
# CLIMATE CHANGE ADAPTATION AND MITIGATION IN THE FOOD AND AGRICULTURE SECTOR

**TECHNICAL BACKGROUND DOCUMENT**

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# CLIMATE CHANGE ADAPTATION AND MITIGATION IN

# THE FOOD AND AGRICULTURAL SECTOR

## Maintaining food security in a changing climate

Many countries worldwide are facing food crises due to conflict and disasters, while food security is being adversely affected by unprecedented price hikes for basic food, driven by historically low food stocks, high oil prices and growing demand for agro-fuels, and droughts and floods linked to climate change. High international cereal prices have already sparked food riots in several countries. In addition, rural people (who feed the cities) are now, for the first time, less numerous than city dwellers and developing countries are becoming major emitters of greenhouse gases. Many traditional equilibriums are changing, such as those between food crops and energy crops and cultivated lands and rangelands, as is the nature of conflicts in general. These changing equilibriums are, and will be, affected by changing climate, resulting in changed and additional vulnerability patterns.

The Intergovernmental Panel on Climate Change (IPCC) predicts that during the next decades, billions of people, particularly those in developing countries, will face changes in rainfall patterns that will contribute to severe water shortages or flooding, and rising temperatures that will cause shifts in crop growing seasons. This will increase food shortages and distribution of disease vectors, putting populations at greater health and life risks. The predicted temperature rise of 1 to 2.5$^{o}$ C by 2030 will have serious effects, including reduced crop yield in tropical areas. The impact of a single climate-, water- or weather-related disaster can wipe out years of gains in economic development.

Climate change will result in additional food insecurities, particularly for the resource poor in developing countries who cannot meet their food requirements through market access. Communities must protect themselves against the possibility of food-shortage emergencies through appropriate use of resources in order to preserve livelihoods as well as lives and property. It is imperative to identify and institutionalize mechanisms that enable the most vulnerable to cope with climate change impacts. This requires collaborative thinking and responses to the issues generated by the interaction of food security, climate change and sustainable development.

## Impacts and vulnerability

*Impacts* of climate change on food security are global and local. Climate change will affect agricultural food systems in all countries, including exporters and importers as well as those at subsistence level. Changes in mean rainfall and temperate as well as the increase in extreme events will affect agriculture, livestock, forestry as well as fisheries (see Table 1). Many impacts, such as increased land degradation and soil erosion, changes in water availability, biodiversity loss, more frequent and more intense pest and disease outbreaks as well as disasters need to be addressed across sectors.

**Table 1** Examples: projected climate change impacts on agriculture, forestry and fisheries

| Phenomenon and direction of trend in weather and climate events | Possible impacts on agriculture, forestry, fisheries and ecosystems |
|---|---|
| Warmer and fewer cold days and nights; warmer and more frequent hot days and nights over most land areas (virtually certain) | Increased yields in colder environments; decreased yields in warmer environments; increased insect pest outbreaks |
| Warm spells and heat waves increasing in frequency over most land areas (very likely) | Reduced yields in warmer regions due to heat stress; increased danger of wildfire |
| Heavy precipitation events increasing in frequency over most areas (very likely) | Damage to crops; soil erosion; inability to cultivate land due to waterlogging of soils |
| Drought-affected area increases (likely) | Land degradation and soil erosion; lower yields from crop damage and failure; increased livestock deaths; increased risk of wildfire; loss of arable land |
| Intense tropical cyclone activity increases (likely) | Damage to crops; uprooting of trees; damage to coral reefs |
| Extremely high sea levels increase in incidence (excludes tsunamis) (likely) | Salinization of irrigation water, estuaries and freshwater systems; loss of arable land and increase in migration |

Based on IPCC, 2007

*Vulnerability* refers to the degree to which a system or societies are susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity (IPCC, 2007). Since impacts and adaptive capacity of systems may vary substantially over the next decades and within countries, vulnerabilities can be highly dynamic in space and time. Consequently, there is a strong need to build resilient agricultural systems that have a high capacity to adapt to stress and changes and can absorb disturbances.

## Climate change impacts on food security

FAO defines food security in four dimensions, namely food availability, access to food, stability of food supply and utilization of food (see Definitions in Annex 1). This goes far beyond food production. In the short term, socio-economic factors such as those linked with market forces may dominate food security. However, in terms of the long-term stability and sustainability of food production and food supply, environmental factors become crucial. Although there will be some positive impacts, the following list illustrates that climate change will have mostly negative effects on the food security dimensions:

- availability of food – will be reduced by a drop in food production caused by extreme events, changes in the suitability or availability of arable land and water, and the unavailability or lack of access to crops, crop varieties and animal breeds that can be productive in conditions have lead to changes in pests and diseases;
- access to food – will be worsened by climate change events that lead to damages in infrastructure and losses of livelihood assets as well as loss of income and employment opportunities;

- stability of food supply – could be influenced by food price fluctuations and a higher dependency on imports and food aid;
- utilization of food – can be affected indirectly by food safety hazards associated with pests and animal diseases as well as the increased presence of human diseases such as malaria and diarrhoea.

Although climate change impacts on food security on national and subnational levels remain highly uncertain, the following IPCC regional assessments project regional variations in climate change impact (see Appendix 2).

**Food insecurity hotspots**

Food insecurity vulnerability patterns will be modified by climate change. Small-scale rainfed farming systems, pastoralist systems, inland and coastal fishing and aquaculture communities, and forest-based systems are particularly vulnerable to climate change. Moreover, the urban poor, particularly in coastal cities and floodplain settlements face increasing risks. Generally, impacts of climate change on smallholder and subsistence farmers, pastoralists, artesanal fisherfolk and forest dwellers including indigenous people are complex and highly localized. Vulnerability also varies within communities, dependent on factors such as land ownership, gender, age and health.

Globally, the IPCC expects only a marginal increase in the number of people facing hunger due to climate change. However, many of the 82 low income, food deficit countries have only limited financial capacity and rely heavily on their own production. It may not be possible to offset declines in local supply without increased reliance on food-aid.

Global studies must include comprehensive national assessments of climate change impacts on agriculture and food security to support national and subnational decision-making. While existing studies mainly focus on the effect of downscaled climate change scenarios on major crops, future studies should look at a wider range of crops and also take into account food delivery systems, the greater international connectivity, food prices, agricultural policy implications and possible development pathways. However, in some regions, such as large parts of Africa, studies are hampered by highly uncertain trends in rainfall, the insufficient resolution of climate models and lack of climate observation data.

In additions, studies should also consider the increasing competition over land use because of demand for agro-fuel; the impact of climate change and $CO_2$ fertilization on pests, weeds and diseases; and the role of land tenure and rights systems in accessing natural resources.

**The need for adaptation**

Adaptation is defined by IPCC as an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation (see Appendix 1).

Historically, people whose livelihoods depend on agriculture have developed ways to cope with climate variability autonomously. Today, the current speed of climate change will modify known variability patterns to the extent that people will be confronted with situations they are not equipped to handle. Thus, anticipatory and planned adaptation is an immediate concern. However, vulnerabilities are mostly local and, thus, adaptation should be highly location specific.

Anticipatory adaptation and technology innovation should attempt to improve resilience to future and uncertain impacts. However, they will have immediate and future costs, with trade-offs between optimization in current conditions and minimizing vulnerability to anticipated shocks. For instance, diversifying agriculture may reduce profitability in the short term but will reduce the risk of crop failure and future vulnerability. As with volatile markets that must diversify to reduce the risk of financial losses, agriculture has to diversify in order to enhance food security in a rapidly changing climate. The safest approach is to promote diverse and flexible livelihood and food production strategies at local, national, regional and global levels in combination with flexible and robust institutions, risk reduction initiatives for food and feed, and planned food security adaptation and transformation.

The most effective adaptation approaches in developing countries, as highlighted in UN Framework Convention on Climate Change (UNFCCC) meetings, are those that address a combination of environmental stresses and factors. Strategies, policies and programmes that are most likely to succeed need to link with coordinated efforts aimed at alleviating poverty, enhancing food security and water availability, combating land degradation and soil erosion, reducing loss of biological diversity and ecosystem services as well as improving adaptive capacity and improving the food production chain within the framework of sustainable development. Where possible, adaptation strategies should address social inequalities, such as differences in land tenure and lack of access to resources such as credit, education and decision-making that affect people's ability to adapt. The Millennium Development Goals are a necessary backdrop to integrating adaptation into development policy.

Food security must be regarded as one of the main criteria for the effectiveness of adaptation at the national and local levels. Food security considerations should be made explicit in adaptation of the agriculture, forestry and fisheries sectors to climate change and variability. This can be achieved by raising awareness of policy-makers, providing incentives and promoting the most resilient food production systems. Adaptation to climate change must also occur through the prevention or removal of maladaptive practices. Maladaptation refers to adaptation measures that increase vulnerability rather than reducing it.

Risk transfer mechanisms should be included in adaptation strategies from the national to the household level. This can include crop insurance or diversified livelihoods such as integrated aquaculture-agriculture systems which allow activities to shift in response to changes in the suitability of land and availability of water to produce food. Safety nets will be required in cases where benefits of diversification are limited, such as changes that affect all aspects of the food production systems.

Economic diversification within sectors to reduce dependence on climate-sensitive resources, particularly for countries that rely on narrow ranges of climate-sensitive economic activities, such as the export of climate-sensitive crops, is an important adaptation strategy discussed within the context of UNFCCC negotiations and its Nairobi Work Programme. For example, coffee in Uganda, a vital source of national income, will suffer a drastic reduction in suitable growing areas under climate change. Improved food security through diversification is one of the priority projects identified by National Adaptation Programmes of Action (NAPAs). This includes developing and introducing drought, flood and saline-tolerant crops, improving livestock and fisheries breeding and farming techniques, developing local food banks for people and livestock, and improving local food preservation.

Effective application of good management practices has many requirements:

- *Use of indigenous knowledge and local coping strategies as a baseline and starting point of adaptation planning.* Although there is a large body of knowledge within local communities on coping with climatic variability and extreme weather events, rapidly changing climate conditions will require upgrading local knowledge with more scientific observations and establishing collaboration among neighbours and neighbouring countries to transfer knowledge from areas already experiencing these changes.
- *Development of low-cost strategies with multiple benefits.* This can include establishing meaningful financial incentives such as microcredit, payments for environmental services and reducing the marketing influence of the agricultural supply industry.
- *Inclusion of gender-sensitive strategies.* Strategies should take into account the different roles, responsibilities, rights and resources of men and women, boys and girls.
- *Encouragement of relevant national agricultural research.* Research should focus on varieties adapted to drought, heat, salinity and new pests and diseases, with support of the Centres of the Consultative Group on International Agricultural Research (CGIAR), and take into account that methodologies and materials must be developed to meet rapidly changing conditions.
- *Promotion of multidisciplinary and multisectoral institutions and processes.* Broad-based institutions and processes can facilitate changes in resource access and use, solve conflicts, and secure land and natural resource rights of groups and individuals.

**Adaptation planning requires a broad view**

Any adaptation planning must recognize the levels of uncertainty in climate change scenarios and the plans themselves must be adaptable. The following indicates some of the problems adaptation planning may face and what must be considered in looking for a solution.

- *Adaptation is urgent, but also requires substantial resources*. It is unlikely that developing countries, in particular the least developed countries, have the financial resources and technical knowledge for anticipatory and planned intervention. Financial and technical assistance will be required for the additional costs of designing and implementing interventions.
- *Climate change is local and location specific*. Methodologies to assess adaptation need to analyze local impacts in detail to understand and plan interventions but recognize that, at implementation, it will be necessary to include interventions into larger scale coherent adaptation programmes.
- *Climate change impacts will change over time, and individual elements of adaptation must change with them.* Adaptation work requires a variety of technical measures that can be applied at different speeds at different times. This also means that any required inputs should be programmed and sustained for the whole of the adaptation period.
- *Areas affected by climate change may be flooded or become unsuitable for agriculture, fisheries and forestry.* Diversification to other economic activities and migration will need to be considered seriously under such conditions.

**Mitigation options in the agriculture and forestry in the food sector**

Agriculture and land-use change (deforestation) are major contributors to climate change. The IPCC Fourth Assessment Report found that agriculture, which consists of cropland, pasture and livestock production, and forestry contribute, respectively, 13 and 17 percent of total anthropogenic greenhouse gas emissions. This contribution does not include other emissions associated with agriculture such as production of fertilizers (accounted under industry), food supply (transport and industry), packaging (waste), and cooling and heating (energy supply).

While carbon dioxide emissions from agriculture are small, the sector accounts for about 60 percent of all $N_2O$ and about 50 percent of $CH_4$ emitted, mainly from soils and enteric fermentation, respectively. The GHG impact through radiative forcing of $N_2O$ is 300 times that of $CO_2$. Methane and nitrous oxide emissions increased by 17 percent from 1990 to 2005 and are projected to increase by another 35 to 60 percent by 2030, driven by growing nitrogen fertilizer use and increased livestock production. Increases in agricultural emissions are expected as population and economic growth increase food demand.

Mitigation of climate change is a human intervention aimed at reducing the sources or enhancing the sinks of greenhouse gases (IPCC 2007). Mitigation of climate change is a global responsibility. Agriculture and forestry provide, in principle, a significant potential for GHG mitigation. See Table 2 for selected examples of mitigation technologies, policies and measures, constraints and opportunities for agriculture and forestry sectors.

IPCC estimates that the global technical mitigation potential for agriculture (excluding forestry and fossil fuel offsets from biomass, and including all gasses) will be between 5 500 and 6 000 Mt $CO_2$-equivalent per year by 2030, 89 percent of which are assumed to be from carbon sequestration in soils The assessment of mitigation potential remains a major tool for priority setting at the national level.

Mitigation in the natural resources sector should focus on its five major sectors, namely: livestock, forestry, rangeland, agriculture and fisheries. The classical mitigation options in the agricultural sector at large include forest-related measures of reducing deforestation and forest degradation and increasing afforestation and reforestation, along with forest management interventions to maintain or increase forest carbon density, and efforts to increase carbon stocks in wood products and enhance fuel substitution.

*Cropland mitigation* measures remain unexplored although many adaptation options also contribute to mitigation. Among these measures are: soil management practices that reduce fertilizer use and increase crop diversification; promotion of legumes in crop rotations; increasing biodiversity, the availability of quality seeds and integrated crop/livestock systems; promotion of low energy production systems; improving the control of wildfires and avoiding burning of crop residues; and promoting efficient energy use by commercial agriculture and agro-industries.

*Soil carbon sequestration* is one of the most promising options with a wide range of synergies. By increasing carbon concentrations in the soil through better management practices, this option offers benefits for biodiversity, soil fertility and productivity, and soil water storage capacity. Further, it stabilizes and increases food production and optimizes the use of synthetic fertilizer inputs, reversing land degradation and restoring the “health” of ecological processes.

Fertilizers, pesticides and monoculture production have failed to optimize soil carbon sequestration or to moderate GHGs. Any attempts to increase production by increasing mineral nitrogen use need to be evaluated with respect to the fertilizer’s efficiency and N2O emissions. Experience from long-term studies has shown that nitrogen fertilizers do not support organic matter build-up. Fertilizer evaluations also must include off-site effects such as water contamination and off-site N2O emission, particularly in the most advanced countries. On the other hand, integrated crop and animal production, use of intermediate and catch crops and cover crops, compost application, crop rotation and diversification, and zero or reduced tillage have potential to improve soil carbon sequestration and reduce greenhouse gas emissions.

Increased emphasis on energy efficiency and biologically based production practices is needed to address GHG and climate change issues related to the food and agricultural system. Developing food and agricultural systems based on energy efficiency and improved soil carbon levels has potential to improve the greenhouse gas and climate change scenarios.

*Livestock* is responsible for significant GHG emissions, as noted above. Mitigation options to reduce these emissions include: improving livestock waste management through covered lagoons, improving ruminant livestock management through improved diet, nutrients and increased feed digestibility, improving animal genetics, and increasing reproduction efficiency.

Mitigation implementation may suffer because the fragmentation of agriculture and the localized nature of mitigation make implementation resource intensive. Also, if intensive systems of developing countries are to play a significant part in mitigation of emissions, there is need to invest in agro-ecological research and capacity building.

For the most vulnerable people as well as regions, the potential for implementation of mitigation measures is rather low and adaptation is the major concern. On the other hand, farming systems with reduced external inputs that are based on recycling nutrients and using natural processes to provide sufficient crop growth (e.g. nitrogen fixing cover crops) reduce dependence on purchasing fertilizers and other inputs. In the long run, these systems are a valid mitigation option that may enhance adaptation synchronously and that need to be developed locally.

In this respect, mitigation is perceived very differently for countries that have an obligation to reduce their emissions (mostly developed) and those that increasingly suffer from climate changes affecting climate variability patterns. However, international mechanisms that could channel international financial resources to the most vulnerable in developing countries provide a new opportunity that is still very far from affecting the lives of smallholders. Indeed, some mitigation measures may even disrupt traditional food production systems thereby compromising their food security.

Preventing activities known to contribute to global warming is the simplest and most cost-effective approach to avoid negative impacts of human activities on the climate and food production systems.

Evaluation standards are needed to ensure mitigation strategies have no negative impacts on food security. For instance, clear guidelines would help resolve some of the conflicts between rural income from bioenergy and food security, taking into account likely short- and long-term impacts of individual decisions and national policies, and their effect on other resources such as water and on price trends.

**Table 2**. Examples: mitigation technologies, policies and measures, constraints and opportunities for agriculture and forestry sectors.

| Sector | Key mitigation technologies and practices currently commercially available. | Environmentally effective policies, measures and instruments | Key constraints or opportunities |
|---|---|---|---|
| Agriculture | Improved crop and grazing land management to increase soil carbon storage; restoration of cultivated peaty soils and degraded lands; improved rice cultivation techniques and livestock and manure management to reduce $CH_4$ emissions; improved nitrogen fertilizer application techniques to reduce $N_2O$ emissions; dedicated energy crops to replace fossil fuel use; improved energy efficiency; mulch farming, conservation tillage, cover cropping and recycling of bio-solids. | Financial incentives and regulations for improving land management, maintaining soil carbon content, and making efficient use of fertilizers and irrigation | Opportunities: May encourage synergy with sustainable development, reducing vulnerability to climate change, and thereby overcoming barriers to implementation |
| Forestry | Afforestation; reforestation; forest management; reduced deforestation; harvested wood product management; use of forest products for bioenergy to replace fossil fuel use.<br>By 2030, forest mitigation technologies will include: tree species improvement to increase biomass productivity and carbon sequestration. Improved remote sensing technologies for analysis of vegetation and soil carbon sequestration potential, and mapping land-use change | Financial incentives (national and international) to increase forest area, reduce deforestation and maintain and manage forests; land-use regulation and enforcement | Constraints: lack of investment capital and land tenure issues.<br>Opportunities: Help poverty alleviation and provide essential ecosystem services to protect watershed, conserve biodiversity and advance conservation recreation |

## Trade-offs and mitigation and adaptation synergy in agriculture and forestry

There can be negative trade-offs between adaptation and mitigation. Adaptation measures in one sector can negatively affect livelihoods in other sectors. For example, river fisheries can be negatively affected from adaptations in other livelihood sectors upstream. In particular, irrigation's additional water needs, such as in the Ganges region, can reduce flows and affect seasonal spawning and fish productivity. Mitigation measures, such as reduced emissions from deforestation, can threaten the land rights and livelihoods of rural people and undermine efforts to improve food security and sustainable development.

It is possible to reduce trade-off risks by promoting diverse and flexible livelihood and food production strategies, flexible and adaptable institutions, food security risk reduction initiatives and planned food security adaptation to climate change.

In many cases, there is evidence that adaptation, mitigation and food security enhancement and rural development can go hand in hand. Unlike other sectors, adequate agriculture and forestry strategies can simultaneously increase adaptive capacity and mitigate climate change. For example, increasing soil organic matter in cropping systems, agroforestry and mixed-species forestry can improve soil fertility and soil moisture holding capacity, reduce impact of droughts or floods, reduce vulnerability and sequester carbon. There is need to explore and promote the synergy between adaptation and mitigation in the agriculture and forestry sectors (IPCC).

Although the most vulnerable countries should focus on food security and adaptation, they also should look for synergies with mitigation whenever possible. Adaptation and mitigation and their synergies and antagonisms are often location specific, although some patterns are based on elements such as climate, soil type, farming system and level of development.

**Data and research needs**

Because of the global nature of many climate change issues, and the increasingly global nature of food security issues, data are needed at several levels: (i) national data and coarse grids at the global and regional scales to understand and model climate, and (ii) local data for local impact assessments, policy-making and other interventions.

Countries must be aware that their locally collected data on climate, agriculture, natural resources and markets are required to develop meaningful and reliable global climate system models and dynamic global equilibrium models. In turn, such models will provide more consistent data to estimate future local conditions with an increasing degree of accuracy. Large countries may adopt the first sub-national administrative unit scale to take into account the variety and the disparity of sub-national conditions.

*Data gaps* exist in the context of food insecurity and climate change, the most blatant of which include indicators of recent past and projected rates of change; sex- and age-disaggregated data on the tasks, time and resources available for different groups of community members; and basic climate data for major agricultural and forested areas. As a consequence of intertwined scales of global modelling (climate scenarios, trade) and local impacts on food security, exchange of data must be improved among the national, international and regional levels. It is important for countries and organizations, such as FAO, to stress the crucial need to identify well-established and new data, develop robust indicators relevant for food security, ensure that they become an integral part in the ongoing data collections, and harmonize them, starting at the national level.

The UNFCCC may stimulate national contributions to international datasets. Central meta-databases are needed to improve knowledge of data availability, methods and coverage and facilitate integration of datasets. In view of the inherently multisectoral nature of climate change and food security issues, UN agencies should have a coherent data approach and share data among themselves and the community of users.

*Proper data usage* is as important as the proper collection of data. There is a strong need to strengthen the capacity of less developed countries to make efficient use of available data. Provision of data to end-users entails power dynamics between the providers and end-users, as well as among end-users (e.g. men and women). In addition, it cannot be assumed that data turn into information or that information turns into knowledge. Local communities need access to global information and analyses specifically tailored to their needs that supports their specific adaptation and planning requirements. This needs to cover markets as well as weather and climate and requires invigorated extension services.

*Modelling* of future climate impacts on complex food security systems is still very much a research subject, especially for addressing local impacts in agro-ecological zones at the national level. In modelling current and future climate change impacts, countries and the international community would greatly benefit from the creation of detailed national and international knowledge and data bases of impacts on the four components of food security. This requires the development of methods and tools for local impact and vulnerability studies and an enhanced understanding of people's responses to a changing climate and local knowledge and decision-making. National policies needs to recognize that successful operational adaptation interventions often can build best on what local people are already doing. Therefore, inventories need to identify and document best practices, traditional knowledge and alternative practices for coping with increasingly variable climate as well as mal-adaptations.

*Climate-proof research* is possible. For example, it may cover climate change impacts on crops, livestock, fisheries, forests, pests and diseases; evolving "adverse climate tolerant" genotypes and land-use systems; value-added weather management services (including contingency plans, climate predictions for reducing production risks, and pest forecasting systems); compiling traditional knowledge for adaptation; water management; measures to counter the impacts of saltwater intrusion; and decision-support systems. Social issues cannot be left out. They include migration and changing household composition; loss of labour due to HIV/AIDS; land tenure security; access to credit and technologies; and household activities such as water and fuel collection and food preparation.

*Disaster risk management* (DRM) can be useful in the context of food security. It seeks to reduce the likelihood of negative outcomes resulting from disasters. With regard to food security, this means ensuring a more constant food supply. DRM involves three types of actions: risk identification, risk reduction and risk transfer. Once identified, risk reduction involves measures to prevent losses such as early warning systems that are based on observations and research on the mechanisms of impacts and people's responses; operational emergency planning and training of response staff, and the development of contingency plans. Risk transfer involves the use of financial mechanisms to share risks and transfer them among different actors. Examples of such tools include weather derivatives, catastrophe bonds and different types of insurance.

*Research* provides the backbone for adaptation and mitigation methodologies. It needs to be linked with social science research on how to introduce new methodologies, crop varieties, etc., to communities, whether they will be taken up, and how different members of vulnerable communities can benefit. However, research for a rapidly changing situation is different from research for static ecological conditions. Traditional knowledge and local biodiversity are likely to be surpassed in a rapidly changing situation in which methodologies, crops and crop varieties need to be developed for future conditions. This requires strong national and international agricultural, forestry and fisheries research and relegates an important role to the CGIAR Centres. Research results need to be public and there needs to be an enabling environment in which agriculture, forestry and agroforestry methods, germplasm, crops varieties, animal breeds, crops and trees are accessible for use and introduction in adaptation programmes.

Additional basic research is needed to increase understanding of the mechanisms of adaptation. Simple, transparent methods, tools and indicators are required for decision-makers at all levels to assess the technical effectiveness and the social and environmental impacts of adaptation and mitigation measures, while at the same time explicitly keeping track of ecosystem services and food security

**National awareness and capacity**

In many countries, the general attitude of decision-makers towards climate change, especially in agriculture, appears to be a lack of concern, often justified by the uncertainties that affect many projected impacts at the local level. That is why it is necessary to build capacity to raise awareness of the future risks and immediate benefits that can be derived from developing national strategies for adaptation and mitigation including prevention of new GHG-producing activities. Policy-makers and agricultural research and extension services need to be sensitized to the issues related to the climate change and food security nexus.

The capacity to identify, collect and share data, use information and build knowledge relevant for climate change adaptation, mitigation and food security is critical because of rapidly changing climatic, environmental and socio-economic conditions. Countries should be enabled to undertake an assessment of impacts, adaptation and mitigation options and potentials, to participate in international fora and to take advantage of existing international options, such as Kyoto and post-Kyoto mechanisms, for the benefit of their agriculture, forestry and fisheries sectors.

To ensure that options are made available to food producers and that coping strategies are preserved and enhanced at the local level, the communication among policy- makers, researchers and extension experts and farming communities needs to be improved. At the same time, it is important to understand the dynamics of local decision-making: Who decides which issues within a community receive adaptation assistance? The community or outsiders? Who within the community benefits?

Extension services and mechanisms have been weakened greatly during the last two decades. To be able to address adaptation and mitigation, extension will need to be strengthened substantially, while it also will have to provide an efficient interface between policy-makers and the farming community.

**APPENDIX 1**

## Definitions (IPCC 2007)

### Adaptation

Adjustment in natural or *human systems* in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation:

- **Anticipatory adaptation:** Adaptation that takes place before impacts of *climate change* are observed. Also referred to as proactive adaptation.
- **Autonomous adaptation:** Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or *welfare* changes in *human systems*. Also referred to as spontaneous adaptation.
- **Planned adaptation:** Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.

### Adaptive capacity (in relation to climate change impacts)

(i) The ability of a system to adjust to *climate change* (including *climate variability* and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.
(ii) The whole of capabilities, resources and institutions of a country or region to implement effective adaptation measures.

### Climate change

(i) Climate change refers to a change in the state of the climate that can be identified (…) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer whether due to natural variability or as a result of human activity.
or (ii) UNFCCC: a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global *atmosphere* and which is in addition to natural climate variability observed over comparable time periods

### Climate variability

Climate variability refers to variations in the mean state and other statistics of the *climate* on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the *climate system* or to variations in natural or *anthropogenic* external forcing.

### Food security

(i) A situation that exists when people have secure access to sufficient amounts of safe and nutritious food for normal growth, development and an active and healthy life. Food insecurity may be caused by the unavailability of food, insufficient purchasing power, inappropriate distribution, or inadequate use of food at the household level.

or (ii) FAO: Food security exists when all people at all times have physical or economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.

**Mitigation**

A human intervention to reduce the sources or enhance the sinks of greenhouse gases.
Technological change and substitution that reduce resource inputs and emissions per unit of output (…). With respect to climate change, mitigation means implementing policies to reduce GHG emissions and enhance sinks.

**Resilience**

The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change.

**Vulnerability**

Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of *climate change*, including *climate variability* and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its *sensitivity*, and its adaptive capacity.

**APPENDIX 2**

## IPCC regional assessments of climate change impact

**Africa**

- Food insecurity worsening and number of people at risk from hunger increasing.
- Agricultural production severely compromised due to loss of land, shorter growing seasons and more uncertainty about what and when to plant. By 2020, yields from rainfed crops could be halved in some countries and, by 2100, net revenues from crops could fall by 90 percent. General decline in most subsistence crops such as sorghum in Sudan, Ethiopia, Eritrea and Zambia; maize in Ghana; millet in Sudan; and groundnuts in Gambia.
- Fish stocks already compromised will be depleted further by rising water temperatures and other physical and ecosystem changes. Threats of inundation for coast of eastern Africa, coastal deltas, such as the Nile, and degradation of marine ecosystems and other physical and ecosystem changes.
- Grassland degradation, with widespread drying and desertification, particularly in the Sahel and southern Africa.
- Forests face deforestation, degradation and increase in forest fires

**Asia**

- Crop yield decreases in many areas will put many millions of Asians at risk from hunger.
- Water stress will affect more than 100 million people due to decrease of freshwater availability in central, south, east and Southeast Asia, particularly in large river basins such as Changjiang.
- Land degradation and desertification may increase due to reduced soil moisture and increased evapotranspiration. Grassland productivity is expected to decline by as much as 40 to 90 percent with a temperature increase of 2-3$^{o}$C, combined with reduced precipitation in the semi-arid and arid regions.
- Agriculture productivity may expand in northern areas.
- Boreal forest in north Asia may increase northward, although the likely increase in frequency and extent of forest fires could limit forest expansion.
- Fish breeding habitats, fish food supply and, ultimately, the abundance of fish populations in Asian waters will be substantially altered. Aquaculture industry and infrastructure, particularly in heavily populated mega deltas, are likely to be seriously affected by coastal inundation.

**Australia and New Zealand**

- Water security problems to intensify by 2030 in southern and eastern Australia, New Zealand's Northland and some eastern regions. Major land degradation problems such as erosion and salinization are likely to expand.
- Agricultural production is projected to decline by 2030 throughout much of southern and eastern Australia, and throughout parts of eastern New Zealand, due to increased drought and fire. In contrast, there could be moderate yield increases in north eastern Australia and main parts of New Zealand due to a longer growing season, less frost and increased rainfall.
- Livestock productivity in Australia is projected to suffer heat stress, lower pasture productivity, lower forage quality and expansion of animal diseases such as cattle tick.

- Forests will benefit from $CO_2$ fertilization, higher rainfall, longer growing season along with negative impacts of increased water stress, pests, fires and erosion.
- Marine fisheries will have additional stress due to increasing sea surface temperature, rising sea level, acidification and changes in the Southern Ocean circulation which will cause changes in species distribution, particularly for species at the edges of suitable habitats

**Europe**

- Crop productivity will have small increases overall that might be far outweighed by technological development. Yield increases will be mainly in northern Europe, and the largest decreases in the Mediterranean, the southwest Balkans and the south of European Russia.
- Southern European crops such as maize, sunflower and soybeans will have a northward expansion.
- Mediterranean productivity of crops will be affected by more frequent droughts and dryspells leading to reduced yields (e.g. sunflower), scrublands and deciduous forests, increased water demand for irrigation, higher risk of fire and less biodiversity.
- Livestock disease risk will increase for diseases such as bluetongue and African horse sickness.
- Forest productivity will increase substantially in Northern Europe. There will soil carbon losses in boreal forests and seasonal shifts in extent of frost damage.
- Grasslands productivity in temperate Europe will increase.
- Marine fish and shellfish to be affected in the North Atlantic as shifts in species distribution lead to increased production in northern waters and marked decreases at the southern edge of current ranges where there will be increased stress due to pathogens. Aquaculture will suffer local impacts due to organic wastes and spread of pathogens.

**Latin America**

- Food security will be impacted in dry areas where agricultural land will be subject to salinization and erosion, reducing crop yields and livestock productivity.
- Agricultural lands are very likely to be subjected to 50 percent desertification and salinization in some areas by the 2050s.
- Crop yields may be reduced in some areas, although other areas may see increases.
- Habitat loss and species extinction in many areas, including tropical forests, due to higher temperatures and loss of groundwater, especially effecting indigenous communities.
- Low lying areas will be impacted by sea level rise and extreme events, particularly those associated with the El Niño Southern Oscillation (ENSO) phenomenon which will affect the La Plata estuary, coastal morphology, coral reefs and mangroves, location of fish stocks and availability of drinking water.

**North America**

- Rain-fed agriculture is likely to increase yields by 5 to 20 percent in the early decades of the century, but with important variability among regions.
- Water resources will be affected by warming in western mountains which will lead to decreased snowpack, more winter flooding and reduced summer flows, exacerbating competition for over-allocated water resources.

- Crops near the warm end of their suitable range, such as wine grapes, or those that depend on highly utilized water resources will face major challenges.
- Forest growth is likely to increase 10 to 20 percent overall during the twenty-first century as a result of extended growing seasons and $CO_2$ elevation, although with important spatio-temporal variation. Forests are likely to be affected by changes in disturbances from insects, diseases and wild fires, and associated losses depending on the emission scenario.
- Cold water fisheries are likely to be negatively affected, while warm water fisheries will generally gain with mixed results for cool-water fisheries. Higher temperatures will lead to northward shifts of species distribution.

**Small Island Developing States**

- Agricultural land and thus food security will be affected by sea-level rise, inundation, soil salinization, seawater intrusion into freshwater lenses and decline in freshwater supply.
- Agricultural production will be affected overall by extreme events.
- Fisheries will be affected by increasing sea surface temperatures, rising sea level and damage from tropical cyclones. Degradation of coral reefs and bleaching will impact fishing incomes.
- Forests affected by extreme events will be slow to regenerate. Forest cover may increase on some high latitude islands.
- Habitability and thus sovereignty of some states will be threatened due to reduction in island size or complete inundation.

**Polar Regions**

- Northward movement of species in response to higher temperatures and longer growing season provides opportunities for expansion of agricultural and pastoral activities but with associated vulnerabilities related to invasive species, loss of biodiversity and the spread of animal-transmitted diseases. An estimated 10 to 50 percent of the tundra could be replaced by scrubland and forests.
- Ecosystems will be affected by temperature increase, decreased sea-ice cover and shifts in hydrological regimes, leading to detrimental effects on many organisms, including migratory birds, mammals and higher predators.
- Food security of some subsistence systems will be threatened by changes in ecosystems, decreased transport and market access, and lower quality drinking water.
- Biodiversity changes and alterations in the distribution and productivity of marine biota will have mainly negative effects at the northern ice edge but will benefit the most important Arctic and sub-Arctic commercial fish stocks, such as cod and herring, south of the ice edge.