater supply: Changes in geographic and temporal rainfall patterns (e.g. more intense rainfall over shorter and more unpredictable rain seasons, longer and more frequent droughts) and in the overall level of precipitation interfere with all processes in the water cycle; they are likely to affect the availability as well as the quality of water supplies, both on the surface and underground, in most parts of the world. Impacts are and will be increasingly felt both in the regions most directly concerned (e.g. arid and semi-arid regions) and in downstream areas. Desertification and land degradation are expected to progress as a result. The inexorable melting of glaciers affects the availability of water in major glacier-dependent watersheds, which may receive more water in the short term as glaciers melt but experience severe water shortages in the medium- or long-term. In coastal areas, saltwater intrusion in aquifers is likely to increase as a result of sea level rise, reduced stream flows and reduced aquifer recharge rates. These and other effects of climate change on freshwater supply are described in the script dedicated to Water Supply & Sanitation.

- Food supply: Shifts in seasons and changes in rainfall and temperature patterns are expected to have significant and, more often than not, adverse impacts on the productivity of agricultural and other food supply systems (e.g. fisheries and aquaculture). Potential effects on agriculture and fisheries are extensively described in the script dedicated to Agriculture & Rural Development.

- Timber, fuel and fibre supply: Although forest productivity may initially be enhanced in some regions (see 'forest and woodland systems' above), in general forest and grassland degradation as a result of climate change will lead to reduced availability of timber, fuelwood and fibre materials for local populations as well as those that import forest products from other regions. The risks to forest productivity and forestry activities are described in more detail in the script dedicated to Agriculture & Rural Development.

- Nutrient cycling: Climate change (which results from imbalances in the carbon cycle) may interfere in various ways with the

[6] In some regions, some ecosystem services (e.g. food production) may initially be enhanced by the effects of climate change, but "a significant net harmful impact on ecosystem services" is expected "if global mean surface temperature increases more than 2°C above pre-industrial levels or at rates greater than 0.2°C per decade" (MEA 2005a:17).

global nitrogen, phosphorous and sulphur cycles. Soil nutrient loss and accelerated erosion may result directly from heavier rainfall episodes, and indirectly from the degradation of forests and grasslands which may be exacerbated by climate change. The destruction of natural “buffers” between terrestrial and aquatic ecosystems, such as wetlands and riparian forests, may also contribute to the acceleration of nutrient losses from soils to water. The increased rate of desertification increases the incidence of dust storms, which transport nutrients (as well as sand and other materials) over large distances across regions, oceans and continents.

- Human health regulation: Ecosystems regulate the development and virulence of human pathogens and the geographical range of their vectors. Climatic changes are expected to modify the seasonality and/or range of vector-borne diseases such as malaria, dengue, schistosomiasis, leishmaniasis, tick-borne encephalitis, Lyme disease and others. Cholera epidemics and other waterborne diseases, often associated with floods, may become more frequent as a result of the increase in heavy rainfall episodes. A shift in the geographical distribution of non-insect disease vectors or reservoirs (e.g. rodents, aquatic snails, bats, migratory birds) may also lead to changes in exposure to the pathogens they carry (e.g. higher transmission rates of West Nile virus have been observed along bird migratory paths, which are gradually changing with climatic patterns). For a more comprehensive overview of climate change impacts on health, please refer to the Health sector script.

- Water purification, waste processing and detoxification: The capacity of ecosystems to assimilate waste and break down contaminants into harmless or less harmful components depends on local conditions; accordingly, the effects of climate change on these processes may vary across locations, depending for instance on how microbial communities react to changes in moisture and temperature. Wetlands play an important role in filtering and purifying water and buffering excessive nutrient loads, so their degradation as a result of dryer and hotter conditions is likely to reduce water quality and lead to more severe and widespread episodes of eutrophication[7] – with adverse impacts on the availability of potable water. Organic waste decomposition processes are affected by changes in temperature and rainfall patterns (see script on Solid Waste Management). Also, the sensitivity of living organisms to contaminants may increase if they already suffer from climate-induced stress.

- Flood regulation: Some ecosystems, notably wetlands, forests and to some extent grasslands, retain rainwater at the time of rainfall, allowing it to seep into soils and then gradually releasing it. This mechanism contributes to freshwater supply (see above), notably by supporting the recharge of aquifers; it also attenuates variation in stream flows as a result of precipitation, and thus helps prevent or attenuate flooding. Climate-induced forest degradation, as well as the drying of wetlands, may in some regions exacerbate the loss of these important flood mitigation services, with consequences for human settlements and infrastructure (see script on Infrastructure). More marked fluctuations in stream flows also have negative impacts on hydropower generation capacity.

- Pest regulation: Balanced ecosystems usually regulate populations of pests. Climatic changes may result in the multiplication of some pests and/or changes in their range, either directly by creating more favourable conditions for their reproduction or indirectly by modifying the balance and dominance patterns of species in given ecosystems (e.g. multiplication of insects as a result of a fall in the population of predator birds caused by the degradation of bird habitats).

- Storm and fire protection: In coastal zones, the degradation of temperature-sensitive coral reefs (as well as mangroves) may reduce the protection of coastlines against sea surges, storms and erosion. Higher temperatures and reduced rainfall in some regions are already contributing to more frequent and more destructive wildfires in forests and grasslands. This trend is likely to be amplified in future.

- Regulation of local and regional climate: The nature and species composition of ecosystems play a role in global climate regulation (via complex effects on carbon sequestration, the risk of wildfires, the water cycle, the nutrient cycle) but also on local and regional climate. The degradation or destruction of tropical forests, for instance, is known to significantly affect regional climate through reduced precipitation and higher temperatures.[8] In some regions, climate-

[7] See definition in footnote 3.

[8] Reduced precipitation results from the combination of: (i) reduced evapotranspiration and thus reduced moistening of the atmosphere and cloud formation; and (ii) reduced production of the

induced changes in rainfall patterns and in vegetation cover, combined with other pressures, are likely to accelerate desertification – which in turn reduces rainfall at the regional scale, thus creating a vicious circle. The incidence and severity of wildfires is determined in part by the composition of vegetation, which may be altered by climate change. At high latitudes, the increase in forest-covered areas reduces the albedo effect (i.e. the reflection of sunlight by the land surface back to space); more heat is trapped at ground level, leading to increased local (as well as global) temperatures.

- Carbon sequestration: Natural and semi-natural ecosystems, both terrestrial and marine, have a considerable potential for storing carbon away from the atmosphere – and may thus contribute to climate change mitigation or aggravation. Changes in temperature and precipitation patterns and the composition of the atmosphere have complex impacts on this service, which may either be enhanced or reduced depending on a combination of local factors. Section 4 addresses the use of terrestrial ecosystems to store carbon.

- Air quality regulation: Ecosystems exert an influence on atmospheric cleansing, modulating the capacity of the atmosphere to act as a sink for pollutants such as ammonia, nitrogen oxides, sulphur dioxide, methane and tropospheric[9] ozone; they are also sources of atmospheric pollution, e.g. in the form of particulates from biomass combustion, carbon monoxide, nitrogen oxides and tropospheric ozone precursors. Nature's capacity to regulate air quality, and to act as a sink rather than a source of pollutants, may be affected by climate change in various ways. For instance, wildfires, which are expected to become more frequent and severe, generate severe air pollution, with effects felt on a regional scale. Dust storms, increasingly frequent as a result of desertification, may reduce air quality locally and also in locations faraway from their place of origin. Higher temperatures may lead to increased concentrations of ground-level ozone as a result of increased production of ozone precursors. Changes in atmospheric circulation patterns may cause reduced pollutant dispersion and thus slower dissipation of regional air pollution episodes, or on the contrary the transport of air pollutants over longer ranges.

- Cultural and amenity services: The degradation of natural ecosystems and landscape features leads to reduced amenity for local residents as well as external visitors, including the loss of recreational opportunities and aesthetic enjoyment, and the reduced availability of areas conducive to spiritual development or artistic fulfilment. Economic activity is likely to be impacted: for instance, many countries may find that the significant economic opportunities associated with tourism increasingly vanish with the degradation of their beaches, rivers, lakes, landscapes, areas of natural beauty, biodiversity hotspots, etc. Other adverse consequences for human wellbeing include the loss of the substrate in which many human cultures, religions and heritage values developed and are still rooted, and the social strains and social breakdown that have repeatedly been shown to be closely associated with environmental degradation.

cloud condensation nuclei that trigger precipitation. Higher temperatures result from lower evapotranspiration.

[9] *The troposphere is the lower layer of the atmosphere.*

These impacts on ecosystems and the services they provide, in turn, are likely to have adverse effects on agriculture, forestry, fisheries, energy production, health, infrastructure and generally on the livelihoods of rural populations (including indigenous peoples) as well as urban dwellers (see scripts dedicated to Agriculture & Rural Development, Energy Supply, Health and Infrastructure for further details). The degradation of ecosystem services matters because:

- it may severely affect human wellbeing;
- it tends to affect primarily the poor and the most vulnerable (e.g. women, indigenous communities), notably in rural areas where many people directly depend on these services for survival, and also to aggravate inequalities, leading to increased risk of social conflicts; furthermore, poor and vulnerable people are usually the least equipped to cope with the degradation of the natural environment;
- it impairs chances of meeting or sustaining some of the Millennium Development Goals (MDGs), notably those that relate to poverty reduction, improved health and nutrition, improved access to clean water, and environmental sustainability;
- ecosystem degradation represents a destruction of natural capital assets, which for many developing countries represent a sizeable share of the productive asset base on which to build their development.

1.3. Biodiversity loss

As a result of changes in ecosystems (see above), climate change will induce changes in biodiversity, biodiversity loss[10] and higher rates of species extinction. While other human pressures have been responsible for the bulk of losses observed in recent history, in the 21st century climate change is expected to become the dominant driver of biodiversity loss, particularly in vulnerable habitats in mountainous areas, islands, peninsulas and coastal areas.

The ability of a species to adapt to climate change depends on its climate tolerance (i.e. its capacity to survive in a more or less wide range of temperature, moisture and other related conditions), and its ability to migrate to new locations[11], modify its phenology and adapt to changes in the availability of food sources. Factors that contribute to species vulnerability include limited climatic ranges, reduced mobility, strict habitat requirements, and the isolation or small size of populations. Habitat destruction, alteration or fragmentation due to other pressures significantly add to "natural" vulnerability, which makes scientists believe that current anthropogenic climate change may cause more extinctions and result in more biodiversity loss than any past episodes of climate variation. The complexity of interactions between species, and their different sensitivity to changing conditions, add to the difficulty of predicting how climate change will affect biodiversity in specific ecosystems. Biodiversity losses are in any case expected to get more severe as the rate of climate change increases, and the absolute amounts of change get more significant.

The loss of biodiversity (and notably of species diversity within specific ecosystems) reduces the overall resilience of ecosystems, i.e. "the level of disturbance that an ecosystem can undergo without crossing a threshold to a different structure or functioning" (MEA 2005a:12) – including resilience to climatic shocks. Indeed, biodiversity is a key regulator of the functioning and balance of ecosystems and underpins their adaptive potential. Furthermore, the loss of biodiversity:

- is a threat to food security: the genetic diversity of cultivated species, in particular, has decreased dramatically, making food production systems very vulnerable to changes in climatic conditions and pest attacks; the capacity to reintroduce diversity in cultivated species, which may be essential for food production systems' adaptability to new conditions, depends to a large extent on maintaining sufficient levels of wild species diversity, as well as preserving interactions among species (e.g. plant interactions with pollinators and seed disseminators); livestock production is also increasingly relying on a narrow range of domesticated animal species, making it similarly vulnerable to harsher conditions and similarly in need of potential regeneration from a pool of diverse wild species;
- directly affects the livelihoods of the rural poor and indigenous peoples, when it affects traditionally used plant and animal species;
- deprives humanity of a potentially wide range of future options to exploit biodiversity as a source of food, food supplements, botanical medicines, conventional drugs, cosmetics, crop protection systems, pest repellents, environmental clean-up ("bioremediation") and ecological restoration solutions, pollution monitoring devices ("biomonitoring"), enzymes, pigments, adhesives, innovative architectural and engineering designs, new materials and technologies ("biomimetics"), model organisms for research, etc.;
- also causes a loss of "non-use values" (e.g. sense of loss caused by the knowledge that some "charismatic fauna" or remarkable flora species has been irreversibly lost).

1.4. Increased pressures for land use conversion

Climate change is expected to reduce the productivity of agriculture and food production systems in most regions of the world – at a time when policies supporting the production of biofuels increase demand for arable land. It may also force the relocation of large human settlements and some infrastructure, for instance as some flood plains, deltas and low-lying coastal areas have to be evacuated. Pressures for the conversion of the shrinking supply of natural ecosystems to agricultural, industrial and settlement uses are thus likely to get worse.

[10] **Biodiversity loss** was defined by the Conference of the Parties to the Convention on Biological Diversity as "the long-term or permanent qualitative or quantitative reduction in components of biodiversity and their potential to provide goods and services" (MEA 2005b:2).

[11] In this regard, the rate of climate change may be a key factor. Less mobile species may be able to adapt to slow changes but not rapid ones.

V REDUCING VULNERABILITY & ENHANCING ADAPTIVE CAPACITY THROUGH ECOSYSTEMS AND BIODIVERSITY MANAGEMENT

The resilience of ecosystems, and thus their capacity to keep providing essential ecosystem services on a sustained basis in spite of potentially disrupting short-term variation and long-term changes in climate, will play a significant role in reducing human vulnerability to the effects of climate change and enhancing adaptive capacity. Greater biodiversity is deemed to enhance ecosystems' capacity to withstand shocks, including climatic ones. Therefore, preserving biodiversity and protecting ecosystems to support and enhance their resilience to the effects of climate change should be considered an essential and high-priority component of any adaptation strategy.

The concept of "green infrastructure" is useful to address climate-related challenges. It was developed in response to the fact that on a planet marked by the massive transformation of natural ecosystems and development of built infrastructure, it is increasingly necessary to plan and manage the use of land so as to preserve an adequate provision of life-supporting services, on which economic activity and human wellbeing critically depend. The term "green infrastructure" may have different meanings; here it is used to refer to "the network of open space, woodlands, wildlife habitat, parks and other natural areas that sustains clean air, water and natural resources and enriches our quality of life" (Benedict & McMahon 2001:3).

The green infrastructure approach provides a framework within which all new developments should ideally be planned, with environmental, social and economic sustainability as the ultimate goal. It emphasizes:

- network and systemic aspects: if essential ecosystem services and biodiversity are to be preserved on an adequate scale, including under stress conditions such as those generated by climate change, managing "green spaces" in an isolated manner is not sufficient; to build resilience in the system, green spaces must be interconnected to form a comprehensive system, with large and medium-sized "hubs" (such as national parks, wildlife refuges, forests, wetlands, semi-natural agricultural areas and grazing lands, urban parks, etc.) connected with each other by means of "linking elements" such as conservation corridors, natural landscape linkages, green paths, waterways with undeveloped riverbanks, and buffer zones in which special attention is paid to the maintenance of ecological services; in this way, plant and animal species maintain opportunities to "migrate" across natural habitats, to gradually modify their range in response to changing climatic conditions, and to maintain genetic diversity in their populations;[12] interconnection is also critical to maintaining critical ecological services such as the supply of freshwater, the control of stormwater runoff, the cleaning and renewal of urban air, pollination, seed dispersal, carbon sequestration, etc.;

- the need to plan land use in a comprehensive and strategic manner, in order to exploit potential synergies between man-made infrastructure and natural infrastructure (e.g. with regard to water and flood management), sustainably manage the unavoidable tradeoffs between produced and natural capital assets, and avoid useless damage to the environment that may ultimately damage built infrastructure or compromise its capacity to deliver the expected services at an affordable cost; this increasingly requires environmental

[12] Habitat fragmentation has been shown to reduce both the number and the size of wild species populations. Populations confined in an enclosed territory are deprived of opportunities to renew their gene pool, which reduces their adaptive capacity and may lead to extinction as a result of inbreeding.

engineering skills to complement traditional engineering practices;

- professionalism: green infrastructure approaches are based on science and proven techniques; their implementation requires the same rigour as traditional approaches to the planning, design and financing of man-made infrastructure, and the mobilisation of a wide range of professional competences;

- participation and transparency: in line with the principles of sustainable development, green infrastructure approaches involve active stakeholder and community participation in planning, decision-making and monitoring.

Adopting a green infrastructure approach to development has the potential to decisively support efforts to reduce vulnerability and adapt to climate change in a variety of ways. For instance:

- the maintenance of sufficient forest cover and wetlands in critical areas, and of adequate infiltration capacity in built-up areas, can reduce the incidence and severity of floods in case of heavy rainfall; it can also contribute to the replenishment of aquifers, the availability of base flows of water during drought episodes and the reliability of hydropower generation;

- the maintenance of natural coastal defences such as dune systems, mangroves and coral reefs can protect coastal (man-made) infrastructure against sea surges and absorb part of the energy of storms, thus reducing the damage they inflict;

- land use planning that takes account (where this is still possible) of the location of natural floodplains, and prohibits any new settlement or significant infrastructure building in flood-prone areas, could increase the resilience of new settlements to floods without requiring costly flood defence infrastructure; similarly, land use planning based on a green infrastructure approach can contribute to increased resilience by avoiding new developments close to fuelwood plantations or areas particularly exposed to storms – which are better left undeveloped to play their role of natural buffers;

- the maintenance of forest cover on mountain slopes and the conservation of healthy grasslands, combined with agricultural practices that promote soil conservation, can reduce soil erosion and therefore contribute to maintaining the productivity of the food supply systems on which humanity critically depends;

- the maintenance of forest cover can also contribute to regulating the regional climate and in particular to attracting sufficient rainfall, thus reducing the risk of droughts, destructive wildfires and, in some regions, desertification;

- the maintenance of sufficient wetland areas can act as a buffer against water pollution by nutrients and therefore prevent the eutrophication of freshwater and coastal water ecosystems, thereby supporting the productivity of fisheries and fish farms;

- the maintenance of unexploited or little exploited natural areas in regions dominated by agriculture and commercial forestry ("spatial heterogeneity") can contribute to the balance of species, the regulation of pests and diseases, and the maintenance of genetic diversity in domesticated plant and animal species – all features that are valuable to support the resilience of food, fibre, fuel and timber production systems during times of climate-related stress;

- compared with disturbed and degraded ecosystems, natural ecosystems with intact structures and biodiversity have been shown to offer better protection against the introduction and dissemination of human and animal pathogens brought by human migration and settlement; this may play an important role in containing the spread of infectious diseases that might be associated, in future, with growing climate-induced migrations;

Note that the maintenance of natural ecosystem services is generally much cheaper than either attempts to restore them after they have been degraded or investments in man-made infrastructure to provide equivalent services. This is an important consideration at a time when climate change adaptation and mitigation are expected to require the mobilisation of significant financial resources. Governments willing to adopt a long-term perspective in the formulation of their climate response strategy should consider this argument and use it to give high priority to an approach based on preventing any further damage to key ecosystems.

W Adapting to climate change in ecosystems and biodiversity management

Even if serious efforts are undertaken to reduce greenhouse gas (GHG) emissions, stabilise their atmospheric concentration and thus reduce the magnitude of long-term global warming, some amount of climate change is now inevitable. Nor can the loss of biodiversity be stopped in the foreseeable future.[13] However, a lot can be done to slow down the rate of biodiversity loss (one of the targets under MDG #7) and reverse ecosystem degradation; the ultimate extent of the damage climate change ends up inflicting on ecosystems and biodiversity will depend very much on the course of action taken by humanity in the coming few decades.

Some specific measures can be taken to actively restore ecosystems and enhance their resilience to the effects of climate change – but they will not be effective without a comprehensive action plan aimed at addressing both the direct and indirect drivers[14] of ecosystem degradation and biodiversity loss (including, in a medium- to long-term perspective, the stabilisation of greenhouse gases in the atmosphere). Indeed, to protect biodiversity, ecosystems and the services they provide, adaptation strategies necessarily involve reducing (or stopping or reversing, where possible) the human pressures that are often the first and foremost cause of ecosystem degradation and the associated biodiversity losses.[15]

In the sections below, we start by reviewing possible responses based on direct ecosystem protection and restoration. We then provide an overview of more indirect but equally important responses associated with reduced pressures on ecosystems through technological advances, improved environmental and natural resource governance and the mainstreaming of biodiversity.[16]

3.1. Ecosystem protection and restoration

Active human interventions and the use of “environmental engineering” techniques can be used to directly enhance the resilience of ecosystems and biodiversity and/or restore damaged ecosystems. It is necessary to reconsider conservation approaches in the light of climate change, and to enhance scientific understanding of impact pathways in order to develop more effective responses in the field of ecosystem management. Based on current knowledge, increased resilience, ecosystem service restoration and biodiversity protection can be achieved, for instance, by:

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13 Because of the significant lag times between changes in drivers of ecosystem change and eventual impacts on biodiversity.

14 See first footnote for a list of direct and indirect drivers.

15 The Millennium Ecosystem Assessment estimates that “for terrestrial ecosystems, the most important direct drivers of change in ecosystem services (…) have been land cover change (in particular, conversion to cropland) and the application of new technologies, which have significantly contributed to the increased supply of services such as food, timber and fiber. (…) For marine ecosystems and their services, the most important direct driver of change (…) has been fishing. (…) For freshwater ecosystems and their services, depending on the region, the most important direct drivers of change (…) include modification of water regimes, invasive species, and pollution, particularly high levels of nutrient loading” (MEA 2005c:75).

16 The contents of sections 3.1 and 3.2 are much inspired by the conclusions of the Millennium Ecosystem Assessment – see for instance MEA (2005a:20-24) and MEA (2005b:10-14).

- increasing the number and size of land-based and marine protected areas (both those aimed at biodiversity conservation and those aimed at sustainable exploitation of resources);
- adopting a holistic "ecosystem approach"[17] to the management of natural resources and protected areas;
- connecting natural reserves and biodiversity-rich areas by means of "green linkages", to reverse habitat fragmentation and provide corridors for the migration of wild species; to support species adaptation to new climatic conditions, the creation of corridors allowing species migrations across latitude as well as altitude ranges may be increasingly necessary;[18]
- adopting proactive species protection (preferably in situ or, if not possible, ex situ) and recovery measures for endangered species;
- promoting the seeding and/or re-planting of diverse tree species (preferably native ones if they are adapted to the new prevailing conditions) in the context of afforestation and reforestation schemes;
- restoring damaged ecosystems such as wetlands, estuaries, mangroves, coral reefs, forests, peatlands and grasslands, which usually harbour a large amount of species and provide essential services; various restoration techniques exist (e.g. improved water management practices can contribute to wetland and peatland restoration, and fire protection measures to the restoration of forests, peatlands and grasslands; mangroves can be regenerated by replanting trees); the choice of techniques should be adapted to local circumstances and take account of the primary causes of degradation.

Note that ecosystem restoration techniques are improving and getting increasing scientific and political attention; however, ecosystem restoration tends to be much more expensive than preventive measures aimed at avoiding degradation in the first place.

In some cases, synergies exist between conservation goals and sustainable use (e.g. increased productivity of fisheries adjacent to marine protected areas). They should be systematically exploited since they improve the social acceptability of ecosystem protection schemes and increase the chances of compliance with the constraints conservation imposes.

3.2. Reduced pressures on ecosystems through technological advances

Technological development (which is addressed as a specific topic in the script dedicated to Trade & Investment) is a source of both threats and opportunities for ecosystems and biodiversity. Technological innovation and development oriented towards the alleviation of existing pressures on the environment is part of the response to ecosystem degradation and biodiversity loss. It is useful, for instance, to support the development and dissemination of:

- agricultural techniques and technologies that increase crop yields and livestock productivity without significant adverse impacts on the environment (in relation to water, nutrient loading, pesticide use, soil erosion, waste, etc.) – and may thus contribute to increased food production without ever increasing the surface of croplands and pasturelands (for more details on available techniques, see the script dedicated to Agriculture & Rural Development);
- technologies that promote energy efficiency, water efficiency and efficiency in the use of materials;
- low-carbon and "clean" sources of energy, as long as they cause minimal disruption to the functioning of ecosystems; in this regard, the promotion of biofuels should be envisaged with extreme caution since their production may significantly threaten ecosystems while failing to achieve any substantial net emission reductions (e.g. peat swamp forest conversion to oil palm

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[17] An **ecosystem approach** is "a strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way". It "involves a focus on the functional relationships and processes within ecosystems, attention to the distribution of benefits that flow from ecosystem services, the use of adaptive management practices, the need to carry out management actions at multiple scales, and intersectoral cooperation" (MEA 2005b:14). Ecosystem approaches such as sustainable forest management, integrated watershed management and integrated coastal zone management provide an adequate framework for identifying and managing environment-development tradeoffs, balancing the interests of various stakeholders and planning coordinated responses.

[18] In specific cases, conservation specialists may even consider assisting the migration of species to new locations deemed more suitable for their survival under new climatic conditions. However, this approach is fraught with risk, as past experience of transplanting species has shown.

plantations in south-eastern Asia); wind power and hydropower are also known to have potential adverse impacts on ecosystems or some species (e.g. interference of wind farms with migratory bird flyways); the Energy sector script includes more details on alternatives to fossil fuels and under which conditions they may be considered environmentally sustainable;

- industrial processes that minimise GHG emissions as well as all other forms of pollution.

3.3. Natural resource governance and mainstreaming of biodiversity

Adaptation strategies in support of biodiversity and ecosystem resilience should also include a mix of the following elements:

a) Changes in institutional and environmental governance frameworks:

These frameworks must evolve to create enabling conditions for improved management of ecosystems. This may involve, for instance:

- mainstreaming ecosystem management, biodiversity protection and sustainability objectives (as well as climate change) in national development and poverty reduction strategies, in all policies, in sector and regional development strategies, in plans and programmes;
- increasing informed public participation, transparency and accountability in planning and decision-making processes;
- in support of the green infrastructure approach: making land use planning and management a more prominent and more competently exercised function of government, clarifying and optimising the distribution of competences, across levels of government, for environmental and natural resource management as well as territorial planning – and developing the required skills and capacities accordingly;
- clarifying property rights and other issues relating to access to resources, with a view to creating incentives for long-term sustainability;
- empowering groups that are particularly dependent on ecosystem services for their livelihoods, notably indigenous peoples (e.g. in the context of community-based resource management programmes);
- improving and actually enforcing environmental legislation;
- strengthening coordination on environmental management among government bodies, and among multilateral environmental agreements and the structures in charge of implementing them (e.g. search for synergies and coordinated responses with regard to biodiversity protection, wetland protection, climate change adaptation and mitigation, and the fight against desertification).

b) Knowledge-based responses:

One of the barriers to the sustainable management of ecosystems is the fact that many ecosystem services, not being marketed, do not have a recognised monetary value. As a result, markets fail to provide the signals (e.g. increased price resulting from increasing scarcity) that would support their efficient allocation and sustainable use – and decision makers are often unaware of their actual value. More systematic consideration of the total economic value of biodiversity and ecosystem services in the economic analysis of development strategies and interventions – and more widespread use of decision support tools such as cost-benefit analysis (incl. the analysis of cost and benefit distribution), risk-benefit analysis, vulnerability analysis, multi-criteria analysis, etc. – would in certain cases support sounder decisions.[19] Indeed, in many cases economic arguments would provide a strong justification for adopting biodiversity protection measures, and opting for development paths that are compatible with the preservation of healthy ecosystems.

Other knowledge-based responses include:

- the enhancement of institutional capacity to monitor ecosystem change and biodiversity loss, and to assess their impacts on human wellbeing;
- the development of "adaptive management" capacities aimed at taking the best possible decisions in the presence

[19] In this regard, the European Commission and other partners are supporting an initiative that should enhance capacity to assess the economic value of ecosystem services. A large-scale study entitled "The Economics of Ecosystems and Biodiversity" is under way (interim results have already published, final results are expected between the fall of 2009 and the end of 2010), and is expected to deliver a set of practical tools and reference values allowing much more systematic consideration of ecosystem and biodiversity value in policy making and planning decisions. See http://ec.europa.eu/environment/nature/biodiversity/economics/index_en.htm for more details.

of uncertainty, in recognition of the particularly high levels of uncertainty that prevail when attempting to predict the combined effects of climate change and other pressures on complex ecosystems;

- the development of scientific knowledge and good practices in support of “ecosystem approaches” for the management of important resources such as protected areas, forests and fisheries;
- more systematic consideration of traditional and local practitioners’ knowledge in assessments and decisions that involve impacts on ecosystems;
- the financing of research to “fill” gaps in information and knowledge about the impacts of climate change on ecosystems and how best to promote their adaptation;
- the development of training programmes aimed at disseminating good environmental practices among private sector operators.

c) Modification of economic incentives:

The fact that many ecosystem services are not marketed nor appreciated at their true economic value (see above) results in the misalignment of private financial incentives with what would be a socially optimal allocation and exploitation of resources. Measures in support of reduced human pressures on ecosystems and biodiversity should therefore, where the context allows, encompass measures aimed at correcting these "market failures", and re-aligning private incentives with overall economic efficiency objectives. This may include, for instance:

- removing subsidies that encourage excessive, unsustainable use of ecosystem services (e.g. fossil fuel subsidies, many types of subsidies for agriculture and fisheries);
- taxing activities and products that impose significant “external costs” on ecosystems and biodiversity (e.g. tourism, timber and mineral extraction, use of fossil fuels);
- promoting systems of “payment for environmental services”, in which the end users of ecosystem services pay the people who live in the ecosystems from which the services originate to maintain them and ensure their continued provision (e.g. city dwellers may pay the residents of mountain areas located upstream of the city to maintain adequate forest cover and therefore guarantee adequate water supply while reducing the risk of floods);
- promoting cap-and-trade systems, which allow setting a ceiling for the emission of some pollutants and letting polluters exchange limited “rights to pollute” in markets – thus ensuring that pollution abatement takes place at the lowest possible cost;
- at the micro level, developing programmes that enable local communities to be more aware and to capture the benefits of natural resource use, and thus give them an incentive to sustainably manage local resources.[20]

d) Social and behavioural responses:

Awareness-raising among the population and education of the public should in principle support the changes in consumption patterns and lifestyles that are very much needed if environmental pressures are to be reduced in spite of a growing population. Improved understanding of the value of biodiversity and ecosystem services, and of the ways of preserving them, is essential to secure lasting and widespread behavioural changes – so this type of response is linked with the adoption of knowledge-oriented responses and the modification of economic incentives.

[20] To be sustainable, these approaches must address the question of property rights, provide adequate access to information and capacity building, and involve all stakeholders.

X Contributing to climate change mitigation: opportunities for storing carbon and reducing GHG emissions in biodiversity and terrestrial ecosystems management

While ecosystems and biodiversity are threatened by climate change but can, if adequately protected, enhance societies' resilience and adaptive capacity, they are also an essential element in the mitigation response. Their management offers a variety of possibilities to contribute to climate change mitigation efforts through reduced emissions and through carbon sequestration[21] in natural and semi-natural ecosystems, in particular in soils and, to a lesser extent, vegetation.[22] In many cases, these possibilities are congruent with the adaptation options reviewed in Section 3 above: carbon management in ecosystems involves significant potential co-benefits, notably in terms of biodiversity and ecosystem service protection (e.g. drylands offer opportunities for combining carbon sequestration with land restoration). Furthermore, it is often a very cost-effective approach – and one that allows the contribution of developing and emerging countries to the global mitigation effort.

Globally, it is estimated that terrestrial ecosystems[23] store approx. 2,100 Gt of carbon (i.e. almost three times as much as the atmosphere) in biomass and soil organic matter. Tropical and sub-tropical forests are the biome that stores the most carbon (approx. 550 Gt); they are followed, in decreasing order of importance, by boreal forests; temperate forests; tropical and sub-tropical grasslands, savannahs and shrublands; temperate grasslands, savannahs and shrublands; deserts and dry shrublands; and tundra (Trumper et al. 2009). The potential for carbon management is related to forests, peatlands, cultivated ecosystems and, to a lesser extent, grasslands; it is more significant in some types of biomes than in others.

Soils' capacity to act as carbon sinks depends on their capacity to retain organic matter. Soil organic matter, which is made up of carbon-based compounds of biological origin, contains approximately 50% carbon; it originates from plant residues (e.g. roots, tree leaves, harvest residues) and animal residues (e.g. dead animals, excreta from animals, applied manure) which are broken down by a range of soil micro-organisms (mainly fungi and bacteria), in successive stages, into organic and other compounds; the degraded organic matter that has reached a point of stability and will not undergo further decomposition is called humus. Aerobic decomposition processes (i.e. those that take place in the presence of oxygen) involve the release of carbon to the atmosphere, in the form of carbon dioxide – but a more or less important "stable fraction"

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[21] In the atmosphere, carbon (in the form of carbon dioxide and methane) contributes to global warming. Carbon sequestration is the retention or storage of carbon in other media than the atmosphere, in ways that avoid its release to the atmosphere.

[22] Globally, it is estimated that soils contain about twice as much carbon as the atmosphere, and three times as much as vegetation.

[23] For the record, note that some experiments are taking place to increase carbon sequestration in oceans, notably using a geo-engineering method called "iron fertilisation" which aims to stimulate phytoplankton growth by spreading iron sulphate (a limiting factor to planktonic growth in some seas) on the sea surface. Phytoplankton growth absorbs carbon dioxide; carbon should thus be locked up on the seabed as the tiny algae die and sink to the bottom. Initial results have been disappointing, however (see for instance The Economist 2009), and the method (which amounts to voluntarily generating an algal bloom) is controversial since it may, if used on a wide scale, result in significant adverse ecological impacts. For this reason, in 2008 the meeting of the Parties to the Convention on Biological Diversity imposed a moratorium on large-scale ocean fertilisation experiments. So far no ecologically acceptable method of enhancing the carbon storage capacity of marine ecosystems has been developed – hence the focus on terrestrial ecosystems in this script.

of carbon remains in soils. The amount of carbon thus stored in soils ultimately depends on the balance between additions of plant and animal residues, and the amount of carbon lost to decomposition processes – the latter being influenced by soil management and texture, vegetation and climatic factors.

Before reviewing a range of potential mitigation measures linked to land use and soil management, it should be noted that the processes involved in ecosystem-based climate mitigation are characterised by complexity as well as considerable uncertainties. Little is still known, for instance, about the net carbon sequestration potential in different conditions and the stability and permanence of carbon retention. Some land use and soil management strategies may have a positive net impact on GHG emissions in some locations and ecosystems but not in others. Some strategies involve a trade-off, in the sense that a reduction in emissions of one GHG is accompanied by an increase in emissions of another one. For example, nitrogen fertilisation in relatively nutrient-poor soils is generally deemed to increase the carbon sequestration potential (through increased biomass production and possibly reduced soil respiration), but this advantage may be more or less offset by increased atmospheric emissions of nitrous dioxide (N_2O), a more powerful GHG than carbon dioxide (CO_2). There is thus no universally applicable list of good practices: scientific advice should be sought before choosing a mitigation strategy. It is essential to keep financing research in this field, so that policy makers can base their decisions on an increasingly sound scientific foundation.

Another important aspect to keep in mind is the necessary balance to be achieved between carbon management policies, rural livelihoods and the need to feed the population: there are potential synergies but also tradeoffs between these objectives, and policy makers should be aware of them.

4.1. Carbon sequestration in forests

Forests have significant potential as carbon sinks, and generally store carbon more permanently than, for instance, croplands; they store carbon in tree biomass as well as in the soil's organic matter. In contrast, deforestation (especially where slash-and-burn techniques are employed, for instance to clear land for agriculture and ranching) releases significant quantities of CO_2. The conversion of forests to croplands generally causes significant losses of soil organic carbon (SOC) as well as losses in carbon biomass above ground. Conversion to grasslands, on the other hand, does not necessarily result in SOC losses but its net impact on carbon sequestration is still negative due to the loss of carbon in tree biomass.

Curbing deforestation is considered one of the most cost-effective ways of reducing GHG emissions: avoiding deforestation could achieve significant emission reductions in the short term, without requiring new technology, and at a low cost in comparison with other mitigation options – even if compensation is offered to cover the opportunity costs of not exploiting forests. The latter point is likely to be critical for the success of REDD (reducing emissions from deforestation and forest degradation)-based approaches, which at the time of writing this paper were subject to intensive negotiations in preparation for the December 2009 UNFCCC Conferences of the Parties in Copenhagen.

Other possible options include reforestation (i.e. replanting forests in areas that have been deforested) and afforestation (i.e. planting forests on previously non-forested areas). Conversion from croplands to forests increases carbon sequestration, both in soils and in above-ground biomass (even though a net carbon loss may occur during a brief period following afforestation). Conversion from grasslands to forests also has a long-term positive effect on carbon stocks, primarily via the sequestration of carbon in above-ground biomass.[24] Reforestation and afforestation may play a role in mitigation strategies but since native, natural forests are expected to be more resilient to climate change than plantation forests, the protection and restoration of existing forests is a more sustainable and, from the point of view of long-term mitigation potential, a more effective option. Furthermore, the afforestation of non-forested ecosystems may result in some adverse environmental impacts, such as the destruction of valuable non-forest habitats or the lowering of the local water table.

The carbon sequestration potential of forests varies over time and is sensitive to a wide

[24] The duration of carbon sequestration in above-ground biomass is highly variable, depending the vegetation's natural lifecycle (i.e. years before it starts decaying) and on how frequently it is harvested. Trees have the capacity to store carbon for long periods. When they are cut, they release carbon to the atmosphere if they are burnt or left to decay; they can keep storing carbon for long periods if they are used for timber.

range of factors, including their species composition, their age and how they are managed. Generally speaking, unmanaged, unexploited forests store larger amounts of carbon (and support more biodiversity) than managed ones. However, economic imperatives are likely to make the option of non-exploitation unrealistic; while it is desirable to protect part of the world's remaining forests from any form of exploitation[25], sustainable exploitation of the rest is the best alternative. Possible measures to contribute to climate change mitigation in relation to forestry are described in the script dedicated to Agriculture & Rural Development.

Finally, note that although forests are carbon sinks, part of the benefits they provide in terms of global warming mitigation may be offset by the fact that they have lower albedo (i.e. sunlight reflection potential) than other types of land cover – and thus contribute to increased temperatures at the surface of the earth. The decrease in snow- and ice-covered surfaces at high latitudes, and the corresponding increase in darker, much less reflective forested areas, is actually one of the feedback mechanisms that contribute to the acceleration of global warming.

4.2. Carbon sequestration in peatlands

Peatlands are the largest and most efficient terrestrial store of biomass carbon; they can store up to 10 times more carbon per hectare than other terrestrial ecosystems (in humid tropical areas), and can sequester atmospheric carbon for thousands of years. They form as vegetation residues largely remain intact under conditions of permanent water saturation: waterlogging suppresses aerobic decomposition processes, so that much more carbon remains stored than would otherwise be the case. Because some decay processes occur in anaerobic (i.e. oxygen-deprived) conditions, peatlands emit some methane (CH_4), a more powerful GHG than carbon dioxide; however, in natural peatland ecosystems, much of the carbon remains trapped in soils and "the long-term negative effect of methane emissions is smaller than the positive effect of CO_2 sequestration" (UNEP-GEF-GEC-WI 2007:10).[26]

Peatlands cover over 4 million km² (approx. 3% of the world's land surface) and account for between one third and half of the world's wetland ecosystems. They are found in at least 180 countries, across all continents and over a wide range of latitudes and altitudes. The largest peatland areas are located in the cold tundra regions of Northern Russia and Canada, and in south-eastern Asia (which accounts for 60% of all tropical peatland resources and over 85% of tropical peatland carbon storage, as the thickness of the peatland layer in this region may reach up to 25 metres). Smaller tracts of tropical peatlands are located in Africa, Latin America and the Caribbean, and high mountain peatlands are found in the Andes and the Himalayas. In addition to their significant carbon sequestration potential, peatlands are also key ecosystems for biodiversity support and conservation, and they provide essential services in terms of freshwater storage and hydrological flow regulation.

The conservation and restoration of peatlands, in particular in tropical regions, is deemed to be an extremely cost-effective carbon sequestration technique. On the other hand, when they are cleared and drained to be converted to agricultural or managed forestry uses (or for peat extraction as a fuel and soil amendment), peatlands release large amounts of CO_2 as aerobic decomposition processes resume and the incidence of peat fires increases.[27] After fertilisation, drained peatlands may also become a significant source of N_2O, another GHG. Possible measures to contribute to climate change mitigation by fixing carbon in peatlands include:

- protecting still intact peatlands: this may involve maintaining high water table levels (which involves managing water in a sustainable manner, to avoid the depletion of aquifers), adopting effective fire prevention and fighting methods, and preventing peat extraction and peatland conversion to agriculture or managed forestry;
- reducing the loss of carbon from cultivated and grazed peat soils by

[25] Other than small-scale, low-impact collection of forest products by native communities.

[26] It is estimated that "peatlands are currently contributing to only 3-5% of the total global methane emissions" (UNEP-GEF-GEC-WI 2007:11). Emissions may increase, however, as a result of the thawing of the permafrost in tundra regions: in the Northern hemisphere in particular, huge tracts of peatlands that used to be permanently frozen restart emitting methane as they revert to wetlands conditions.

[27] Outside tundra regions affected by the thawing of the permafrost, the drainage of peatlands is deemed to reduce their methane emissions, but the gains may be at least partly offset by increased methane emissions from the drainage ditches.

avoiding some types of crops, avoiding deep tillage, implementing fire control measures and maintaining sufficiently high water table levels; this blocks or slows down peat oxidation processes and their gradual conversion to mineral soils and reduces the risk of peat fires; new production techniques such as “wet agriculture” should also be promoted to allow some exploitation of peatlands without excessive reduction in their carbon storage capacity;

- restoring degraded peatlands by returning them to their original wet conditions (which involves blocking drainage channels and re-establishing a high water table), adopting fire management measures and possibly replanting some native vegetation; in this case, an assessment should be made of the likely net balance between reduced CO_2 emissions and potentially increased CH_4 emissions, based on local conditions (this balance may be negative in the short term but is generally expected to be positive in the longer term); in addition to benefits in the form of GHG mitigation, peatland restoration supports biodiversity conservation, water storage and flood control.

Note that while the reforestation of logged peatlands with native species may be a good measure, the afforestation of previously non-forested peatlands is generally not an effective means of storing carbon: indeed, carbon storage in above-ground biomass is offset by soil emissions of GHGs as disturbance increases peat decomposition rates. Other types of conventional mitigation measures may also be inappropriate on peatlands, for instance:

- the cultivation of biofuel crops (e.g. palm oil plantations in south-eastern Asia): this practice releases more carbon dioxide than is saved through the substitution off fossil fuels with a renewable agrofuel, and also leads to increased N_2O emissions (as a result of nitrogen fertilisation);
- the flooding of peatlands for creating water reservoirs for hydropower projects, or the setting up of wind farms on drained peatlands: this is likely to result in higher methane emissions (in the first case) and significant releases of CO_2 from soils (in the second case), which are likely to significantly reduce the climate benefits in principle associated with renewable sources of energy.

4.3. Carbon sequestration in grasslands

Grasslands are also net carbon sinks, at least as long as they are not degraded or subject to intensive production practices involving excessive nitrogen fertiliser applications (which lead to emissions of nitrous oxide). Grassland conversion to cropland tends to result in the loss of soil organic matter, and conversely. Forest conversion to grassland does not necessarily lead to a loss of carbon in soils – but of course the amount of carbon stored in above-ground biomass is more important in forests.

Where grasslands are used as grazing lands, management practices can significantly influence the capacity of these lands to store carbon. Limiting grazing pressure is key for maintaining carbon storage capacity. The timing of grazing and even the livestock species can influence carbon storage and dissipation, as well as the composition of the flora, in complex ways that are best assessed on a case-by-case basis. Practices such as the cultivation of legumes in grazing lands (in integrated crop-livestock systems) can promote carbon storage through the enhanced productivity resulting from nitrogen fixation in the root systems of legumes. Fire management measures aimed at reducing the frequency or intensity of wildfires generally increase carbon sequestration in grasslands. On the other hand, nitrogen fertilisation (which increases biomass growth in nitrogen-limited grasslands but also results in higher N_2O emissions) and the introduction of non-native, more productive grass species are not recommended since they have negative impacts on biodiversity. For further information on mitigation measures related to grazing (and generally livestock breeding) practices, please refer to the script on Agriculture & Rural Development.

4.4. Carbon sequestration in cultivated systems

Cultivated systems are both a sink and a source of GHGs. Agricultural lands have the potential to store large amounts of carbon dioxide (CO_2), depending on how soils are managed. Plants absorb CO_2 through photosynthesis and use the carbon to build their stems, leaves and roots which subsequently contribute to soil organic matter. The richer the soil is in organic matter, the more carbon it stores. In addition, higher organic matter levels in soils have considerable benefits in term of productivity and resilience to degradation. As already discussed, natural decomposition processes lead to the release of some CO_2. Agriculture is a source of two other powerful GHGs: nitrous oxide (N_2O) and methane (CH_4), as a result of the microbial transformation of nitrogen fertilisers in soils, the digestion processes of cattle and other ruminant animals (production of fermentation gases), and the storage and spreading of manure. Still, agricultural lands have the potential to store large amounts of carbon, depending on how soils are managed. Minimum tillage and "conservation tillage" systems have the largest potential to increase carbon sequestration in soils; improved manure management and more efficient use of fertilisers are examples of measures that could significantly reduce N_2O emissions.

Given the growing demand for food linked to demographic growth and rising living standards, the conversion of existing croplands to grasslands and forests (in principle better carbon sinks) is unlikely to be a widely applicable way of reducing GHG emissions. Improving the productivity of existing croplands in order to reduce pressures to convert forests and grasslands to croplands, in a way that minimises agriculture-related emissions, is a more realistic option in many parts of the world. Currently, the agricultural sector is deemed to contribute to approx. 13.5% of global annual GHG emissions. In a recent UNEP report, experts consider that making agriculture carbon-neutral by 2030 is a "challenging but achievable goal" (Trumper et al. 2009:6). Possible measures to contribute to climate change mitigation in cultivated systems are described in the script dedicated to Agriculture & Rural Development.

4.5. Biodiversity effects on climate regulation

Biodiversity influences the carbon storage potential of terrestrial ecosystems and their contribution to climate regulation at the local, regional and global levels. The biological composition of vegetation influences its carbon sequestration potential through its effects on biomass growth and turnover rates, on the proportion of biomass made up of wood rather than herbaceous plants, and on the retention of carbon in soils (which depends on leaf litter quality, the structure of root systems, soil temperature and moisture, etc.). There is often a (biodiversity-mediated) tradeoff between short-term carbon accumulation and long-term carbon storage: plant species that grow quickly and have high productivity also tend to decompose at a faster rate, thus releasing carbon more rapidly than others.

As far as climate regulation is concerned, more biologically diverse forests have lower albedo, i.e. tend to retain more solar radiation, than structurally simpler ones; deciduous trees reflect more light back to space than darker conifers do. Forests also produce more evapotranspiration than grasslands and croplands (at least non-irrigated ones), and thus contribute to local climate cooling – their potential for evapotranspiration depending on their structure and biological composition.

y ILLUSTRATIVE EXAMPLES

Illustrative example 1: Tanzania's Great Ruaha River

Background

The catchment of the Great Ruaha River, in Tanzania, is occupied by 6 million people who cultivate a variety of crops, dominated by irrigated rice in the semi-arid and sub-humid parts of the catchment. A significant part of the country's electricity supply is provided by the Mtera and Kidatu hydropower schemes on the river.

The Great Ruaha was once considered a perennial river, however reduced rainfall particularly in the lower parts of the catchment has reduced flow. There are concerns that climate change may aggravate this trend. From 1993, dry-season flows ceased over significant stretches downstream from the Ihefu wetland, with consequences for rural livelihoods, electricity supply, tourism as well as the environment. Concern was such that in 2001 the Prime Minister announced government support for a programme aimed at re-establishing a year-round flow by 2010.

Responses

In 2003 a programme aimed at re-establishing continuous flow commenced. WWF worked with communities in eight districts in the catchment to both develop better catchment management and contribute to poverty reduction. Local Water Users' Associations (WUAs) were created to restore catchments and improve water management by physically rehabilitating the source catchments; negotiating agreements with major users (mainly agricultural) to improve water diversion schedules; and better enforcing existing water laws so as to stop illegal diversions.

The restoration of headwaters and riparian zones involved a number of measures including: controlling the practice of valley-bottom area cultivation; selectively removing alien species known to have a high demand for water, while restoring indigenous vegetation and reducing charcoal production; excluding cattle from sensitive areas; and re-locating some settlements away from river banks. Simultaneously, agreements were made with irrigators to improve water use efficiency via better coordination of water deliveries and reduced water abstraction during the dry season. A dam was constructed to provide water for livestock in a less sensitive area of the catchment, thus supporting breeding activities. Livelihood strategies were also diversified into new, less water-intensive activities such as retailing and beekeeping, and training allowed rice farmers to improve yields through the adoption of better practices.

Outcomes

Since 2004 sustained flows into the Ihefu wetlands have been restored, and the zero-flow periods downstream of these wetlands have been significantly reduced. Importantly, local institutions have been strengthened that will render communities less vulnerable to future conditions of water scarcity. The Water Users' Associations have a voice in larger catchment decision processes which ultimately contribute to the development and implementation of national water policies.

Lessons from the Great Ruaha project show how a range of simple community-based measures, both physical and institutional, can restore essential ecosystem services and increase resilience to water scarcity in the face of the challenges posed by climate change. In particular, the benefits of strengthening the capacities of communities and organisations to improve governance, diversify livelihoods and promote adaptive management practices have been demonstrated. This approach has significant potential for scaling up, especially as it rests on relatively inexpensive measures.

Illustrative example 2: Moldova – Soil conservation projects

Moldova is an agrarian country with sizeable areas of degraded and eroded agricultural lands. This results in low agricultural yields as well as frequent landslides. Afforestation and reforestation are two effective ways of addressing this problem, since they allow a stabilisation of landslides while promoting land regeneration.

With the help of the Prototype Carbon Fund[28], a soil conservation project was designed to re-plant degraded pasturelands with shrubs and tree species adapted to poor soil conditions. The project's primary objective is to conserve and restore the soils on thousands of hectares of degraded, severely eroded and unproductive lands. In so doing, the project generates many benefits for the local population, such as increased availability of fuelwood, timber and non-timber forest products, reduced damage from landslides, improved productivity of neighbouring fields (thanks to reduced wind erosion and improved hydrological balance), the development of community-based participatory forest management practices, and positive biodiversity effects (through the reintroduction of native species and semi-naturalised species).

By promoting the development of tree vegetation, the project also sequesters considerable amounts of carbon, making it eligible to receive revenue from the sale of carbon credits to the Prototype Carbon Fund. Carbon financing is a key element for the financial sustainability of the project.

Further to the introduction of this "prototype" project, Moldsilva (the State Forestry Agency) has developed other soil conservation projects based on afforestation and reforestation, which also generate significant benefits for local communities while contributing to carbon sequestration and thus to the overall objective of reduction in greenhouse gas emissions. These projects are supported by the BioCarbon Fund.[29]

Illustrative example 3: Peatswamp forest restoration in Indonesia

The logging and drainage of peatlands is estimated to contribute to annual global GHG emissions equivalent to more than 10% of those generated by fossil fuel burning. The problem is particularly acute in Indonesia, in which vast tracts of peatswamp forests have been lost in the past few decades due to illegal logging, the need to accommodate agricultural projects (e.g. rice production, oil palm plantations for biofuel production), and the high incidence of poverty which promotes the use of unsustainable land management practices. Peatland drainage and logging have caused significant GHG emissions as well as severe health problems at the local and regional scales (due to the frequent occurrence of forest fires), the loss of livelihoods for local communities and biodiversity losses.

Wetlands International (WI), in partnership with other NGOs, Indonesian research institutions, local government and some donors, has implemented a number of pilot projects aimed at testing methods and approaches to restore degraded peatlands and prevent further degradation of still relatively intact peatswamp forests.

The Central Kalimantan Peatland Project (CKPP), which took place between December 2005 and November 2008, aimed to restore 60,000 hectares of peatswamp forests in the area of the failed Mega Rice project – a poorly planned agricultural project that aimed to convert 1 million hectares of peatland forest to rice cultivation but had disastrous environmental and social consequences

28 The Prototype Carbon Fund (PCF) supports pilot projects aimed at reducing GHG emissions while promoting sustainable development. It notably supports the development of methodologies for accounting for and monitoring emission reductions, in order to facilitate the sale of certified emission reductions under the Clean Development Mechanism of the Kyoto Protocol or other similar schemes. The PCF is a partnership between 17 companies and 6 governments, and is managed by the World Bank.

29 The BioCarbon Fund was set up by the World Bank to support projects that sequester or conserve carbon in forests and agro-ecosystems while promoting other sustainable development goals, notably biodiversity conservation and poverty reduction.

and had to be abandoned. CKPP activities included:

- hydrological restoration works involving the closing of drainage canals by means of dams;
- the setting up of fire prevention and control measures (e.g. setting up of community-based fire brigades and a fire early warning system, digging of wells for fire-fighting purposes, changes in land clearance practices);
- the replanting of vegetation (and subsequent maintenance and monitoring), including the planting of indigenous species with a commercial value, to provide local communities an incentive to prevent and control fires;
- the conservation of remaining intact or quasi-intact peatswamp forest areas, which are notably host to dwindling populations of orang-utan;
- a livelihood development programme based on sustainable agro-forestry practices and improved access to markets.

Community involvement, including (in the initial phase) the conduct of participatory rural appraisals, was an essential feature of the project. Villages in the project areas were supported to prepare and implement locally-owned development plans, and to set up community groups for management and monitoring. Collaboration with local authorities was also emphasized. Early successes were registered and some useful lessons were learned.

In Sumatra, demonstration projects are also being implemented in the area of the Greater Berbak and Sembilang national parks to try and find a sustainable balance between peatland ecosystem conservation and the livelihoods of local communities. Local people receive loans to stop logging, protect remaining intact forest tracts from illegal logging and fires, reverse the drainage of peatswamps, reforest degraded areas and set up sustainable small businesses such as chicken farming. If they are successful, their loans are converted into grants.

In 2008, WI set up a Global Peatland Fund that will invest in more such projects. The projects will produce independently verified Voluntary Emission Reductions and Emission Removals (VERs) which the Fund will buy and resell on the international carbon markets, thus generating a return for the Fund's equity holders as well as some money to be invested in community development projects. Project promoters will receive advance payments (enabling them to undertake initial investments) as well some technical support. As in the case of the pilot projects described above, supported projects will simultaneously pursue objectives in terms of climate change mitigation, poverty reduction and biodiversity conservation.

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Illustrative example 1

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Illustrative example 2

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(18) Other projects supported by the World Bank's BioCarbon Fund:
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Illustrative example 3

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http://www.wetlands.org/Whatwedo/Wetlandsandclimatechange/Peatlandsandclimatechangemitigation/tabid/837/Default.aspx

The provisional report on the Central Kalimantan Peatland Project (CKPP) is available on:
http://www.ckpp.org/Portals/16/CKPP%20products/CKPP%20Provisional%20Report%20ENG%20final.pdf

{ FURTHER INFORMATION AND SUPPORT

For further support in relation to the use of sector scripts, including the identification of sources of information on climate change projections in specific regions, you may contact the team in charge of providing advisory services for environmental integration in EC development/external co-operation:

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