

EC Cooperation: Responding to climate change

Sector Script for Agriculture & Rural Development

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(not to be disseminated or published)

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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 covers a wide range of topics, including agriculture, forestry, fisheries and food security – but it does not cover all those possibly relevant to agriculture & rural development. 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.

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RESPONDING TO CLIMATE CHANGE: SECTOR SCRIPT
SECTOR: AGRICULTURE & RURAL DEVELOPMENT

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EXECUTIVE SUMMARY



Climate change impacts on agriculture and rural development

Agriculture is generally considered one of the most vulnerable sectors with regard to the effects of climate change, due to its sensitivity to climatic factors and dependence on natural resources such as soils and water. Other sectors that depend on primary production and are directly relevant to rural livelihoods, such as forestry, fisheries and aquaculture, are also likely to be seriously impacted. Rural development is not only about primary sector activities, but it is obviously highly dependent on them. Processing industries, another key element of rural development, depend on climate-sensitive primary resources as well as the availability of infrastructure services. Tertiary sector activities, in turn, depend on the strength of the primary and secondary sectors, as well as the capacity of societies to sustain the functioning of essential infrastructure.

All these sectors related to rural development are exposed, sometimes significantly, to the impacts of climate change. Crop production, livestock breeding, forestry, fisheries and aquaculture are directly exposed to the biophysical effects of climate change: changes in rainfall and temperature patterns, shifts in seasons, increased frequency and severity of extreme weather events, changes in water availability and quality, changes in ecosystems and the services they provide, etc. are likely to have adverse impacts on productivity. These sectors may also suffer if essential infrastructure on which they depend, such as roads, harbours and food storage facilities, is damaged or impaired by

extreme weather events, increased climate variability or permanent changes in climatic conditions. Secondary and tertiary sector activities are also at risk of damage to essential infrastructure and the disruption of services such as transport, energy supply, water supply and telecommunications. All sectors and activities may be adversely impacted by the increased prevalence of malnutrition, the rise in conflict situations (notably over access to increasingly scarce natural resources) and migrations away from rural areas.

As a result, food security is likely to be adversely impacted, through impacts on all the four pillars on which it depends: food availability, food accessibility and affordability, food safety and the quality of nutrition, and the stability of food supply systems.

Adapting to climate change

To reduce vulnerability to these potential impacts, a wide range of possible adaptation measures are available. Some of them, such as modifications in the range of crops to match changes in agro-climatic zones or the adoption of new crops and/or varieties deemed better adapted to the new climatic and ecological conditions, specifically address the effects of climate change. Many potential adaptation measures, however, are not climate-specific but constitute good practices that contribute to wider developmental and sustainability objectives. Promoting water efficiency and Integrated Water Resources Management, adopting cultivation techniques that reduce soil erosion, strengthening land planning and management institutions, maintaining a critical mass of diversified, natural ecosystems, adapting storage and distribution systems to reduce vulnerability to extreme weather events, diversifying sources of rural income, or promoting access to insurance are examples of such good practices that lead to greater overall resilience and sustainability.

With regard to food security, few adaptation measures aimed at addressing impacts on food availability are really specific to climate change. Generally speaking, all measures that effectively contribute to the increased climate resilience of food production, storage

and distribution systems also contribute to enhancing food security. National and international efforts to support the conservation of biodiversity in food plant species are also necessary and likely to be useful – as are efforts to conserve biodiversity-rich, well-functioning ecosystems. As far as food prices are concerned, it may not always be possible or desirable to directly control food prices, but some measures can be adopted to reduce price volatility or the incidence of artificial food shortages. On the demand side, access to food by poor households may be supported by means of insurance mechanisms and social protection programmes. Measures aimed at improving capacities to monitor and predict outbreaks of foodborne diseases, and to detect, prevent and respond to cases of food contamination, can address concerns about food safety.

Contributing to climate change mitigation

The way in which some key rural development activities are managed can have a significant impact on greenhouse gas (GHG) emissions. Agriculture is an important source of two powerful GHGs: nitrous oxide (N₂O) and methane (CH₄). On the other hand, agricultural lands have the potential to store large amounts of carbon, depending on how soils are managed. Forests have even greater potential as “carbon sinks”, and generally store carbon more permanently than croplands. On the other hand, deforestation releases significant quantities of CO₂. Peatlands are the largest terrestrial store of biomass carbon: they store on average 10 times more carbon per hectare than other terrestrial ecosystems. When they are cleared, drained or burnt to be converted to agricultural or managed forestry uses, they release large amounts of CO₂ into the atmosphere.

According to the 2007 IPCC report, agriculture and forestry/deforestation account for, respectively, approx. 13.5% and 17.4% of global anthropogenic emissions. Changes in these two sectors in particular thus have considerable potential to contribute to the global climate change mitigation effort:

- Curbing deforestation is generally 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. In the short term, reducing the rate of deforestation produces more benefits than afforestation – however, even taking into account that the

carbon mitigation potential of forests differs significantly across regions, afforestation is a good option in most places if one takes a longer-term perspective. Sustainable forest management practices that maintain or increase forest carbon stocks while delivering a sustained flow of other benefits (e.g. timber, fuelwood, fibre, other non-timber forest products, biodiversity conservation, water filtering, protection against erosion, balancing of hydrological flows) generally produce the most benefits from a social point of view.

- The conservation and restoration of peatlands is another extremely cost-effective carbon sequestration technique.
- Some agricultural practices (such as reduced tillage, the more efficient use of fertilisers or improved manure management practices) can contribute to mitigation either by increasing the amount of carbon stored in soils or by reducing GHG emissions from soils. Generally speaking however, mitigation measures in relation to agricultural practices are still characterised by many uncertainties (e.g. about the carbon sequestration potential in different conditions, and about the stability and permanence of carbon retention) – and there is no universally applicable list of good practices. Some measures may have a positive net impact on GHG emissions in some locations and agricultural systems but not in others. Some measures involve a trade-off (e.g. reduction in emissions of one greenhouse gas but increase in emissions of another one). It is therefore recommended to seek technical or scientific advice before opting for a given mitigation option.

Some mitigation options are congruent with adaptation options (especially in agriculture and forestry), and thus produce a double stream of benefits. Other mitigation options, however, may inadvertently result in increased vulnerability and threaten or cancel out adaptation efforts (e.g. biofuels may have adverse impacts on food security, food prices, water availability and ecosystems) – or even have a negative net impact in terms of mitigation (e.g. increased deforestation to accommodate cropland extension for biofuels). It is thus important to carefully consider the pros and cons and possible unintended effects of any envisaged mitigation measures.

U HOW CLIMATE CHANGE MIGHT AFFECT AGRICULTURE AND RURAL DEVELOPMENT



Climate change may affect agriculture, rural development and related sectors (e.g. forestry, fisheries) and topics (e.g. food security) through a range of biophysical and socio-economic impacts. The table below shows the main links between such impacts and the sectors considered in this script.

| | Agr | Fish | FS | For | Rur |
|--|-----|------|----|-----|-----|
| 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 | • | • | • | • | • |
| Loss of habitats, changes in ecosystems and related services | • | • | • | • | • |
| Increase in disease and pest outbreaks | • | • | • | • | • |
| Socio-economic impacts | | | | | |
| Damage to infrastructure | • | • | • | • | • |
| Reduced availability of energy (hydropower) | • | | • | • | • |
| Economic and social disruption, loss of livelihoods | • | | • | | • |
| Increased malnutrition | | | • | | • |
| Increased mortality and morbidity | | | | | • |
| Increased probability and intensity of conflicts | • | • | • | • | • |
| Population displacement and human migrations | • | • | • | • | • |

Legend:

Agr = agriculture

Fish = fisheries (marine and freshwater fisheries)

FS = food security

For = forestry

Rur = rural development (in general)

Agriculture is generally considered one of the most vulnerable sectors with regard to the effects of climate change. Other sectors that depend on primary production and are directly relevant to rural livelihoods, such as

forestry and fisheries, are also likely to be seriously impacted. Rural development is not only about primary sector activities, but it is obviously highly dependent on them. Processing industries which are an element of

rural development depend on climate-sensitive primary resources, as well as the availability of infrastructure services. Tertiary sector activities, in turn, depend on the strength of the primary and secondary sectors, as well as the capacity of societies to sustain the functioning of essential infrastructure. All sectors depend on capacity to maintain a degree of social harmony. In the sections below, we review a series of sectors that are relevant to rural development, and also address food security. Note that ecosystems and biodiversity are addressed in the script on [Ecosystems & Biodiversity Management](#), and issues relating to indigenous people in the script on [Governance](#).

1.1. AGRICULTURE: CROPS

Agriculture is widely recognised as the sector most directly and significantly affected by climate change, due to its sensitivity to climatic factors and dependence on natural resources such as soils and water. Crops are directly affected by temperature and rainfall patterns, droughts, floods, storms, pest outbreaks, changes in the spatial distribution of pests and diseases, freshwater availability, soil erosion, shifts in seasons, shifts in agro-climatic zones, etc. They are also likely to be indirectly affected by the loss of habitats and changes in ecosystems, notably where these changes involve the local extinction of species (some of which may be useful to agriculture), shifts in the range of animal and wild plant species, more favourable conditions for the development and spreading of invasive species, and/or changes in the balance/dominance patterns of species. Soil erosion (which can be aggravated by drought episodes as well as heavy rainfall), land degradation, coastal erosion, coastal land salinization and desertification may lead to the loss of arable land.

The main threats associated with these potential effects of climate change are higher yield variability (associated with increased climate variability), reduced crop yields, crop failures, crop destruction by extreme weather events and the loss of arable land – with obvious negative consequences for food security and for the stability of food prices (see further). Smallholders and subsistence farmers are expected to be the most affected, having less capacity and fewer means to adapt. In mid- to high-latitude regions however, warming (as long as it remains reasonably mild) is likely to have beneficial effects on crop yields, and to lengthen the growing season. It is also recognised that under unstressed conditions,

the growth of some plants increases with higher atmospheric concentrations of CO₂.¹

In addition, agriculture may be indirectly impacted by other consequences of climate change. Damage to transport and storage infrastructure may hinder production (e.g. if essential inputs cannot be delivered in time), prevent the timely transportation of agricultural produce to markets, or prevent adequate conservation of food stocks. Irrigated agriculture, on top of being sensitive to water availability problems (see script on [Water Supply and Sanitation](#)), may be affected by damage to rural electricity infrastructure. Conflicts related to access to natural resources or triggered by human migrations may temporarily or more permanently disrupt the sector by preventing the timely seeding/planting of crops and displacing farmers. Increased morbidity and mortality, the increased prevalence of malnutrition, and migrations away from rural areas may negatively impact on agricultural production by reducing the availability and productivity of labour. In the vicinity of cities, migrations encouraged by climate change may lead to urban sprawl and thus the loss of agricultural land.

1.2. AGRICULTURE: LIVESTOCK²

The same factors that affect crop yields also affect the productivity of grazing lands (and thus their carrying capacity) and forage crops. Pasturelands may be lost to erosion and desertification. Increased water stress in many regions is likely to have a negative impact on livestock productivity. Changes in habitats and ecosystems, and in the range, prevalence and transmission cycles of disease vectors (notably waterborne ones), may lead to changes in the prevalence of parasitic and other infectious diseases. The transmission of pathogens between animals may also increase as a result of climate-induced changes in husbandry practices, such as the crowding and intermingling of animals over smaller areas. Animals may suffer from heat stress, with adverse effects on health, growth and reproduction. Conflicts between herders (especially nomadic ones), ranchers, farmers and other land users may intensify as a result of the increasing scarcity of “usable” land.

¹ This phenomenon is sometimes referred to as “carbon fertilisation”.

² Livestock is important since for many subsistence farmers, it is the only “bank” in which their savings can be invested.

1.3. FORESTRY

The productivity of forests is influenced by climatic factors, in particular temperature and rainfall patterns. Prolonged and recurrent droughts increase the risk of destruction by wildfires. Forests may be damaged by storms. Changes in habitats and ecosystems may result in the emergence of new pests, increased vulnerability to existing pests, as well as shifts in the range of specific tree, plant and animal species. Transport infrastructure needed to take timber and other forest products to markets may be damaged or destroyed by extreme weather events (or by a reduction in river flows, where timber floating is used as a means of transportation). As a result of climate change, farmers in search of new land to cultivate, ranchers/herders in search of new grazing lands, and migrants in search of new livelihoods may all exercise deforestation pressures. On the positive side, forestry productivity is expected to increase in some regions (in low latitudes in the short term, in higher-latitude regions in the longer term).

1.4. FISHERIES AND AQUACULTURE

Changes in sea surface temperature, in salinity and oxygen levels, in oceanic circulation patterns, in the acidity of oceans may all affect the productivity of marine fisheries. The ranges of many fish species have already changed and may change further, as planktonic growth is affected by changing conditions. The genetic composition and phenology (i.e. life cycle events) of fish stocks is also affected, and in some areas the development of invasive new species is facilitated by new conditions. The breeding sites of some valued species are threatened by damage to mangrove and coral reefs. In coastal fisheries, harmful algal blooms (which occur in conditions of eutrophication³ and may become more frequent as a result of increased precipitation and flash floods) may regularly decimate local fish stocks. Changes in marine ecosystems, combined with unsustainable fishing practices, are likely to result in the accelerated extinction of some species and changes in the balance/dominance patterns of the surviving

³ **Eutrophication** is the sudden proliferation and then decay of aquatic plants or phytoplankton, leading to a significant reduction in dissolved oxygen in water and the destruction or impairment of local fauna and flora. This phenomenon is observed both in freshwater and in marine ecosystems (where it causes algal blooms). Excessive nutrient loads are the primary cause of eutrophication; more frequent heavy rainfall and flash floods increase the risk of eutrophication episodes as surface runoff washes out nutrients from soils and transports them to rivers and then to coastal and marine waters.

ones.

The productivity of coastal aquaculture operations is likely to be affected by changes in water temperature, acidity and turbidity, the increased incidence of algal blooms, as well as changes in the prevalence of pests and diseases. Freshwater aquaculture may suffer from reduced water flows, changes in water temperature, turbidity and biochemical quality, increased risks of eutrophication, and changes in pest and disease patterns caused by wider ecosystem changes.

More violent and frequent storms may damage or destroy fishing fleets as well as harbour, coastal and aquaculture infrastructure – which is also at risk from rising sea levels. The general pressure on food resources (both marine and land-based ones) may be a source of conflicts, e.g. between local fishermen and external ones, or between established fishermen and new entrants.

1.5. PROCESSING INDUSTRIES

All the processing industries built around primary production and extractive activities will suffer if the upstream activities on which they depend are negatively impacted by climate change. Damage to industrial and commercial infrastructure, as well as to public infrastructure (transport, energy, telecoms), may disrupt their operations. Increased morbidity and mortality, the increased prevalence of malnutrition, and migrations away from rural areas may reduce the availability and productivity of labour. And of course, conflicts of all kinds may be a threat to both infrastructure and operations.

1.6. TERTIARY SECTOR ACTIVITIES, GOVERNANCE AND INSTITUTIONAL DEVELOPMENT

Rural development is also concerned with the development of tertiary sector (service) activities, including (eco)tourism, and institutions at all levels. In this area, climate change-related risks are mostly indirect. Public and private sector operations may be disrupted by damage to infrastructure and conflicts. Increased morbidity and mortality, the increased prevalence of malnutrition, and migrations away from rural areas may reduce the availability and productivity of labour. The long-term development of sectoral institutions may be neglected if more frequent and severe climate-related emergencies result in the slashing of resources available for institutional strengthening, in favour of more immediate but less “structuring” objectives. Conversely,

the emergence of new climate-related challenges may provide the impetus needed to tackle difficult sector organisation issues and strengthen key institutions, such as those in charge of land planning and management and environmental/natural resource management.

1.7. SPECIAL FOCUS: FOOD SECURITY

Food security could be impacted by climate change in various ways:

- impacts on food availability: lower productivity in cropping systems, livestock breeding, fisheries and aquaculture is likely to have negative impacts on the availability of food in many regions, especially where several “shocks” on food production systems combine their effects⁴; in some regions, the proportion of arid lands unsuitable for agriculture is expected to increase; in most parts of the world, increased water stress is likely to impose severe constraints on food production systems; access to land for food production may also become increasingly problematic in some areas, notably as a result of competition between food and fuel crop production systems; damage to essential food storage and transformation infrastructure could similarly reduce food availability; the loss of biodiversity is also a threat to food security since it reduces possibilities to diversify food production and switch to species that may be better adapted to the new conditions or more resistant to pests (see script on [Ecosystems & Biodiversity Management](#));
- impacts on food accessibility and affordability: damage to transport infrastructure could reduce the physical accessibility of food, even in regions where overall availability is in principle sufficient; even more significantly, increases in food prices resulting from the growing relative scarcity (at the regional or global level) of some agricultural commodities could reduce access to food, especially for the poorest and for those who see their livelihoods adversely affected by the effects of climate change, including small farmers; damage to crops, lower productivity of croplands

and pasturelands, water scarcity and competition with biofuel crops are all factors that are likely to lead to higher food prices but not higher income for small farmers;

- impacts on food safety and the quality of nutrition: climate change could impact on the safety of food in various ways, including: increased transmission and changes in the range of foodborne and waterborne disease agents; increased risks of contamination of the food chain by diseases of animal origin, by fungi and mycotoxins, by environmental contaminants and chemical residues (e.g. as a result of extreme weather events, increased methylation and subsequent uptake of mercury by fish, increased use of phytosanitary products); increased incidence of harmful algal blooms (which may lead to the contamination of seafood by dangerous toxins); and increased risks of food contamination associated with emergency situations; in addition, some of the biophysical, health-related and socio-economic impacts of climate change may affect food consumption patterns and therefore the quality of nutrition; for instance, once-abundant sources of protein such as fish or game may become scarcer and be replaced with less nutritious foods; climate-induced public health deterioration may reduce the ability of some individuals or communities to produce or collect nutritious foods; the increased incidence of diarrhoeal disease may reduce the absorption of nutrients; people displaced by conflicts and natural disasters may suffer from reduced nutrient intake as a result of reduced food diversity and the impossibility of cooking in their temporary settlements;
- impacts on the stability of food supply systems: increasing climate variability is one of the features (and early manifestations) of climate change; this increasing variability will affect the stability of food supply systems, notably by making yields and quantities produced in any given growing season even more unpredictable than in the past; the increased frequency and severity of extreme weather events is also likely to negatively impact on the reliability of the infrastructure on which food storage and transport depend.

⁴ Food shortages in one region can in principle be compensated by imports and food aid from other regions, but this assumes that: (i) other regions are willing to export food – which they may be reluctant to do if they fear shortages themselves; (ii) the food storage and transport infrastructure, in particular in the importing region, is adequate and operational. Reciprocally, in view of the growing phenomenon of “land grab” by foreign governments or multinational agribusiness companies, some of the food produced in a given country or region may in fact not be available for local consumption because it is earmarked for export.

Some of these impacts may lead to occasional, short-term threats to food security but many are also likely to result in a structural deterioration of food security conditions, unless adequate measures are taken to increase resilience.

✓ ADAPTING TO CLIMATE CHANGE IN AGRICULTURE AND RURAL DEVELOPMENT



Adaptation measures may have a better chance of success if combined measures are adopted, to take advantage of possible synergies. Given the size and complexity of the challenge, strong rural development institutions, at supra-national, national, regional and local level, will be needed to help rural societies “weather the storm” and adapt to the expected effects of climate change. Collaboration between all levels of government, and between public and private sector organisations, will be required. Finally, attention should be paid to the possible unintended consequences of adaptation measures, e.g. undesirable environmental effects, negative externalities in other locations, or net increase in GHG emissions.⁵

2.1. AGRICULTURE: CROPS

Agriculture has historically been confronted with climate variability (if not the levels of predicted climate change) and has generally shown high levels of adaptability. Many adaptation options are in effect extensions of existing risk management and production-enhancing techniques. Possible adaptation measures include:

- conversion to alternative land uses that may be better adapted to the new climatic conditions;
- modifying the range of crops to match changes in agro-climatic zones (realising however that crop exposure to new ecosystem conditions may have some

⁵ For instance, the increased use of fertilisers if not very carefully managed may result in increased emissions of nitrous oxide (N₂O), a greenhouse gas, into the atmosphere. Furthermore, the inadequate use of fertilisers is a significant source of water pollution.

unexpected adverse impacts, resulting for instance from exposure to new pests and diseases);

- adopting new crops and/or varieties that may be more resilient to droughts, floods, high temperatures, emerging pests, soil salinity – or generally better adapted to the new climatic and ecological conditions;
- creating or strengthening national centres for the conservation and use of biodiversity in food plant species (e.g. rice, potato, corn) – or participating in international initiatives to this effect;
- adjusting seeding/planting and harvesting periods to take account of new seasonal patterns as well as water efficiency considerations;
- with due regard for environmental sustainability, altering the use of inputs such as fertilisers and pesticides to optimise production under new conditions, and generally improving the effectiveness and sustainability of pest, disease and weed management practices (e.g. Integrated Pest Management);
- improving soil moisture retention by the appropriate use of micro-catchments, mulches and soil organic matter management (e.g. crop residue retention);
- where rain-fed agriculture is at risk, developing water-efficient (e.g. drip) irrigation systems (if possible given current and future constraints on freshwater availability); where irrigation is already in place, making more efficient use of water;
- developing rainwater harvesting and storage techniques, and possibly desalination (an environmentally acceptable option only if it is powered by renewable e.g. solar energy);
- promoting water-use efficiency measures and other water management measures, such as water recycling, increased use of water metering and pricing, the development of water markets (to facilitate reallocation of the resource to the most valued uses) – but also any existing indigenous practices for sustainable use of water;

- where irrigated agriculture is not a sound option from an economic or environmental point of view, promoting the substitution of some local productions with imports from regions with better water endowments;
- promoting Integrated Water Resources Management (see script on [Water Supply & Sanitation](#)) at the appropriate scales (i.e. those that are most likely to allow effective responses to specified needs);
- adopting cultivation techniques that reduce soil erosion (e.g. reduced tillage or no-till agriculture, planting of hedgerows to prevent soil washout and act as windbreaks), conserve soil moisture (see above) and maintain biodiversity (notably as a natural protection against pest outbreaks);
- developing appropriate defences around cultivated areas and key infrastructure, including human settlements (e.g. dykes, seawalls, embankments, dunes or overflow routes against floods, "green barriers" against desertification, vegetation-cleared firelines against wildfires);
- maintaining a critical mass of (unexploited or sustainably exploited) natural ecosystems including wetlands throughout the territory, in particular in agricultural regions and in coastal areas (to enhance overall ecosystem resilience and ensure the continued provision of essential ecosystem services) (see script on [Ecosystems & Biodiversity Management](#));
- promoting local electricity generation based on renewable sources, notably to power irrigation pumps (see script on [Energy Supply](#));
- taking account of climate risks in the building of rural transport infrastructure, and in the choice of locations and technical specifications for food storage and other essential rural facilities (see script on [Infrastructure](#));
- promoting diversification of farmers' income;
- strengthening land planning and management institutions, and adopting land reforms that promote sustainable land management (e.g. by clarifying and securing property rights, whether private or collective, or by transferring the ownership and management of some resources to local communities) (see script on [Governance](#));

- in vulnerable coastal and delta areas, adopting 'managed retreat' where coastal protection is not feasible or unaffordable;
- implementing adequate conflict prevention and management mechanisms;
- developing monitoring, information sharing, seasonal climate forecasting and early warning systems (e.g. for droughts, floods, storms, pest outbreaks, environmental changes and consequences such as impending famine);
- developing and testing emergency preparedness plans at various levels;
- promoting farmers' access to training, advisory services and financial services, including insurance or other forms of risk sharing.

2.2. AGRICULTURE: LIVESTOCK

Possible adaptation measures include:

- designing and enforcing policies aimed at keeping livestock stocking rates within sustainable limits;
- rotating pastures;
- modifying grazing times;
- altering mixed livestock/crop systems (e.g. adaptation of forage crops, reassessment of fertiliser use to optimise productivity under new conditions while avoiding negative impacts on the environment);
- gradually switching to animal species (e.g. cows, sheep, goats) that are more resilient / better adapted to the new prevailing conditions (including heat, water shortages and diseases); in the case of industrial livestock farms, this may involve re-introducing traditional local species;
- installing or adapting ventilation in buildings that house livestock;
- diversifying sources of forage, partially switching to feed concentrates;
- developing appropriate defences around grazing lands (e.g. "green barriers" against desertification, vegetation-cleared areas against wildfires);
- ensuring adequate supply of water, in quantity and quality (e.g. by developing rainwater harvesting techniques, by fighting parasitic diseases at water points);

- adapting veterinary practices to changes in disease patterns;
- maintaining a critical mass of (unexploited or sustainably exploited) natural ecosystems including wetlands (to ensure the continued provision of essential ecosystem services);
- promoting diversification of herders' and ranchers' income;
- adopting land reforms that promote sustainable land management (e.g. by clarifying and securing collective or private property and access rights);
- implementing adequate conflict prevention and management mechanisms;
- promoting herders' and ranchers' access to training, advisory services and financial services, including insurance or other forms of risk sharing.

2.3. FORESTRY

Possible adaptation measures include:

- for managed forestry, altering the mix of tree species and gradually switching to species that may be more resilient / better adapted to the new climatic conditions;
- modifying rotation periods;
- adopting harvesting techniques that reduce soil erosion and exposure to wildfires, and promote the conservation of biodiversity (e.g. keeping dead timber in situ);
- building firebreaks and adjusting/strengthening fire management systems and procedures; this may include, for instance, the use of controlled burning as a protection against uncontrolled wildfires, the installation of surveillance towers and water reservoirs, the provision of better equipment and capacity building for firemen, the development of regional fire control forces equipped for aerial surveillance and interventions, and the integration and coordination of regional, national and international fire-fighting forces; tougher laws and sanctions against arson may also be part of the arsenal of measures;
- improving insect control techniques (with due regard for environmental considerations);
- maintaining a critical mass of diversified, natural forest ecosystems throughout forested regions;

- taking account of climate risks in the building of forest transport infrastructure;
- strengthening land planning and management institutions, and adopting land reforms that promote sustainable land management (e.g. by clarifying and securing private or collective property and access rights);
- implementing adequate conflict prevention and management mechanisms.

2.4. FISHERIES AND AQUACULTURE

Coastal fishing communities have a long experience of coping with fluctuations in fish stocks (notably fluctuations resulting from climate variability) and changes in the range of planktonic ecosystems and fish species. They have generally shown high levels of adaptability – although in recent decades this capacity has been tested by a sharp increase in human-induced stresses and pervasive policy failures. Most adaptation options are focused on altering catch size and fishing effort. Possible adaptation measures include:

- implementing policies aimed at keeping fishing fleets and fish catches within sustainable limits, enforcing rules (possibly with the help of new technologies such as GPS-based fishing fleet tracking systems), and in particular enforcing a strict ban on the most damaging fishing practices (e.g. bottom trawling, mercury, explosives);
- mapping changes in the range of fish species and strengthening the monitoring of fish stocks;
- adopting ecosystem-based approaches to fishery management;
- developing a network of marine protected areas where all fishing is banned;
- strictly enforcing the protection of fish breeding areas such as mangroves and coral reefs – and more generally, protecting coastal ecosystems (especially wetlands);
- managing and upgrading coastal infrastructure including “natural infrastructure” to avoid the destruction of fish breeding areas and improve water quality along the coast (e.g. mangrove restoration, development of wastewater treatment facilities);
- where essential infrastructure has to be protected (e.g. harbour infrastructure) and managed retreat is not

an option, strengthening natural coastal defences (e.g. mangrove regeneration) and/or building sea defences (with due regard for environmental considerations);

- adopting Integrated Coastal Zone Management practices (see script on [Water Supply & Sanitation](#));
- promoting diversification of artisanal fishermen's income;
- implementing adequate conflict prevention and management mechanisms;
- promoting artisanal fishermen's access to training, advisory services and financial services, including insurance or other forms of risk sharing;
- inland, implementing policies aimed at preserving the quality of freshwater resources used for aquaculture;
- financing research specifically aimed at supporting the sustainable adaptation of saltwater and freshwater aquaculture to the new prevailing conditions.

2.5. PROCESSING INDUSTRIES

Possible adaptation measures include:

- making own infrastructure as "climate-resilient" as possible, including in the choice of locations;
- ensuring that the public infrastructure on which transformation industries depend (e.g. transport, energy, telecoms, water) is gradually made as "climate-resilient" as possible;
- adapting storage and distribution systems to reduce vulnerability;
- implementing new techniques and upgrading infrastructure to reduce water and energy consumption and diversify energy supply sources;
- developing capacities for integrating climate risk management into overall business strategies;
- supporting suppliers of key raw materials and inputs in the adoption of practices that enhance resilience to the effects of climate change.

2.6. TERTIARY SECTOR ACTIVITIES, GOVERNANCE AND INSTITUTIONAL DEVELOPMENT

Possible adaptation measures include:

- making service enterprises' and public sector infrastructure (e.g. administrative buildings) as "climate-resilient" as possible, including in the choice of locations;
- ensuring that public infrastructure (e.g. transport, energy, telecoms, water and sanitation) is gradually made as "climate-resilient" as possible, including in the choice of locations;
- implementing new techniques and upgrading infrastructure to reduce water and energy consumption and diversify energy supply sources;
- developing capacities for integrating climate risk management into overall business strategies, notably in the (eco-)tourism sector;
- promoting access to financial services, including insurance or other forms of risk sharing;
- supporting awareness raising, knowledge sharing and capacity building among public and private organisations involved in rural development activities;
- promoting disaster preparedness at various levels of government and at community level;
- making the case for institutional strengthening in the context of climate-related challenges, by showing the added value of improved sector management in terms of productivity and resilience.

2.7. SPECIAL FOCUS: FOOD SECURITY

With regard to impacts on food availability, few adaptation measures are really specific to climate change. Generally speaking, all measures that effectively contribute to the increased climate resilience of food production, storage and distribution systems also contribute to enhancing food security. Efforts to improve water management and sustainable access to water are of particular importance. National and international efforts to support the conservation of biodiversity in food plant species are also necessary and likely to be useful – as are efforts to conserve biodiversity-rich, well-functioning ecosystems. The genetic modification of plants is particularly controversial from an environmental point of view and is generally considered to limit, rather than increase, the range of seed varieties used to grow crops. Nevertheless, some recent advances in the development of food crops engineered to resist droughts and high levels of salinity may

in future offer partial solutions in specific contexts.

With regard to impacts on food accessibility and affordability, any measures aimed at strengthening the resilience of transport systems (including, at the local and regional level, rural roads) should enhance adaptation capacity. As far as food prices are concerned, it may not always be possible or desirable to directly control food prices (as price controls may induce damaging distortions in markets that end up reducing, rather than enhancing, food security) – but some measures, such as the maintenance of sufficient strategic food stocks and international agreements that prevent or limit the possibility of banning exports of surplus food commodities (in particular cereals) at times of stress on world food markets, can be adopted to reduce price volatility or the incidence of artificial food shortages. On the demand side, access to food by poor households may be supported by means of insurance mechanisms (in particular for farmers) and social protection programmes, including for example the provision of substitution income, of food stamps, the development of food-for-work programmes or similar measures.

With regard to impacts on food safety and food use, adaptation measures include:

- improving capacities to monitor and predict outbreaks of foodborne diseases, including those of animal origin;
- improving capacities to detect, prevent and respond to cases of mycotoxin contamination and seafood contamination;
- regularly updating guidance on good agricultural, animal husbandry, veterinary and aquaculture practices in the light of new knowledge of how best to respond to changing climatic conditions;

- improving food safety management in the context of disaster reduction and emergency preparedness programmes;
- strengthening coordination between public health, veterinary, environmental health and food safety services, so as to ensure more effective responses to existing and new threats;
- promoting the (affordable) diversification of food sources as well as education on nutrition;
- in rural areas, taking steps to preserve sustainable access to land and to diversified sources of food (including wild plants and animals) for local communities.

Finally, with regard to impacts on the stability of food supply systems:

- any measures aimed at supporting the resilience of ecosystems and protecting biodiversity are likely to enhance the short- and long-term resilience of food production systems in the presence of increasing climate variability;
- any measures aimed at supporting the resilience of food storage and transport systems (including building and infrastructure protection, continuous energy supply, etc.) should also enhance the stability of food supply systems;
- the setting up or strengthening of early warning systems should help provide earlier, more effective responses to situations that jeopardise this stability.

As with other adaptation (and mitigation) measures, the impact of any measures aimed at enhancing food security should be carefully assessed, since some of them (such as the promotion of new cultivated or animal species) may have unintended, adverse consequences.

3.

W OPPORTUNITIES FOR REDUCING GHG EMISSIONS IN AGRICULTURE AND RURAL DEVELOPMENT



The way in which some key rural development activities are managed can have a significant impact on greenhouse gas (GHG) emissions. Agriculture is an important source of two 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. On the other hand, agricultural lands have the potential to store large amounts of carbon, depending on how soils are managed.⁶ Forests have even greater potential as “carbon sinks”⁷, and generally store carbon more permanently than croplands: they store carbon in tree biomass, and also in the soil’s organic matter. On the other hand, deforestation (especially where slash-and-burn techniques are employed, for instance to clear land for agriculture and ranching) releases significant quantities of CO_2 . Peatlands are the largest terrestrial store of biomass carbon: they store on average 10 times more carbon per hectare than other terrestrial ecosystems. When they are cleared, drained or burnt to be converted to agricultural or managed forestry uses, they release large amounts of CO_2 into the atmosphere.⁸

According to the IPCC’s Fourth Assessment report (IPCC 2007), agriculture and

forestry/deforestation account for, respectively, approx. 13.5% and 17.4% of global anthropogenic emissions.⁹ Changes in these two sectors in particular thus have considerable potential to contribute to the global climate change mitigation effort. Curbing deforestation, in particular, 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 conservation and restoration of peatlands is another extremely cost-effective carbon sequestration technique.

Although it supports a ‘Land Use, Land Use Change and Forestry’ component, the Clean Development Mechanism developed in the framework of the Kyoto Protocol is often perceived as too cumbersome to finance GHG emission reduction projects from agriculture and forestry projects on a routine basis – and it will anyway expire in 2012. It will be essential, however, to monitor the development of new financing mechanisms under the post-Kyoto arrangements (which should in principle be agreed at a major UN gathering to be held in Copenhagen in late 2009), as well as any other new instruments developed to address global deforestation and facilitate North-South financial transfers.

In the meantime, several mechanisms already support the financing of projects by developed countries under both compliance and voluntary emission reduction schemes. The Worldbank’s BioCarbon Fund and Forest Carbon Partnership Facility are particularly suitable for activities in agriculture and forestry – but other funds may also be relevant (see <http://carbonfinance.org> for more information). In future, carbon prices are likely to determine to a large extent which mitigation measures are viable and which ones are not.

⁶ Chlorophyllous plants absorb CO_2 through photosynthesis and use the carbon to build organic matter. The richer the soil is in organic matter, the more carbon it stores.

⁷ More carbon is stored in forest biomass than in the atmosphere.

⁸ The “un-freezing” of peatlands in permafrost regions is also a significant source of methane emissions.

⁹ According to an FAO report, “the livestock sector is [...] responsible for 18 percent of greenhouse gas emissions measured in CO_2 equivalent”, if one adds up the methane resulting from enteric fermentation by ruminants, the manure-related nitrous oxide emissions and the changes in land uses (primarily deforestation) caused by the expansion of pastures and land cultivated for feedcrops (FAO 2006: xxi).

Some mitigation options are congruent with adaptation options (especially in agriculture and forestry), and thus produce a double stream of benefits. Other mitigation options, however, may inadvertently result in increased vulnerability and threaten or cancel out adaptation efforts (e.g. biofuels may have adverse impacts on food security, food prices, water availability and ecosystems) – or even have a negative net impact in terms of mitigation (e.g. increased deforestation to accommodate cropland extension for biofuels). Just as with adaptation measures, it is thus important to carefully consider the pros and cons and possible unintended effects of any envisaged mitigation measures.

3.1. AGRICULTURE: CROPS

Generally speaking, mitigation measures in relation to agricultural practices are still characterised by many uncertainties (e.g. about the carbon sequestration potential in different conditions, and about the stability and permanence of carbon retention) – and there is no universally applicable list of good practices. Some measures may have a positive net impact on GHG emissions in some locations and agricultural systems but not in others. Some measures involve a trade-off (e.g. reduction in emissions of one greenhouse gas but increase in emissions of another one). It is therefore very important to seek technical or scientific advice before opting for a given mitigation option. Possible mitigation measures include:

- enhancing carbon sequestration in soils by conversion to reduced tillage or no-till agriculture, retaining crop residues (a precursor of soil organic matter), converting drained croplands back to wetlands, restoring degraded lands, converting some croplands to grassland, avoiding bare fallow, growing temporary vegetative cover (“catch crops”) between main agricultural crops or between rows of trees and vines, using biochar¹⁰ as a soil amendment, etc.;
- making more efficient use of fertilisers (more efficient delivery of nitrogen to root systems reduces atmospheric emissions of N₂O);

¹⁰ Biochar is charcoal produced from biomass using pyrolysis techniques. It can be used as a soil amendment, and has the advantage of allowing the storage of significant amounts of biomass carbon into soils, in a stable form. On top of improving soil quality and reducing irrigation and fertiliser requirements, the use of biochar as a soil amendment has the advantage of reducing emissions of nitrous oxide and methane, two powerful GHGs. (Source: Wikipedia)

- adopting cropping systems with reduced reliance on fertilisers, pesticides and other inputs (including but not limited to organic farming), including rotating or intercropping with legume crops (to reduce reliance on external nitrogen inputs);
- adopting rice cultivation methods that reduce methane emissions (e.g. more frequent draining of fields, improved water management, composting of residues before incorporation in soils, capture of methane for producing biogas to be used as fuel for energy production);
- avoiding the drainage of organic and peaty soils, protecting and restoring peatlands;
- converting the fossil fuel-based systems used to power the pumps of irrigation systems to renewable sources of energies;
- using crop residues for renewable energy production;
- developing biofuel crops (only to the extent this can be done sustainably and without adversely affecting food production, ecosystems and land rights – see script on [Energy Supply](#)), and investing in the development of ‘second-generation’ biofuels, which will rely on improved conversion technologies and on a wider range of biomass resources (e.g. crop residues, forestry by-products) – thus reducing pressures on food production and ecosystems compared to ‘first-generation’ biofuels;
- intensifying (in an environmentally sustainable manner) agricultural practices on existing croplands for the purpose of reducing pressure on forest and other natural ecosystems that store carbon;
- reducing the energy consumption associated with processing and transporting agricultural products in/to distant markets; public education campaigns may for instance be undertaken to encourage the consumption of local and regional products, where possible and where it can be demonstrated that a switch to local consumption does indeed lead to reduced overall GHG emissions (which cannot be taken for granted in all cases);
- integrating climate change mitigation objectives in the design of agri-environmental measures and rural development policies (e.g. creation of incentives to adopt practices that curb emissions and enhance the “carbon sink” potential of agriculture);

- using and enforcing environmental regulation to control some practices that have an impact on climate (e.g. regulation of nitrogen fertiliser use).

3.2. AGRICULTURE: LIVESTOCK

Possible mitigation measures include:

- rehabilitating degraded pasturelands (e.g. by alleviating nutrient deficiencies, re-planting grasses);
- making more efficient use of fertilisers, particularly nitrogen;
- maintaining permanent pastures;
- introducing grass species with higher productivity or deeper roots, and introducing legumes in grazing lands;
- reducing the frequency and intensity of fires in pasturelands through improved fire management practices (more effective fire suppression, vegetation management, etc.);
- adopting improved manure management practices (e.g. covered storage of manure; in intensive systems, installation of anaerobic digestion plants for the production of biogas to be used as fuel for energy production; promotion of solid rather than liquid handling of manure);
- modifying ruminant animals' diet and breeding practices to reduce methane emissions per kg of meat produced;
- developing sustainable sylvo-pastoral projects;
- using and enforcing environmental regulation to control some practices that have an impact on climate (e.g. regulation of manure application on crop- and pasturelands).

3.3. FORESTRY

The carbon mitigation potential of forests differs significantly across regions. In the short term, reducing the rate of deforestation produces more benefits than afforestation – however, afforestation is a good option in most regions if one takes a longer-term perspective. Sustainable forest management practices that maintain or increase forest carbon stocks while delivering a sustained flow of other benefits (e.g. timber, fuelwood, fibre, other non-timber forest products, biodiversity conservation, water filtering, protection against erosion, balancing of hydrological flows) generally produce the

most benefits from a social point of view. Possible mitigation measures include:

- developing sustainable afforestation and re-forestation projects specifically designed to support environmental and poverty alleviation goals as well as carbon sequestration;
- increasing carbon density in forests;
- developing sustainably managed plantations (e.g. as a source of fuelwood, timber or pulp for paper mills) for the purpose of alleviating pressure on natural forests;
- adopting harvesting practices that minimise carbon losses (e.g. maintaining partial forest cover, minimising losses of organic matter, avoiding most slash-and-burn techniques);
- avoiding the drainage of forest soils and in particular peatlands, which should be protected from clearing, burning and exploitation, and restored where they are degraded;
- developing sustainable agro-forestry projects (e.g. in replacement of unsustainable subsistence farming and cattle grazing);
- developing financing mechanisms ("payments for environmental services") to avoid deforestation and promote forest regeneration;
- promoting eco-tourism and recreational uses of forests in order to generate income and thus create an economic incentive for forest conservation;
- adopting fire prevention and fire management good practices;
- strengthening the regulatory and institutional mechanisms required to reduce illegal logging and unplanned deforestation, incl. the definition of forest property rights and of the rights and obligations of forest owners;
- improving the enforcement of legislation aimed at preventing deforestation or unsustainable timber production activities.

3.4. PROCESSING INDUSTRIES

Possible mitigation measures include:

- using wood waste (e.g. sawdust, wood chips, bark) from sawmills, paper mills and other wood processing industries to generate electricity and heat;

- using crop residues and biomass wastes from agriculture and agro-food businesses (e.g. beet and sugarcane bagasse) to generate electricity and heat;
- producing wood products to displace more fossil-fuel intensive construction materials such as concrete, steel, aluminium, plastics;
- adopting less energy-intensive technologies and investing in energy-efficient equipment, rolling stock and facilities;
- switching to cleaner sources of energy.

3.5. TERTIARY SECTOR ACTIVITIES, GOVERNANCE AND INSTITUTIONAL DEVELOPMENT

Possible mitigation measures include:

- investing in energy-efficient equipment, rolling stock and facilities;
- switching to cleaner sources of energy;
- developing capacities to implement mitigation activities and take advantage of opportunities arising from the development of carbon markets.

X ILLUSTRATIVE EXAMPLES

Illustrative example 1: Bangladesh – Enhancing adaptation capacity of coastal communities

Communities living in the coastal areas of Bangladesh are increasingly exposed to the effects of climate change (salinity intrusions, tidal and storm surges, erosion, water logging), with adverse consequences for their livelihoods. Coastal agriculture, fisheries and generally the livelihoods of the poor are considered extremely vulnerable to the effects of climate change; increased water salinity is also a threat to the health of coastal populations.

A project managed by Caritas Bangladesh, started in July 2008, aims to enhance the adaptive capacities and resilience of coastal communities by directly involving 250 poor households from small coastal communities in a variety of complementary actions, on a pilot basis. The households involved live in three villages in the Satkhira district, in the vicinity of the mangrove forest. They belong to various occupational groups and were selected on the basis of their socio-economic and livelihood conditions. Project activities include:

- an environmental school programme, which will deliver training to school teachers on the impacts of climate change and sea-level rise and thus participate in awareness raising and capacity building;
- the (re-)excavation of ponds and canals to improve freshwater supply;
- mangrove plantation on river banks to increase protection from erosion and cyclones;
- diversification of agriculture (notably by promoting salt-tolerant high-yielding rice varieties);
- home-based horticulture and vegetable cultivation;
- the development of brackish water fish species in aquaculture;
- the promotion of alternative livelihoods (e.g. crab fattening, plant nursery for mangrove regeneration);
- awareness raising on climate change impacts/risks/vulnerability, and institutional strengthening of community-based organisations.

Learning from the project is to be shared at the local, regional and national level and will hopefully allow the replication and scaling-up of successful coping strategies in future.

Illustrative example 2: Eritrea – Adapting livestock management to climate change

Livestock breeding accounts for a significant share of rural incomes and subsistence in the north-western lowlands of Eritrea. However, this activity is increasingly threatened by changes in land and groundwater use, as rangelands are converted to rain-fed and irrigated croplands. The process of confinement of livestock to marginal areas is aggravated by a desertification process that is converting perennial grasslands to more arid savannah. These pressures are and will be increasingly exacerbated by climate change. Livestock production systems already exceed carrying capacities; the related livelihoods are considered highly vulnerable to climate change effects in the long term, as significant rises in temperature are expected. The frequency of droughts has already increased, leading to lower water availability, reduced vegetation productivity, changes in ecosystem services and heat stress. Livelihoods diversification should be promoted, but is hindered by lack of access to credit and markets, lack of information and lack of skills.

To address this situation, a joint UNDP-GEF project is being designed to enhance the resilience of

pastoral communities to climate change and climate variability. It focuses in particular on the development of water harvesting for the purpose of improving rangeland productivity. The project, which started in 2008, will: (i) support national research capacity for climate risk assessment; (ii) promote institutional and human resource capacity development for adaptive rangeland management; (iii) develop a financing framework aimed at making water provision, maintenance and extension services financially sustainable and developing alternative saving mechanisms for pastoralists; and (iv) promote evidence-based adaptation of policies and regulations related to land use and pastoralism. On top of providing training and extension services in relation to land and pasture management and climate risks, the project will support the development of an early warning system, of participatory resource use and management plans, and of land use and natural resource planning guides.

Illustrative example 3: 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 Fund¹¹, 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.¹²

Illustrative example 4: Brazil – Sugar bagasse co-generation projects

Sugar bagasse is a fibrous by-product of sugarcane processing. The State of Sao Paulo in Brazil accounts for 70% of Brazil's sugar production; sugarcane mills in this region generate large quantities of bagasse every year. Many Brazilian sugarcane mills burn this by-product in boilers for the purpose of generating electricity and heat to power their own operations; however, the energy production processes used so far have not been very efficient, notably because there was no possibility for sugar mills to sell the extra power they generated to the national grid and so no

¹¹ 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.

¹² 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.

incentive to invest in generating capacity beyond their own needs.

Thanks to changes in electric sector legislation, electricity purchase from independent power producers is now possible. With some support from the World Bank-managed Prototype Carbon Fund, the Alta Mogiana sugar mill in the State of Sao Paulo is implementing a project to significantly upgrade its energy generation capacities. The company is re-furbishing existing pressure boilers and investing in new equipment to move to high-efficiency co-generation of steam and power. This allows the extraction of much more energy from the residual biomass of sugar and ethanol production activities. The extra power generated is sold to the national grid, on a commercial basis. Furthermore, being located in an industrial region, the new facilities reduce energy losses from transmission by supplying power closer to where it is consumed. Overall, the project thus contributes to enhancing energy efficiency and the productivity of agricultural land.

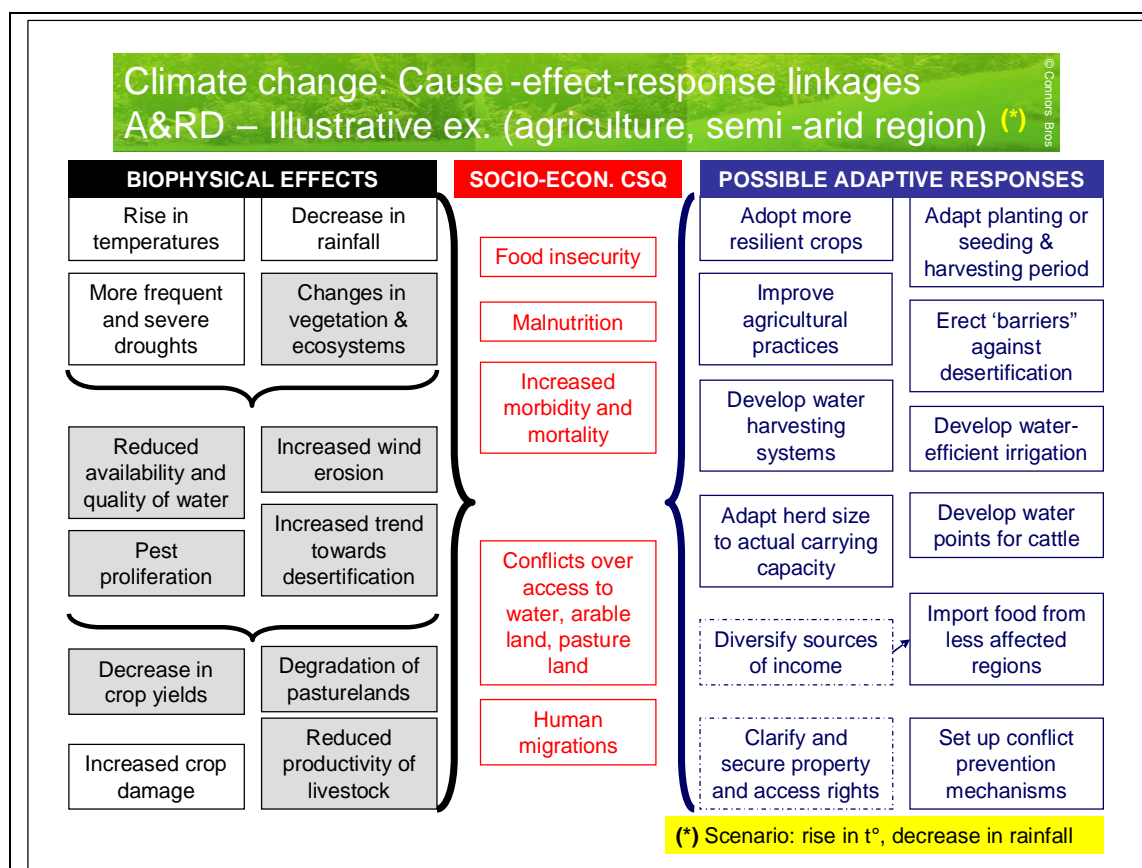
The sale of electricity to the grid would not on its own be sufficient to justify the investment involved. However, the project also contributes to a reduction in greenhouse gas emissions by substituting electricity produced by fossil-fueled thermal power plants with electricity from a renewable source. In recognition of this, it receives revenue from the sale of verified and certified emission reductions under the Clean Development Mechanism (CDM) of the Kyoto Protocol. This extra source of income makes the project financially sustainable. Several similar projects are being implemented in Brazil and in other sugar-producing countries.

ILLUSTRATION OF LINKAGES

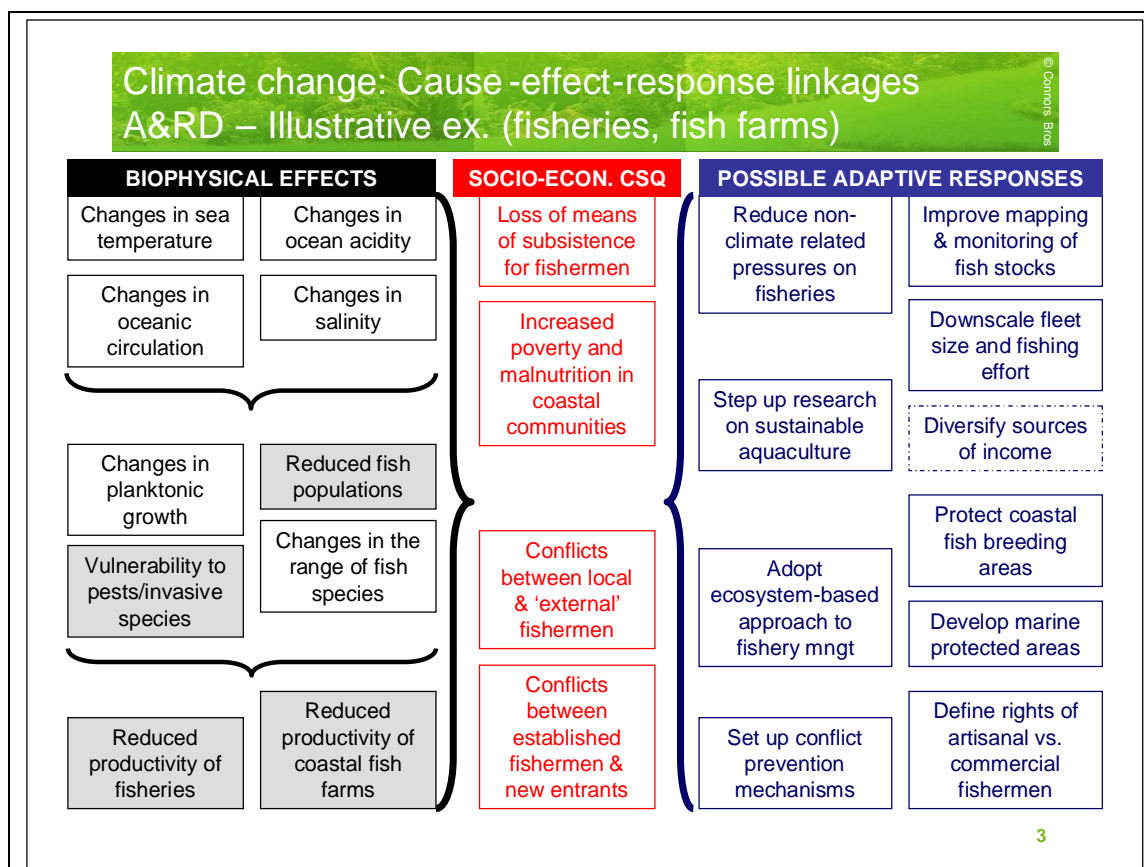
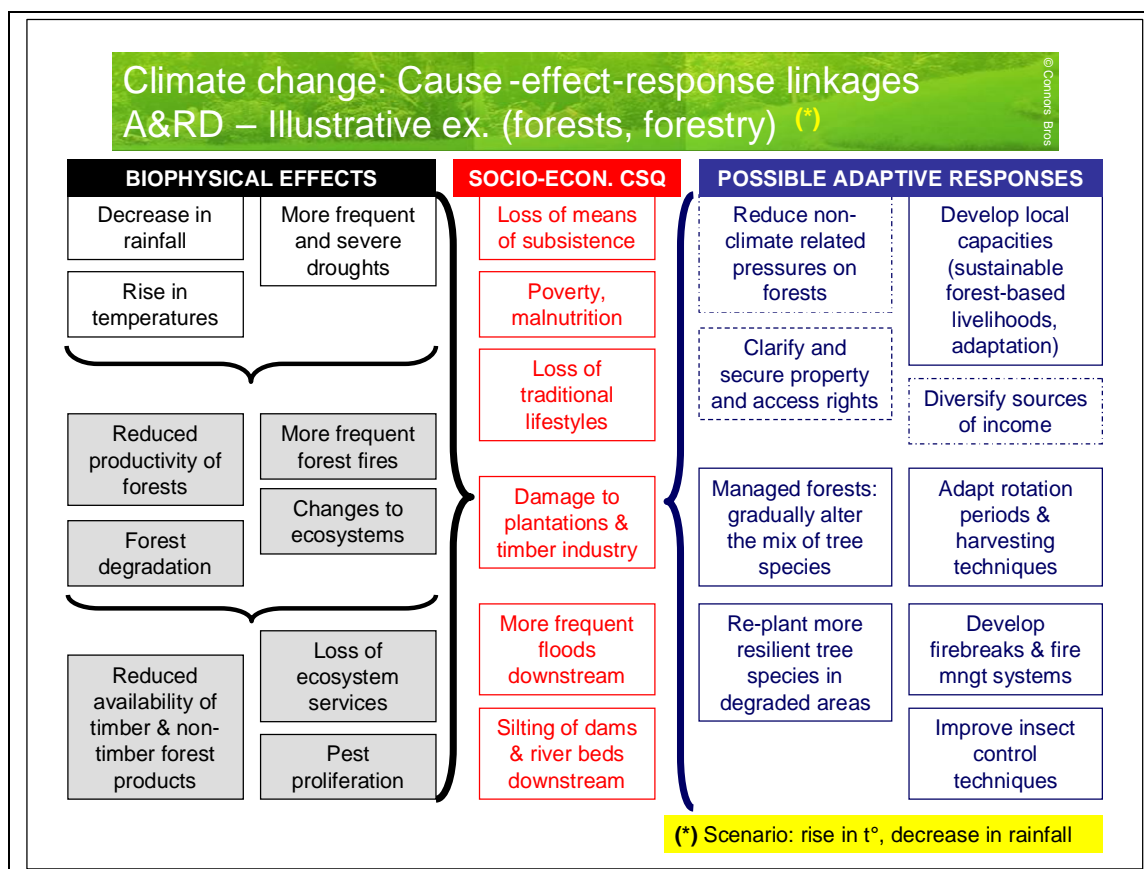
Below are a few illustrations (in a format that was voluntarily kept simple¹³) of the linkages between biophysical effects of climate change, potential socio-economic consequences and possible adaptive responses. They are provided to help visualize some important cause-effect relationships and how adaptive responses relate to the identified manifestations and impacts of climate change.

Legend:

| | |
|--|--|
| Changes to ecosystems | Grey boxes show biophysical impacts that are not exclusively or even primarily caused by climate change – but are also significantly influenced by other pressures resulting from human activities. |
| Develop migration & conflict management capacities | Boxes framed with a dotted line show possible responses that are in principle not under the direct control of the concerned sector authorities – but depend on the development of a cross-sectoral coordinated response. |

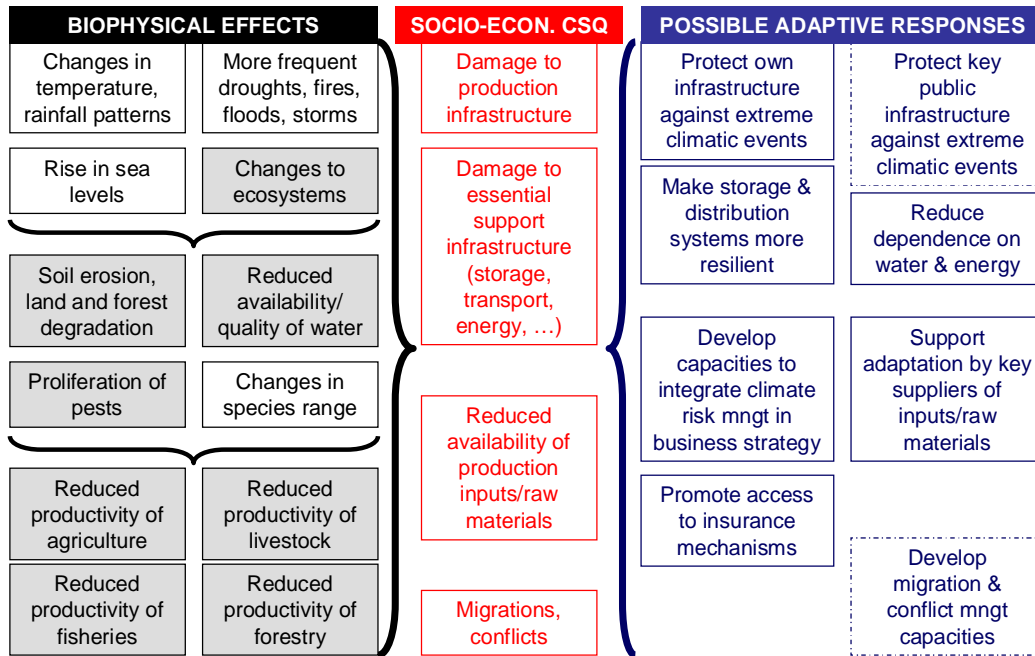


¹³ These illustrations are not meant to be comprehensive, or to be universally applicable; the simple format retained does not allow showing the multiple systemic interactions (including feedback loops) between various elements.



Climate change: Cause-effect-response linkages A&RD – Illustrative ex. (processing industries)

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- (8) IPCC (2007) – Climate Change 2007 – Impacts, Adaptation and Vulnerability, contribution of Working Group II to the Fourth Assessment Report, Intergovernmental Panel on Climate Change/Cambridge University Press. Available on: <http://www.ipcc.ch/ipccreports/assessments-reports.htm> (see in particular Chapter 3 on "freshwater resources and their management", Chapter 4 on "ecosystems, their properties, goods and services", Chapter 5 on "food, fibre and forest products", Chapter 6 on "coastal systems and low-lying areas, and Chapter 7 on "industry, settlement and society")
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- (10) UNEP-GEF-GEC-WI (2007) – Assessment on peatlands, biodiversity and climate change, Executive summary, UN Environment Programme/Global Environmental Fund/Global Environment Centre/Wetlands International. Available on: <http://www.gecnet.info/index.cfm?&menuid=48>

Illustrative example 1

- (11) <http://www.southsouthnorth.org/> (Project Portfolio – Adaptation projects – Bangladesh_Project_Satkira.pdf)

Illustrative example 2

- (12) <http://www.undp-adaptation.org/project/livestock>

- (13) http://www.adaptationlearning.net/downloads/ALM_Profile_UNDPEritrea.pdf

Illustrative example 3

- (14) Prototype Carbon Fund project:
<http://carbonfinance.org/Router.cfm?Page=Projport&ProjID=9612>
- (15) Other projects supported by the World Bank's BioCarbon Fund::
<http://carbonfinance.org/Router.cfm?Page=Projport&ProjID=26320>
<http://carbonfinance.org/Router.cfm?Page=Projport&ProjID=35579>

Illustrative example 4

- (16) Alta Mogiana project: <http://carbonfinance.org/Router.cfm?Page=Projport&ProjID=9618>
<http://cdm.unfccc.int/Projects/DB/TUEV-SUED1134666922.78>
- (17) <http://cdm.unfccc.int/Projects/index.html> for other similar projects (type "bagasse cogeneration" in the "project search" box)

{ 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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