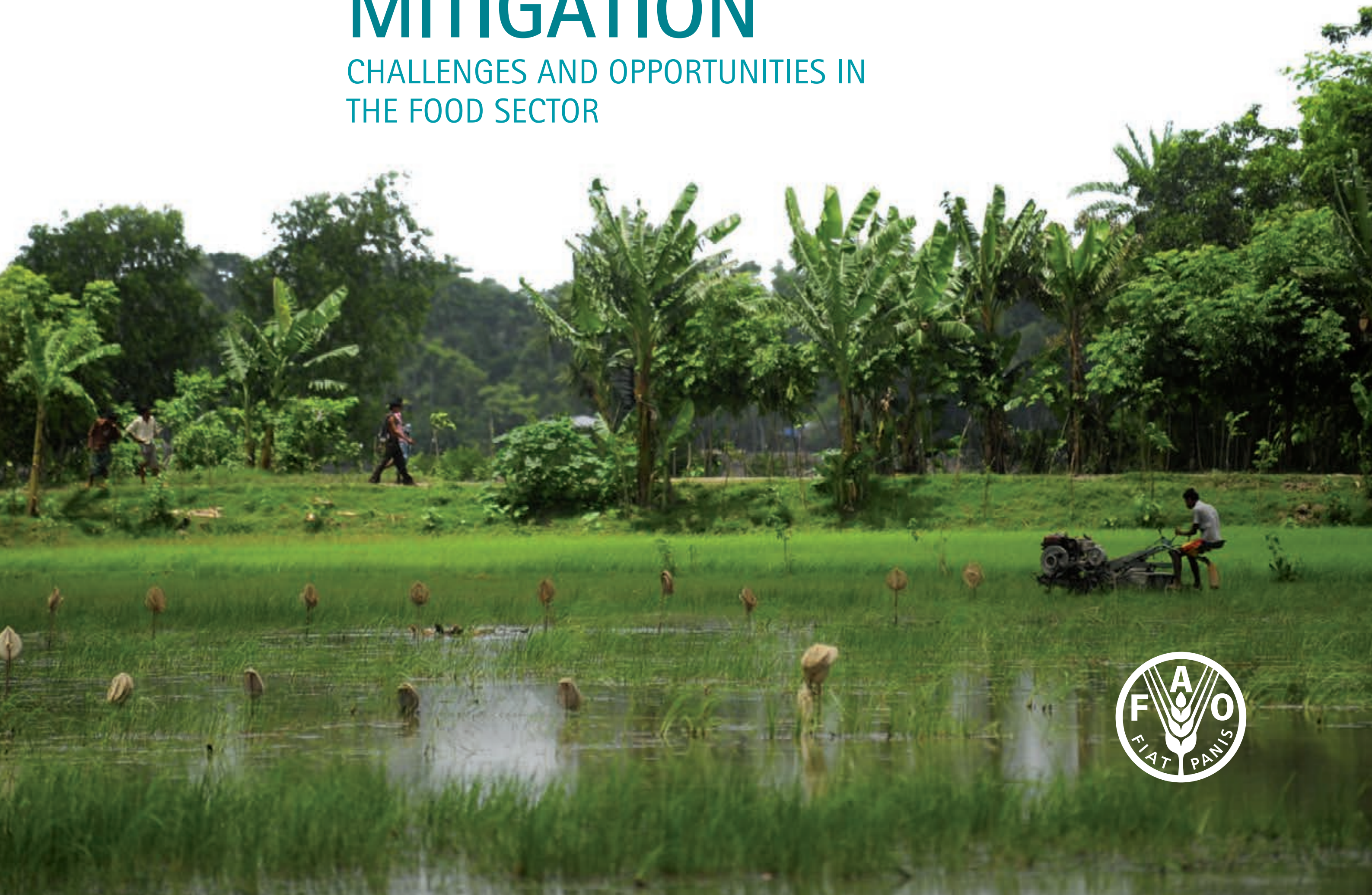
CLIMATE CHANGE ADAPTATION AND MITIGATION

CHALLENGES AND OPPORTUNITIES IN THE FOOD SECTOR



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CHALLENGES AND OPPORTUNITIES IN THE FOOD SECTOR

Food and Agriculture Organization of the United Nations (FAO)
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This publication reproduces one of the discussion papers of the High-Level Conference on World Food Security: the Challenges of Climate Change and Bioenergy, FAO, Rome, Italy, 3-5 June 2008 (www.fao.org/foodclimate). Should this study be revisited today, the author would define the implementation periods as follows: "short term" would be up to 2015, which is the time the international community requires for new climate agreements; "medium term" would be from 2015 to 2020, which is the run-up to the beginning of the new rules, as well as to implementation and to taking further the future role of agriculture in climate agreements; "long term" would be beyond 2020, which is the time for full implementation of the new rules, including the role of agriculture.

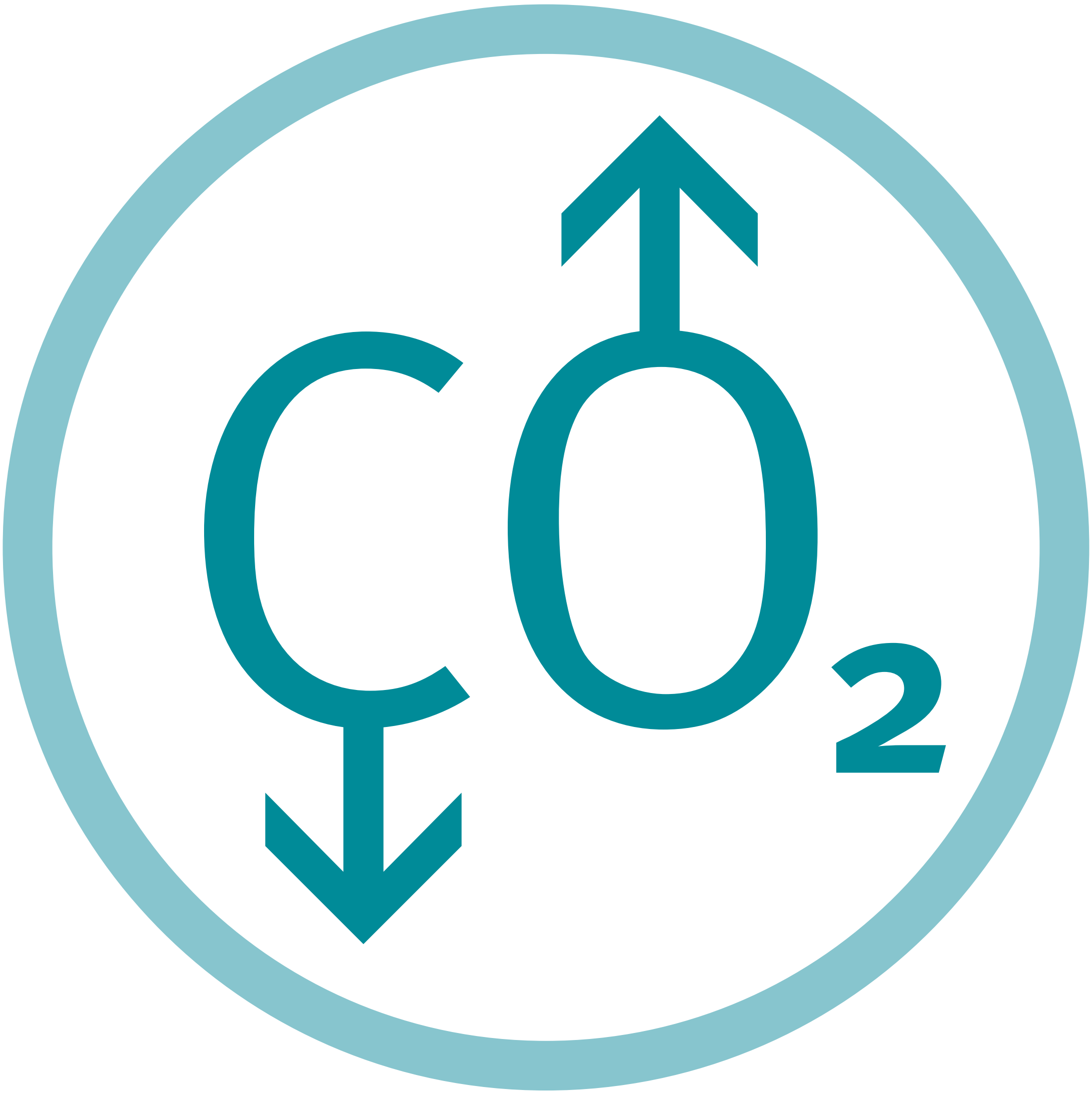
Tubiello, F. 2012. Climate change adaptation and mitigation: challenges and opportunities in the food sector. Natural Resources Management and Environment Department, FAO, Rome. Prepared for the High-level conference on world food security: the challenges of climate change and bioenergy, Rome, 3-5 June 2008.

TABLE OF CONTENTS

List of tables and boxes

ABBREVIATIONS AND ACRONYMS

A/R	Afforestation and Reforestation
CDM	Clean Development Mechanism
CGIAR	Consultative Group on International Agricultural Research
FR	Forest Restoration
IPCC	Inter-Governmental Panel on Climate Change
MDGs	Millenium Development Goals
REDD	Reducing Emissions from Deforestation and forest Degradation
SFM	Sustainable Forest Management including .
UNFCCC	United Nations Framework Convention on Climate Change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INTRODUCTION

Agriculture and the future of global food security figure very importantly in climate change negotiations. As stated in Article II of the United Nations Framework Convention on Climate Change (UNFCCC), the goal is to ensure stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent "dangerous anthropogenic interference with the climate system".

"Such a level," it mandates, "should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

Agriculture, rural livelihoods, sustainable management of natural resources and food security are inextricably linked within the development and climate change challenges of the twenty-first century. Indeed, not only is food security an explicit concern under climate change; successful adaptation and mitigation responses in agriculture can only be achieved within the ecologic, economic and social sustainability goals set forth by the World Food Summit, the Millennium Development Goals and the UNFCCC.

The scope of this paper is to identify a strategy for climate change responses in agriculture that are consistent with safeguarding food security, rural livelihoods and the provision of environmental services. Special focus is given to existing and potential future mechanisms necessary to support adaptation, mitigation, technology transfer and financing at national, regional and international levels.

The most important challenge for agriculture in the twenty-first century is the need to feed increasing numbers of people – most of whom are in developing countries – while at the same time, conserving the local and global environment in the face of limited soil and water resources and growing pressures associated with socio-economic development and climate change.

Projected population and socio-economic growth will double current food demand by 2050. To meet this challenge in developing countries, cereal yields need to increase by 40 percent, net irrigation water requirements by 40-50 percent, and 100-200 million ha of additional land may be needed, largely in sub-Saharan Africa and Latin America.

Food insecurity will continue to be a serious issue in coming decades. Despite significant projected overall reductions in hunger projected by the end of the century – from the current 850 million to about 200-300 million – many developing countries will continue to experience serious poverty and food insecurity, due to localized high population growth rates, poor socio-economic capacity and continued natural resource degradation. By the end of the century, 40 to 50 percent of all undernourished are expected to live in sub-Saharan Africa. Projections indicate that MDGs for undernourishment will not be met, despite robust projected economic growth. Indeed, prevalence of hunger may indeed be halved, but not before 2030, unless additional policy measures are implemented.

Climate change will superimpose itself on these existing trends, significantly increasing production risk and rural vulnerability, particularly in regions that already suffer from chronic soil and water resource scarcity, high exposure to climatic extremes including droughts and flooding, poverty and hunger (see Box 1). Climate change pressures will be compounded by a pronounced lack of sufficient knowledge, infrastructure, organization and resources that local populations and national governments need to cope with and adapt to climate change. This will be especially true in many poor tropical arid and semi-arid regions, increasing the risk of large overall negative impacts on food security, natural resources and rural livelihoods in coming decades and further increasing the gap between developing and developed countries.

Increased and new vulnerabilities

How resilient is the agricultural system in the face of future socio-economic pressures and climate change challenges of the next decades? To answer this, it is important to consider all relevant local, regional and international aspects determining the world food situation, from production to trade and supply.

Indeed, as has been seen, the recent increases in food prices and their immediate negative impacts on food security demonstrate that the current system is already, unexpectedly, quite vulnerable. Most importantly, one of the main factors identified as the cause of the current commodity cost crisis – climate extremes that have reduced production in key exporting countries – is the very factor that is projected to increase in frequency and severity in coming decades.

Although climate change will result in both challenges and opportunities for agriculture, it is well understood that factors that may have led to the current food security crisis are likely to multiply under climate change. In particular, climate change may further enhance the food import dependence of most developing countries.

Smallholder and subsistence farmers, pastoralists and fisherfolk in developing countries may not be able to cope with climate change effectively, due to reduced adaptive capacity and higher climate vulnerability. Under such conditions, pressure to cultivate marginal land or to adopt unsustainable cultivation practices as yields drop is likely, and may increase land degradation, water scarcity and endanger biodiversity. This vicious dynamic may lead to large-scale migrations, as rural poor populations abandon regions that no longer can support livelihoods, food and fuel.

Yet, in general, impact risk thresholds of food production systems are poorly represented in current impact assessments of agriculture under climate change. This has led to a dangerous complacency based on the assumption that impacts and related

Box 1
Key impacts of climate change

Global warming. Early decades of the twenty-first century will see a moderate warming of 1-2ºC, resulting in reduced crop yields in seasonally dry and tropical regions, while crop and pasture yields in temperate regions may benefit. Further warming in the second half of the century will negatively affect all regions, although agriculture in many developing countries in semi-tropical and tropical regions will bear the brunt of the effects.

Extreme climate events. Increased frequency and severity of extreme climate events, such as more heat stress, droughts and flooding, is expected in coming decades due to climate change. It will increase negative impacts on agriculture, forestry and fisheries in all regions. In particular, it will modify the risks of fires, and pest and pathogen outbreaks, with negative consequences for food, fibre and forestry.

Undernourishment. The number of undernourished is likely to increase by 5-170 million people by 2080, with respect to a baseline with no climate change. Even small amounts of warming will increase risk of hunger in poor developing countries, due to negative impacts on food production and availability. Most of the increases are projected in sub-Saharan Africa.

Food stability, utilization and access. Additional negative impacts of climate change on food security, with the potential of reducing access to and utilization of food in many regions already vulnerable today, are expected but have not been quantified. In particular, stability of food supply is likely to be disrupted by more frequent and severe climate extremes. Utilization of food may be affected negatively by increases in crop, livestock and human pests and diseases, as well as by reduced water availability and water quality, of importance for food preparation.

(Easterling, *et al.*, 2007)

crises will not become pronounced until the second half of this century. However, negative surprises such as continued increase in frequency of extreme events linked to droughts and flooding, and increased incidence of crop pests and diseases are likely, portending large impacts on food systems as early as the 2020s-2030s.

These are reasons for serious concern, especially in terms of significant negative effects on the most vulnerable, who are located in developing countries. At the same time, developed countries may face larger risks directly and indirectly, due to increased global vulnerability from climate change. This implies that adaptation and mitigation strategies to limit damage from climate change in developing countries must be consistent with, build upon and provide new direction for existing and future development plans focusing on rural poverty and agricultural development at all relevant scales, from national to international.

Agriculture and global climate change

Agriculture is not only a fundamental human activity at risk from climate change, it is a major driver of environmental and climate change itself. It has the largest human impact on land and water resources. About 1.4 billion ha of arable land (10 percent of total ice-free land) are used for crop cultivation and an additional 2.5 billion ha are used for pasture. Roughly four billion ha are forested land, five percent of which is used for plantation forestry. Two billion tonnes of grains are produced yearly for food and feed, providing two-thirds of total protein intake by humans. About ten percent of total world cereal supply is traded internationally. In addition, 150 million tonnes of fish and other aquatic products are consumed annually. Aquatic products contribute 50 percent or more of total animal protein intake in some small islands and other developing countries.

In addition to land resources, agriculture is a major user of water. Over 200 million ha of arable land is under irrigation, utilizing 2 500 billion m^3 of water annually, representing 75 percent of fresh water resources withdrawn from aquifers, lakes and rivers by human activity. Irrigation sustains a large portion of total food supply – about 40 percent in the case of cereals. Finally, significant quantities of chemical inputs are applied to achieve high yields in intensive production systems including about 100 million tonnes of nitrogen used annually, leading to significant regional pollution.

As a result of these large-scale activities, agriculture is a significant contributor to land degradation and, in particular, a major emitter of greenhouse gases. It emits into the atmosphere 13-15 billion tonnes CO_2e per year, about a third of the total from human activities. Overall, agriculture is responsible for 25 percent of carbon dioxide (largely from deforestation), 50 percent of methane (rice and enteric fermentation), and more than 75 percent of N_2O (largely from fertilizer application) emitted annually by human activities.

If emissions of greenhouse gases, including those from agriculture, are not controlled in the coming decades, continued growth of their atmospheric concentrations is projected to result in severe climate change throughout the twenty-first century. If “dangerous anthropogenic interference” with the climate system is to be avoided in coming decades and warming is to be limited to “acceptable” temperature increases, then stabilization of atmospheric concentrations must be achieved. This will require significant cuts in global emissions, starting now and certainly no later than 2020-2030.

In particular, a number of mitigation strategies in the agriculture and forestry sectors have been identified as useful in achieving the goal of stabilization of atmospheric concentrations between 450-550 ppm CO_2.[1] These include reduced deforestation and degradation of tropical forests (REDD), sustainable forest management (SFM) and forest restoration (FR), including afforestation and reforestation (A/R). In agriculture, they involve reduction of non-CO_2 gases through improved crop and livestock management and agroforestry practices, enhanced soil carbon sequestration in agricultural soils via reduced tillage and soil biomass restoration.

Table 1
Anthropogenic greenhouse gas emissions

2005	G tonnes CO_2e yr^{-1}	Share %
Global	50	
Agriculture	5-6	10-12%
Methane	(3.3)	
N_2O	(2.8)	
Forestry	8-10	15-20%
Deforestation	(5-6)	
Decay and Peat	(3-4)	
TOTAL Ag. & For.	13-15	25-32%

Sources: IPCC AR4, WGIII Chapters 8 and 9; UNFCCC 2007.

Table 2 indicates that technical mitigation potential achievable by a complex mix of actions in both the agriculture and forestry sector is significant. For comparison, it ranges between a third and a half of total mitigation required under a mid-range International Panel on Climate Change Special Reports on Emission Scenario (IPCC SRES) mitigation scenario. Most of the mitigation is achievable in the forestry sector, with important implications for climate policy options. Importantly, the total mitigation potentially achievable in the land-based sector is quite close to total emissions of the agriculture sector as a whole. If achieved, they would contribute to making this sector nearly carbon-neutral.

1 See also *Financial mechanisms for adaptation and mitigation to climate change in the food and agriculture sector* (HLC/08/INF/4), which is a companion paper to this one.

Table 2
Mitigation potential in agriculture and forestry in 2030

2030 Reductions	G tonnes CO_2e yr^{-1}
Global	15-25
Agriculture	1.5-5.0
Methane, N2O	(0.3-1.5)
Agroforestry	(0.5-2)
Agricultural soils	(0.5-1.5)
Forest	2.5-12
REDD	(1-4)
SFM	(1-5)
FR	(0.5-3)
Bioenergy	0.1-1.0
Total	4-18

Global reductions in 2030 correspond to those needed to achieve stabilization of atmospheric concentrations between 450-550 ppm CO_2, under a mid-range IPCC SRES.

Sources: IPCC AR4, WGIII Chapters 8 and 9.

Adaptation and mitigation strategies

Because of inertia with both the climate and socio-economic systems upon which greenhouse gas emissions depend, we are bound to face a degree of climate change and its related negative impacts, regardless of the mitigation strategy chosen. However, the sooner the mitigation activities begin, the lower the likely impacts. Nonetheless, adaptation will be needed to protect livelihoods and food security in many developing countries that are expected to be the most vulnerable, even under moderate climate change.

This indicates that the overall challenge of climate policy will be to find the efficient mix of mitigation and adaptation solutions that limit the overall impacts of climate change. This includes recognizing that many mutually re-enforcing synergies exist between specific mitigation and adaptation solutions that can lead to more efficient allocation of “climate response” resources. Importantly, many of these synergies exist in the forestry and agriculture sectors and are of great relevance to rural livelihoods in developing countries.

Global challenges and key perspectives

Climate change brings critical new perspectives to important global challenges relevant to food security and rural livelihoods. Mainstreaming climate change issues into development is a necessary step of overall development policy, but it is not sufficient. To be sufficient, sustainable development policies must also be reformulated in order to include important new temporal and spatial scales that have become relevant only because of climate change.

Actions to limit damage from climate change need to be implemented now in order to be effective. Mitigation actions involve direct reduction of anthropogenic emissions or enhancement of carbon sinks that are necessary for limiting long-term climate damage. Adaptation is necessary to limit potential risks of the unavoidable residual climate change now and in coming decades. Importantly, there are significant differences in the policy nature underlying adaptation and mitigation actions. The benefits of adaptation choices will be realized almost immediately but will matter most under moderate climate change, perhaps up to about mid-century. By contrast, benefits of mitigation may only be realized decades from now, becoming relevant towards the end of the century.

It follows that a significant challenge of climate policy is to identify and then develop instruments that allow for a portfolio of adaptation and mitigation strategies that are effective in time and space and focus on balancing actions across the most appropriate sectors, and within the chosen scope of specific climate response policies. In the case of a focused priority on food security and rural vulnerability, a number of limitations on the usefulness of certain mitigation strategies may emerge with respect to adaptation requirements.

One important example is related to bioenergy and biofuel production which, as a mitigation strategy, may have benefits for rural incomes and thus development. However, in order to prevent serious negative repercussions on food prices, ecosystem functions including biodiversity and carbon cycling, and local food availability, they need to be planned at the appropriate regional and local scales, and in conjunction with focused rural development policy.

All four dimensions of food security will be negatively affected by climate change in the coming decades. While adaptation strategies that minimize expected impacts on access, stability and utilization of food resources involve largely local- to regional-scale actions, safeguarding food availability also requires a global perspective. Climate change adaptation strategies should aim at maintaining, or even increasing, food production in key exporting developed and developing regions, or in regions key to regional food security. Any significant change in food production in these areas, including change resulting from climate change impact, has potential to affect global and regional availability, stability and access to food through direct and indirect repercussions on international and local markets.[2]

Box 2
Adaptation strategies in agriculture

- Altering inputs, varieties and species for increased resistance to heat shock and drought, flooding and salinization; altering fertilizer rates to maintain grain or fruit quality; altering amounts and timing of irrigation and other water management; altering the timing or location of cropping activities.
- Managing river basins for more efficient delivery of irrigation services and prevent water logging, erosion and nutrient leaching; making wider use of technologies to "harvest" water and conserve soil moisture; use and transport water more effectively.
- Diversifying income through the integration of activities such as livestock raising, fish production in rice paddies, etc.
- Making wider use of integrated pest and pathogen management, developing and using varieties and species resistant to pests and diseases; improving quarantine capabilities and monitoring programmes.
- Increasing use of climate forecasting to reduce production risk.
- Matching livestock stocking rates with pasture production, altered pasture rotation, modification of grazing times, alteration of forage and animal species/breeds, integration within livestock/crop systems including the use of adapted forage crops, re-assessing fertilizer applications and the use of supplementary feeds and concentrates.
- Undertaking changes in forest management, including hardwood/softwood species mix, timber growth and harvesting patterns, rotation periods; shifting to species or areas more productive under new climatic conditions, planning landscapes to minimize fire and insect damage, adjusting fire management systems; initiating prescribed burning that reduces forest vulnerability to increased insect outbreaks as a non-chemical insect control; and adjusting harvesting schedules.
- Introducing forest conservation, agroforestry and forest-based enterprises for diversification of rural incomes.
- Altering catch size and effort and improving the environment where breeding occurs; reducing the level of fishing in order to sustain yields of fish stocks.

(Howden, *et al.*, 2007)

2 Although important large-scale policy and economic decisions are made at the national and international level (including those for bioenergy policy, trade barrier policies and subsidies that have significant impact on food security elsewhere and at local and regional scales) they are not within the scope of this paper and will not be discussed in detail, except when clear interactions with mitigation policy exist.

Climate responses and food security

Strategies that help reduce the potential negative impacts of climate change on food production systems with a focus on rural livelihoods in poor developing countries serve to maintain global and regional food security and must be a priority of climate policy responses.

A commitment to feeding the hungry and lifting increasing numbers of rural farmers in developing countries out of poverty for current and future generations must be a strong focus of adaptation and mitigation planning. Augmenting resilience in vulnerable systems and increasing capacity to adapt with a focus on food security is achievable through specific cultural, technical, system and policy options that are embedded within, but also informing, socio-economic development strategies (e.g. diversification of income, rural energy planning) (See Box 2).

Box 3
Synergies in adaptation and mitigation

Reducing methane emissions via integrated rice and livestock systems traditionally found in West Africa, India, Indonesia and Vietnam, is a mitigation strategy that also results in better irrigation water efficiency – it can also provide new sources of income while improving performance of cultivated agro-ecosystems, and enhance human well-being.

Reducing N_2O emissions – can lead to improved groundwater quality and reduced loss of biodiversity.

Integrating animal manure waste management systems, including biogas capture and utilization, for reductions of CH_4 and N_2O – could result in greater demand for farmyard manure and create income for the animal husbandry sector where many poor are engaged.

Restoring land by controlled grazing – can lead to soil carbon sequestration , have positive impacts on livestock productivity, reduce desertification and also provide social security to the poor during extreme events such as drought (especially in sub-Saharan Africa).

Practicing agroforestry – can promote soil carbon sequestration while also improving agro-ecosystem function and resilience to climate extremes by enriching soil fertility and soil water retention.

(Smith, *et al.*, 2007)

Useful synergies for adaptation and mitigation in agriculture, relevant to food security exist and should form the core of climate policy planning and implementation at national and international levels. These include avoided deforestation, forest conservation and management, agroforestry for food of energy, land restoration, recovery of biogas and waste and, in general, a wide set of strategies that lead to conserve soil and water resources by improving their quality, availability and efficiency of use. These strategies are often deeply rooted in local cultures and knowledge, as well as the focus of research, support and application by key international agencies and non-governmental organizations (NGOs). They all tend to increase resilience of production systems in the face of increased climatic pressures, while providing significant carbon sequestration or reducing land-based greenhouse gas emissions. As shown in Box 3, many of these synergies are also relevant to social, economic and environmental sustainability. It is important to recognize, however, that these synergies are often region and system specific, and need to be evaluated case by case.

Several adaptation practices may positively reinforce land mitigation potentials under specific conditions. For example, increased irrigation and fertilization necessary to maintain production in marginal semi-arid regions under climate change conditions may also greatly enhance the ability of soils in those areas to sequester carbon. This would be especially true in sub-Saharan Africa where small improvements in resource use efficiency can have very large effects on biomass production of crops while restoring carbon pools and soil quality. Under scenarios with increased precipitation, especially at mid-latitudes, a shift from fallow systems to continuous cultivation (including also cover crops) would maximize production under the new precipitation conditions and, at the same time, increase soil carbon sequestration potential.

However, some mitigation responses may not be conducive to adaptation. For instance, bioenergy and some land conservation programmes may involve actions that introduce new competition for land and water resources otherwise necessary for enhancing system resilience and safeguarding food production under climate change.

LINKING ADAPTATION AND MITIGATION WITHIN CLIMATE POLICY MECHANISMS

The Bali roadmap[3] indicates that actions aimed at safeguarding food security and rural livelihoods under climate change in the coming decades must focus on synergies between adaptation and mitigation strategies in the agricultural and forestry sectors in order to address climate, environmental, social and economic concerns expressed within both the UNFCCC and the MDGs.

There is a very large, and currently untapped, potential for mitigation in the land sector, related to project activities that are not currently allowed under the Clean Development Mechanism (CDM), such as avoided deforestation, enhanced forest management and agroforestry. To a much lesser extent, it could also include soil carbon sequestration in agricultural soils, which is extremely relevant to improving rural livelihoods and food security prospects: directly, through project activities that strengthen soil and water quality in areas already vulnerable today or indirectly, through increased diversification and income possibilities that are still land based, but away from high-risk subsistence food production.

By including these categories of activities within a modified post-2012 mechanism, additional sequestration potential of up to 10-15 billion tonnes CO_2e yr^{-1} could be generated by 2030. This would be sufficient to counter emissions of greenhouse gases for the entire agricultural and forestry sectors combined, thus making them nearly carbon neutral.

Importantly, mitigation strategies based on forestry and agroforestry activities would generate large revenue. Resources freed up from mitigation investments in less cost-effective areas could be used instead for implementing adaptation activities that are needed to safeguard food security and improve rural livelihoods in the face of climate change, without having to be bound at every step by mitigation constraints.

By focusing mitigation objectives in key cost-effective sectors, adaptation needs in key food producing activities could be chosen to provide mitigation at the same time. Indeed, several adaptation activities leading to increased systems resilience and improved rural incomes may still have significant mitigation value, resulting in no-regrets, win-win situations. For example, this would include the entire set of good practices that lead to improved soil and water resource conservation.

3 The Bali Roadmap presents the climate change adaptation and mitigation strategies of the UNFCCC and the financial mechanisms that have been established within it as a unique opportunity for developing countries.

POLICY AND TECHNOLOGY REQUIREMENTS

Coordinated national, regional and international actions are needed to ensure that issues of food security are part of adaptation, that they address issues of importance to the rural poor and that they provide effective integration with sensible mitigation policy.

Expanding the role of adaptation and mitigation within development policy

As discussed in IPCC Fourth Assessment Report (AR4) Working Group II (WGII), adaptation and mitigation under climate change will require dynamic policies to cope with the high level of uncertainty in the timing and magnitude of potential climate changes and the rapidly evolving knowledge. Furthermore, climate change adaptation policies will interact with sustainable development and natural resource management, such as those necessary to protect human and animal health, foster governance and political rights. These interactions are necessary for broad resilience to risk.

Adaptation choices inform public and private actors of the investment or disinvestment decisions they need to make now and in the near-future in relation to agriculture. For instance, this includes long-term investments in plant and animal breeding programmes (including of under-utilized crops), building capacity in the science and user communities, developing quarantine systems, establishing perennial crops and forest plantations, making land purchases or sales, building (or decommissioning) major infrastructure such as dams and water distribution systems, flood mitigation works, and storage and transport facilities, as well as shorter-term investments to ensure access to food and safety nets. As discussed previously, maximizing societal welfare under future climate risk will likely involve a mix of both adaptation and mitigation, the percentage contribution of each strategy depending on monetary and non-monetary cost-benefit analyses.

Data, Research and operational requirements

With respect to food security and vulnerability of poor farmers in developing countries, specific challenges to adaptation exist. Smallholder and subsistence farmers, including forest dwellers, will suffer locally specific impacts of climate change that will be hard to predict. The variety of crop and livestock species produced and the importance of non-market relations increases the complexity of impacts and adaptation solutions. Small farm sizes, low technology, low capitalization and diverse non-climate stressors will tend to increase vulnerability. Yet, it is important to recognize the presence of resilience factors such as family labour, diversity of plant and animal species, patterns of diversification away from agriculture and possession of indigenous knowledge that may be useful in designing less vulnerable production systems.

Food security systems of the rural poor in developing countries are built around livelihoods of subsistence and smallholder farmers, forest dwellers, pastoralists and artisanal fisherfolk. These farming and survival systems have been characterized as "complex, diverse and risk-prone." Farms are generally small, often held under traditional or informal tenure, and are in marginal or risk-prone environments. Soil-related constraints to productivity are widespread, severe and increasing, although diversity of soils and farmer soil management strategies are also important. Production systems are complex and diverse in the combinations of plant and animal species exploited, the types of integration among them, the production objectives and the institutional arrangements for managing natural resources. Risks are also various, including drought and flood, crop and animal disease, and market shocks, and may be felt by individual households or entire communities.

A conceptual framework is needed to better understand the impacts of climate change on smallholder and subsistence agriculture, and on related livelihoods such as pastoralism and artisanal fishing. This requires harnessing the growing understanding of the biological processes involved as climate change impacts on crop and livestock production as they relate to the specific features of these livelihoods. According to the IPCC[4], such a framework should do the following:

- Recognize the complexity and high location-specificity of these production systems.
- Incorporate non-climate stressors in rural livelihoods and their contribution to vulnerability.
- Recognize that climate change impact on smallholder livelihoods is manifold and scale dependent, including: biological processes affecting crops and animals at the levels of individual organisms or fields; environmental and physical processes affecting production at landscape, watershed or community levels; and impacts of climate change on human health and non-agricultural livelihoods.

It is particularly important to align the scale (both spatial and temporal) and reliability of the information with the scale and nature of the decision. Bottom-up assessments of the potential technical effectiveness of farm-level adaptations in the face of long-term projections, including changes in climate variability, may be quite useful for input into policy and investment analyses.

4 Inter-governmental Panel on Climate Change, 2007. Assessment Report 4, Working Group II, Chapter 5.

Fundamentally, adaptation to climate change is no different from adaptation to climate variability, changes in market forces such as cost-price ratios and consumer demands, and institutional or other factors. A critical difference with these other factors is timing, Importantly, planners need to avoid negative “lock-ins”, by making sure that adaptations now do not undermine the ability of systems to cope with potentially larger impacts later in the century. Importantly, risk reduction in adaptation will depend on the rate of realized climate change, compared to how fast we are able to plan, develop and implement needed solutions.

Box 4
Actions needed to facilitate adaptation responses

Climate monitoring efforts and communication of information: essential to convince farmers that climate changes projections are real and require response actions. Information services should include surveillance of pests, diseases and other factors of importance to production systems.

Policies that support research, systems analysis, extension capacity, industry and regional networks: need to be strengthened in order to provide managers with understanding, strategic and technical capacity to protect their enterprises.

Investment in new technical or management strategies: required so that, where existing technical options are inadequate, options necessary to respond to the projected changes become available. These include improved crop, forage, livestock, forest and fisheries germplasm.

Training for new jobs based on new land uses, industry relocation and human migration: needed where climate impacts lead to major land use changes. This may be achieved through direct financial and material support, alternative livelihood options with reduced dependence on agriculture, community partnerships for food and forage banks, development of new social capital and information sharing, ensuring food aid and employment for the more vulnerable, and development of contingency plans.

New infrastructure, policies and institutions: may be needed to support the new management and land-use arrangements, such as investment in irrigation infrastructure and efficient water-use technologies, appropriate transport and storage infrastructure, revising land tenure arrangements and property rights, and establishing accessible, efficient markets for products, financial services including insurance, and inputs including seed, fertilizer and labour.

Policy must maintain the capacity to make continuing adjustments and improvements in adaptation through “learning by doing” with targeted monitoring of adaptations to climate change and their costs, benefits and effects.

(Howden, *et al.*, 2007)

Changing the decision environment

Adaptation at the management unit level, based on current decision environments, may not be fully adequate for coping with climate change. Planning at local, regional, national and international levels will be needed in order to facilitate a broader range of responses. Many options for policy-based adaptation to climate change have been identified for agriculture, forests and fisheries. These can involve adaptation activities, such as developing infrastructure, capacity building in the broader user community and within institutions and, in general, modifications to the decision-making environment under which management-level adaptation activities typically occur.

The process of mainstreaming adaptation into policy planning in the face of risk and vulnerability is an important component of adaptation planning. However, there are many environmental, economic, informational, social, attitudinal and behavioral barriers to implementation of adaptation and mitigation (see Boxes 4 and 5). Participatory approaches are needed to utilize appropriate scientific knowledge while retaining a focus on values important to stakeholders.

Box 5
Barriers to mitigation

Maximum storage. Carbon sequestration in soils or terrestrial biomass may saturate after 15 to 60 years, depending on management practice, management history and the system being modified.

Reversibility. A subsequent change in management can reverse the gains made in carbon sequestration over a similar period of time. However, many agricultural mitigation options are not reversible, such as reduction in N_2O and CH_4 emissions, avoided emissions as a result of agricultural energy efficiency gains or substitution of fossil fuels by bioenergy.

Reference: The greenhouse gas net emission reductions need to be assessed relative to a reference baseline. The selection of an appropriate baseline to measure management-induced soil carbon changes is still an obstacle in some mitigation projects.

Uncertainty. Uncertainty about the complex biological and ecological processes in agricultural systems makes investors more wary of land-based mitigation options compared to more clear-cut industrial mitigation activities. This barrier can be reduced by investment in research. In addition, high variability at the farm level can be reduced by increasing the geographical extent and duration of the project.

Unclear leakage. Adopting certain agricultural mitigation practices may reduce production within implementing regions, leading to increased production and emissions outside the project region.

Transaction costs. Under an incentive-based system such as a carbon market, the amount of money farmers receive is not the market price, but the market price less brokerage cost. This may be substantial and a serious entry barrier for smallholders. Pooling many activities together can serve to lower transaction costs of participating farmers.

Measurement and monitoring costs. Measurement costs per carbon credit sold decrease as the quantity of carbon sequestered and area sampled increase. Methodological advances in measuring soil carbon may reduce costs and increase the sensitivity of change detection. Development of remote sensing may offer opportunities to reduce costs.

Property rights. Property rights, landholdings and the lack of clear single-party land ownership in certain areas may inhibit implementation of management changes.

Other barriers. Other barriers include availability of capital, rate of capital stock turnover, rate of technological development, risk attitudes, need for research and outreach, consistency with traditional practices, pressure for competing uses of agricultural land and water, demand for agricultural products, high costs for certain enabling technologies.

(Smith, *et al.*, 2007)

POLICY OPTIONS

A series of coherent and integrated development policies in the area of safeguarding food security and rural livelihoods, while implementing adaptation and mitigation measures for climate change, are possible based on the concepts and scope of activities identified in the previous sections. Importantly, there is a need to integrate national and international scales by, for instance, including national plans for food security and forest stewardship into adaptation actions, so that international goals under UNFCCC and MDGs are not only met, but mutually strengthened.

At the same time, there is a need for the UN food agencies to take an active role in coordinating participation in the post-2012 process of the Bali roadmap, so that synergies between adaptation and mitigation actions favorable to rural development and food security are enhanced and properly rewarded. In particular, increased access to climate mechanisms can insure that adaptation actions are implemented in a timely fashion, significantly enhancing resilience to climate change in developing countries while supporting their social, economic and ecologic sustainability.

Short-term (current to 2012)

The objective of short-term recommendations is food security safeguards in multilateral and national policy instruments that focus on eradicating hunger at global, regional and local levels.

International level

Global actions include climate change issues for support and active contribution to UNFCCC-related strategies on adaptation, mitigation, financing and technology transfer, in view of the special role and opportunities identified for the land sector in poor developing countries. This requires focused attention to ensure that important agriculture and forestry sectors, such as avoided deforestation, forest management, agroforestry, soil carbon sequestration in agricultural soils, are included in the post-2012 mechanisms at international level, including:

- Conference of the Parties of the UNFCCC in Copenhagen, in 2009;
- The Post-Kyoto new and enhanced financial mechanisms;
- GEF: exploring potential of GEF funds for land-based adaptation and mitigation;
- UN and international institutions: seeking effective coordination of UN agencies and other international institutions through partnerships for effective research and development and planning for adaptation and mitigation in the context of food security and rural livelihoods, including a joint strategy for assistance under climate change.

Increasing visibility of food security issues is necessary within the broad climate change community itself, especially for efforts of high policy relevance such as:

- proposing and supporting development of an IPCC special publication on *Food security and climate change*;
- fostering enhanced CGIAR-system research programme on climate change and food security, in cooperation with relevant environmental programmes;
- creating a climate change focus within the Global Platform for Disaster Risk Reduction, as part of the Hyogo Framework for Action to reduce the vulnerability of communities exposed to natural hazards.

Such global efforts must include a focus on international coordination between exporting and importing nations, within the context of food security. For instance, appropriate trade policies coherent with the need to increase financial and investment flows to producers in developing countries should include a move to reduce or eliminate barriers to trade and agricultural subsidies, and set guidelines for non-food sectors competing with food production for land and water resources, such as bioenergy.

National level

Effective support to international climate negotiations presupposes strong support of policies and direct contribution of ideas from the national level. Awareness and preparedness on the issues of linkages among food security, climate change and development are best achieved by supporting the following areas:

- including food security targets in National Adaptation Programmes of Action;
- developing specific climate-related targets in National Programmes for Food Security and National Forestry Programmes, including improved adaptive management of natural resource use for reduced system vulnerability and increased resilience to shocks;
- building community capacity of subsistence and smallholder farmers, pastoralists and fisherfolk, with a view to collect indigenous knowledge and enhance resilience through activities such as those aimed at improving rural livelihoods through income diversification.

Medium-term TO Short-term (current to 2020-2030)

Whereas short-term focus must be on putting in place the necessary policy frameworks for action, based on existing and ongoing processes and institutions, the strategy for the medium term must focus on developing practical actions for combating climate change impacts locally and regionally, specifically for poor developing countries most at risk. This requires increased coordination and monitoring:

- Coordination: local actions must be coordinated at national and international levels, in order to maximize resources while keeping response options open to avoid lock-in situations in later decades as climate change impacts progress.

- Monitoring: observation networks and data platforms are needed for monitoring both climate and food production systems. These need to be integrated with climate and impact projections, in order to provide policy-makers and stakeholders with information necessary for understanding adaptation options and needs at successive time horizons, as well as to identify risk thresholds and the steps needed to avoid them. These could take the form of simple climate impact and adaptation "indices" or "metrics". In addition, enhanced monitoring of food supply and demand pressures, embedded in short-to-medium term projections based on socio-economic trends, should be used to evaluate costs and benefits of proposed adaptation and mitigation strategies.

National and international development, implementation and coordination of large-scale avoided deforestation, agroforestry and ecological management in agriculture would need to parallel adaptation efforts. To this end, national and international efforts are needed to insert adaptation and mitigation goals directly into sustainable development strategies.

Longer term (current to 2050 and beyond)

Climate change response strategies that include a focus on rural livelihoods and food security need to be framed within comprehensive and socio-economic development policies that transcend current models. This requires strategies that aim at conserving natural resources and limit carbon footprints in the face of large demand for food, water and other environmental services.

In particular, it should be recognized that beyond 2050, land-based mitigation from avoided deforestation, agroforestry and soil carbon sequestration in agricultural soils, necessary to stabilize emissions in the short term, would have largely reached their potential. New green technologies and land management options will then be necessary to mitigate emissions of greenhouse gases while making agriculture carbon neutral.

It is critical to reducing the overall carbon footprint of agriculture and forestry, and maintaining soil and water resources in the face of socio-economic pressures and climate change while, at the same time, safeguarding food security through enhanced rural livelihoods. This will require attention to complex spatial, temporal and sector interactions that characterize the entire food and ecosystem service chain starting from local production and considering safety and health controls and transport, infrastructure, processing and consumption patterns.

Open economic trade, reduced subsidies and income diversification, coupled with potential new income for rural populations from enhanced environmental services (including carbon and energy), likely represent important steps for sustaining successful adaptation and mitigation strategies.

GLOSSARY OF TERMS

Adaptation. Adjustments in natural or human systems in response to climatic changes. *Autonomous*: Adjustments initiated and implemented by individuals, households or private companies. *Planned*: Adjustments initiated and implemented by governments at all levels. Public adaptation is usually directed at collective needs.

Adaptive capacity. The ability to adjust to climate change to cope with potential damages or take advantage of new opportunities.

Baseline. The baseline (or reference) is the state of a system against which change is measured.

Climate variability. Climate variability refers to variations in the mean state 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 (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

Emission scenario. A plausible representation of the future development of greenhouse gas emission and other anthropogenic forcing, based on socio-economic scenarios.

Extreme event. An event that is rare within its statistical reference distribution over a certain period of time (e.g. rainfall over a season, frequency of floods, droughts).

Impact assessment. The study and quantification of potential consequences of climate change on natural and human systems at local, regional or global scales.

Impacts. Consequences of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts.

Market impacts. Impacts on ecosystems, sectors and people that can be directly expressed as monetary costs or benefits – for example, changes in the food supply, price of agricultural goods or land value.

Non-market impacts. Impacts that affect ecosystems, sectors and people, which are not easily quantifiable in monetary terms – for example, increases in risk of hunger.

Mitigation. An intervention aimed at reducing the severity of climate change by controlling emissions of greenhouse gases and/or enhancing carbon sinks.

Resilience. Amount of change a system can undergo without changing state.

Sensitivity. The degree to which a system is potentially affected by the climate variations it is exposed to.

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