Agriculture and Climate Change

A Scoping Report

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Preface

This Report was developed in the context of the "Global Dialogue on Climate Change and Agriculture," a project facilitated by the Meridian Institute that began in August 2010. The Meridian Institute is an internationally recognized, nonprofit organization that facilitates neutral and independent policy dialogues and assessments. The Global Dialogue is a program intended to provide relevant information and opportunities for productive engagement and discussion among government negotiators, experts, stakeholders, and others involved and interested in climate change and agriculture. For this report, the Institute convened a team of international, independent expert authors, and facilitated the work of the author team as well as a series of informal dialogues with a broad range of country negotiators, nongovernmental organizations, and agricultural experts.

The report is intended to provide context and analysis for addressing agriculture in international climate negotiations with the aim of helping to inform climate negotiators and other stakeholders by identifying options and unpacking issues of interest; and not to express opinions or be prescriptive. To achieve this objective, the report was guided by an iterative process comprised of dozens of individual interviews from August to December 2010, and two in-person group consultations convened February 15-17, 2011 in Johannesburg, South Africa, and April 11-13, 2011, in Bangkok, Thailand.

Both the interviews and group consultations provided invaluable guidance to the author team, and also served as opportunities to discuss and better understand the range of perspectives associated with agriculture and its role in international climate policy. Feedback from stakeholders helped identify and shape the topics covered in this report, and ultimately ensured that the author team took into account complexities and interlinkages of the sector in relation to climate change.

Only the authors are responsible for the content of this report. The consultations did not seek agreement since they were convened to help the authors better understand the dimensions of key issues associated with climate change and agriculture. This report is the work of the authors alone, not of the Meridian Institute or of those consulted.

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Acronyms and Abbreviations

AoA	Agreement on Agriculture
AWD	alternate wetting and drying
AWG-LCA	Ad-Hoc Working Group on Long-Term Cooperative Action
BAU	business as usual
BIIS	Bohol Integrated Irrigation System
CDM	clean development mechanism
CFS	Committee on World Food Security
CGIAR	Consultative Group on International Agricultural Research
CH_4	methane
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COP	Conference of Parties to the UNFCCC
COP/MOP	COP serving as Meeting of the Parties to the Kyoto Protocol
CSIRO	Commonwealth Scientific and Industrial Research Organization
CTCN	Climate Technology Centre and Network
EPPs	environmentally preferential products
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GHG	greenhouse gas
Gt	gigatonne
ICTSD	International Centre for Trade and Sustainable Development
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
IPRs	intellectual property rights
ISO	International Standards Organization
KP	Kyoto Protocol
LDCs	Least-developed countries
LULUCF	land use, land-use change and forestry
MRV	monitoring, reporting, and verification

Mt	megatonnes
N_2O	nitrous oxide
NAMAs	nationally appropriate mitigation actions
NAPAs	national adaptation programmes of action
NCAR	National Center for Atmospheric Research
NGO	nongovernmental organization
ODA	official development assistance
OECD	Organization for Economic Co-operation and Development
PES	payment for environmental services
REDD+	reduced emissions from deforestation and forest degradation, and the role of conservation of forest carbon stocks, sustainable management of forests, and enhancement of forest carbon stocks
SBI	Subsidiary Body for Implementation
SBSTA	Subsidiary Body of Scientific and Technical Advice
TEC	Technology Executive Committee
UNFCCC	United Nations Framework Convention on Climate Change
WTO	World Trade Organization

Executive Summary

This report, *Agriculture and Climate Change: A Scoping Report*, is a product of the Meridian Institute-convened Global Dialogues on Climate Change and Agriculture initiated in August 2010. Reflecting the special characteristics of the agricultural sector, this report aims to contribute to continued policy discussion on agriculture and climate change in the context of the UN Framework Convention on Climate Change (the Convention). Agriculture is characterized by a number of special features that distinguish it from other sectors, such as the sector's role in producing food and meeting basic survival needs; its context and site-specific nature that makes uniform strategies and solutions ineffective; the vulnerability of the sector to being directly affected by climate change compared with most other sectors; its adaptation needs and mitigation potential, mainly through sequestration; and, finally, its complex links to food security, trade, and broader land-use and forestry policies.

Impact of climate change on agriculture. The increase of the world's population to 9 billion people by 2050, the rise in global calorie intake by 60 percent between 2000 and 2050 due to greater affluence, as well the rising demands on land for the generation of food and fuels, will require significant increases in agricultural productivity in the context of more constrained availability of resources. With agriculture contributing 29 percent of developing countries' gross domestic product and providing employment to about 20 percent of the global and 65 percent of developing countries' populations, the impacts of climate change on agriculture have repercussions on livelihoods, food production, and the overall economies of countries. At the same time, the agricultural sector holds significant climate change mitigation potential through reductions of greenhouse gas emissions as well as enhancement of agricultural sequestration.

Food production and climate change. The globally accepted definition of food security is that "food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life." Article 2 of the Convention refers to food security more narrowly when it states that climate change mitigation should be achieved within a time frame sufficient to ensure, among other things, that *food production* is not threatened, ecosystems can adapt naturally, and economic development is pursued in a sustainable manner.

Given growing global food production needs, a carbon-neutral agricultural sector may be difficult to achieve in the short term. Therefore, it may be more appropriate to focus policy interventions on meeting global food production requirements without commensurate increases in emissions. Climate change mitigation may be achieved through greater efficiency in agricultural production (thereby lowering the emissions "intensity" per unit of production) and in some cases through absolute reductions in greenhouse gas emissions, including removal through sequestration in agricultural soils and biomass. However, increasing the profitability of agricultural lands can act as an incentive to expand them, often at the expense of forests. Policymakers must consider these interconnected and dynamic opportunity costs to farmers and forest communities when faced with the multiple objectives of meeting agriculture and adaptation needs, forest conservation goals, and climate change mitigation targets. Integrated land-use planning and landscape approaches may help in the development of appropriate policies as they allow the integration of multiple goals within spatial planning.

Effective mitigation policies could also increase the capacity of farming and food systems to cope with climate change while maintaining or increasing food production. Both farm-level adaptation options and higher-level policies and investments to enable their adoption will be necessary for effective agricultural adaptation. In addition to agricultural measures, there is considerable scope for adaptation throughout the food chain; for example, better post-harvest storage and distribution of food could have a significant positive effect.

National policies and early action. Although there is widespread recognition that the challenges of food security and climate change are closely linked within the agriculture sector, too often, policy, institutional arrangements, and funding channels for climate change, food security, and rural development are poorly coordinated at international levels, and in many cases, at national levels. Early action on climate change in the agricultural sector allows countries to prepare for near- and longer-term agricultural adaptation and mitigation action, closely linked with national food security and development efforts. The concept of climate-smart agriculture focuses on maximizing benefits and minimizing negative trade-offs across the multiple objectives that agriculture is being called upon to address: food security, development, and climate change adaptation and mitigation.

There is as yet no blueprint for climate-smart agriculture. However, there are a number of "early action" measures countries and communities could take to facilitate confidence, capacity, knowledge, and experience to transition to sustainable, climate-smart agricultural production systems. Such measures include data collection, policy development, and the support of demonstration activities. Pursuing early action activities will result in country-specific data and knowledge as well as experience with agricultural practices and policies that could inform long-term national strategies. A strategy that brings together prioritized action, financial incentives, investment policies, institutional arrangements, tenure security, and aggregating mechanisms constitutes an important step in the transition to climate-smart agriculture.

Trade dimensions. Feeding the world's population in a context of climate change will require a gradual and significant expansion of transborder exchanges of agricultural products. It will be imperative to ensure a mutually supportive approach between climate change and trade policies as they relate to agriculture. The biophysical impacts of climate change will alter crop and animal productivity and will further accentuate current trends toward higher food prices. As a result, developing countries' agricultural imports are expected to double by 2050 due to climate change. This evolution is mirrored by a similar increase in developed-country exports. These changes will affect individual countries differently depending on the extent to which they rely on agricultural trade as part of their food security and development strategy. International trade, combined with increased investment in agriculture, can provide an important mechanism to offset climate-induced production decreases in certain regions, and secure access to and availability of food that otherwise may be scantly accessible through domestic production.

Some of the climate change mitigation (response) measures that have emerged in recent years—such as carbon standards and labeling, subsidies for reducing greenhouse gas emissions or promoting alternative energy sources (e.g., biofuels), discussions on border tax adjustments, and free emission allowances under cap-and-trade schemes—may pose challenges to existing trade agreements, depending on how they are designed. Overall, however, good-faith climate change policies are unlikely to breach existing multilateral trade rules, either because they would not be discriminatory or because, if they are, they may be covered by the general exception under the World Trade Organization's (WTO) General Agreement on Tariffs and Trade (GATT) Article XX. Many potential conflicts can be avoided if international consensus on a climate change framework is reached. Possible avenues to advance discussions on trade and climate change can be explored under the Convention and/or in the multilateral trading system.

Enabling conditions. Adopting agricultural practices that are able to withstand changes in climate and contribute to the reduction of greenhouse gas emissions require the application of new technologies, the modification of existing ones, and changes to relevant laws and policies. Technology deployment and related capacity building in agriculture comes with significant costs for which developing countries, in particular, need financial support.

Under the Cancun Agreements, developed countries confirmed their commitment to provide new and additional resources, including forestry and investments through international institutions, approaching US$30 billion for the period 2010–2012 and to mobilize US$100 billion annually by 2020. In the context of agricultural mitigation and adaptation, the following international financing channels may be considered: the Global Environment Facility Trust Fund, UNFCCC and Kyoto Protocol-mandated financing, and—in the future—the Green Climate Fund. Relevant mechanisms to channel mitigation finance for agriculture into developing countries include a reformed clean development mechanism, finance for nationally appropriate mitigation actions or for reducing emissions from deforestation and forest degradation.

Although international climate finance is likely to be scaled up in the future, it is unlikely to address the investment needs for adaptation and mitigation in developing countries. It is, therefore, necessary to use public funds strategically to remove investment barriers and facilitate private investment and to effectively blend traditional agricultural finance with climate finance. Capacity building and institutional strengthening have to complement these efforts to enable individuals, communities, institutions, and other entities to make effective use of available knowledge, resources, and technologies.

The Cancun Agreements defined the broad architecture and functions of a technology mechanism, although without providing the specifics on how the bodies under the mechanism should operate, what their precise priorities should be, or how their activities would be funded. Existing national technology needs assessments identify agriculture and forestry as a priority sector. Harnessing the potential of the technology mechanism to promote the research and development, demonstration, deployment, diffusion, and transfer of agricultural mitigation and adaptation technologies requires the mapping of possible options, proposals, and points of intervention in current discussions about the operationalization of the mechanism.

Measurement and performance. The Convention formulates requirements for performance and benefits measurement for both mitigation and adaptation. Reporting on vulnerability and adaptation occurs through national communications, in relation to national adaptation programmes of action in least-developed countries, and in the context of the operations of the Adaptation Fund. For measurement of adaptation performance, there is no consensus on indicators, frameworks, or methods to use, but emerging practice indicates that results-based frameworks are a suitable approach to track progress in implementing specific adaptation actions and to ensure accountability for the use of adaptation funds.

Approaches to measure mitigation impacts in agriculture already exist at international, national, sectoral, and project levels. Although there is relatively strong consensus on agricultural greenhouse gas reporting frameworks, measurement of agricultural mitigation actions is hampered by inherent variability in agricultural emissions and removals, and by a lack of available data and limited capacities for measurement in many countries. The former can be provided by strengthening existing agricultural monitoring and evaluation systems. Even within developed countries that have elected to account for cropland and grazing land emissions in the Kyoto Protocol's first commitment period, uncertainties associated with agricultural emissions range between 13 and 100 percent. Therefore, there is a strong global interest in improving the emission factors of the Intergovernmental Panel on Climate Change, and for individual countries to move toward more accurate and precise measurement frameworks.

Given the need for increased food production in the future, efficiency-accounting approaches that incentivize increased food output while reducing the intensity of greenhouse gas emissions per unit of output are relevant. Efficiency-accounting (life-cycle) approaches measure the emissions intensity per unit of output. Methods are still under development for many products are data demanding. Given the diversity of agricultural production systems, standardized approaches may not suite all contexts, presenting an obstacle to comparability within and among countries.

Conclusions. Climate change adaptation and mitigation in the agriculture sector will have to be pursued in the context of meeting projected global food production demands. Although there are practices that hold great potential for meeting both needs, there is as yet no international agreement, nor national or global policy framework within which to operate. Given this situation, early action holds great potential for countries to take positive action in the short run that can inform national and international policy, finance, and science. Potential conflicts with the international trading system can be addressed with the continued maturation of global climate policy. The ability to act depends on improved measurement systems, tools, and techniques for adaptation and mitigation. There is some cause for optimism, however, based on the trajectory of work to develop these approaches.

1. Framing the Context: Climate Change and Agriculture

1.1 Scope of the Report

Reflecting the special characteristics of the agricultural sector and its exposure to climate change policies, this report aims at contributing to continued policy discussion on agriculture and climate change in the context of the UN Framework Convention on Climate Change (the UNFCCC or Convention). For the purposes of this report, the term agriculture is used to include all land-use activities involving the cultivation, production, and processing of food, fuel, and fiber. Where needed, sections of the report refer to specific types of agriculture and to the interface between certain land uses. The report focuses on five issues considered by many of those consulted to be among the most relevant to the policy interface between agriculture and climate change:

- Agricultural production and food security (Chapter 2)
- Early action opportunities in agriculture (Chapter 3)
- Trade (Chapter 4)
- Finance, technology, and capacity building for agriculture (Chapter 5)
- Performance and benefits measurement (Chapter 6)

1.2 Interlinkages between Agriculture and Climate Change

The increase of the world's population to 9 billion people by 2050,[1] the rise in global calorie intake by 60 percent between 2000 and 2050 due to greater affluence,2 as well the rising demands on land for the generation of food and fuels will require significant increases in agricultural production in the context of more constrained availability of resources. With agriculture contributing 29 percent of developing countries' gross domestic product (GDP) and providing employment to about 20 percent of the global population and 65 percent of developing countries' populations, the impacts of climate change on agriculture have significant repercussions on livelihoods, food production, and the overall economy of countries, particularly those with agriculture-based economies in the developing world.[3] At the same

[1] United Nations Department of Economic and Social Affairs of the United Nations Secretariat. 2011. 2010 Revision of the World Population Prospects, http://esa.un.org/unpd/wpp/index.htm.

[2] Deutsche Bank. 2009. *Investing in agriculture: Far-reaching challenge, significant opportunity, An asset management perspective*, June, 2009.

[3] Summarized from J. Padgham. 2009. *Agricultural development under climate change: Opportunities and challenges for adaptation.* World Bank, Washington D.C.; Smith, P., D. Martino, Z. Cai, D. Gwary, H. H. Janzen, P. Kumar, B.

time, the agricultural sector holds significant climate-change mitigation potential through reductions of greenhouse gas (GHG) emissions as well as enhancement of agricultural sequestration.[4]

The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) indicates that agriculture will be affected both by *long-term trends* in mean temperature, precipitation and winds, and by increasing climate *variability*, associated with greater frequency and severity of extreme events such as droughts and floods. Changes in the hydrological cycle will affect agriculture in general and food production specifically. Changing wind speeds and directions will also affect crop and animal productivity.[5]

At least 22 percent of the area under the most important crops in the world is expected to suffer negative impacts from climate change by 2050. In Sub-Saharan Africa and Asia, 56 percent and 21 percent of crops, respectively, are expected be negatively affected.[6] Impacts on livestock production are likely to be both direct, for example, productivity losses (physiological stress) owing to temperature increases, and indirect, for example, changes in the availability, quality, and prices of inputs such as fodder, energy, disease management, housing, and water. The distribution and virulence of pests and diseases of crops and livestock will change. New equilibria in crop-pest-pesticide interactions will affect crop production. Changes in agrobiodiversity will have impacts, for example, on pollination. Crops in some areas may benefit from carbon fertilization, though evidence from field trials suggests yield effects may be lower than hoped.[7] Climate change will also have impacts on the effectiveness of irrigation, nutritional value of foods, and safety in food storage and distribution.[8]

McCarl, S. Ogle, F. O'Mara, C. Rice, B. Scholes, and O. Sirotenko. 2007. Agriculture. In *Climate change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* ed., B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer, Cambridge, U.K.: Cambridge University Press.

[4] van Vuren, D.P., *et al*. 2009. Outlook on agricultural change and its drivers. In *Agriculture at a Crossroads* ed. B.D. McIntyre, H.R. Herren, J. Wakhungu, and R.T. Watson. Washington, DC: Island Press: 255-305.

[5] IPCC (Intergovernmental Panel on Climate Change). 2007. In *Climate change 2007: Contributions of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed., M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson. Cambridge, U. K.: Cambridge University Press.

[6] Ramirez, J., A. Jarvis, and P. Laderach. 2011. Empirical approaches for assessing the impacts of climate change on agricultural production: The EcoCrop model and a case study with sorghum (*Sorghum bicolor M.). Agriculture and Forest Meteorology*, under review.

[7] Challinor, A. J., F. Ewert, S. Arnold, E. Simelton, and E. Fraser. 2009. Crops and climate change: Progress, trends, and challenges in simulating impacts and informing adaptation. *Journal of Experimental Botany* 60 (10): 2775–2789.

[8] Vermeulen, S.J., P.K. Aggarwal, A. Ainslie, C. Angelone, B.M. Campbell, A.J. Challinor, J.W. Hansen, J.S.I. Ingram, A. Jarvis, P. Kristjanson, C. Lau, G.C. Nelson, P.K. Thornton, anad E.K. Wollenberg. 2010. Agriculture, food security and climate change: Outlook for knowledge, tools and action. Climate Change, Agriculture, and Food Security (CCAFS) Report 3. Copenhagen: Consultative Group on International Agricultural Research (CGIAR) Research Program on Climate Change, Agriculture and Food Security.

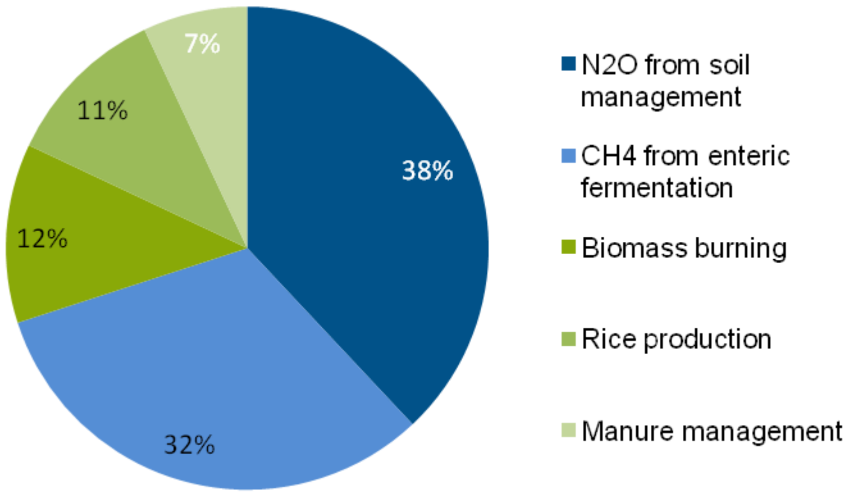
The ability of most rural and urban communities to cope and adapt when confronted with economic and social shocks and changes is high, but needs ongoing, robust support. With increasing climate variability and shocks to agricultural food production, there are added disincentives for farmers to reinvest. Over time, this might lead to cumulative reductions in income and food security. Lack of reinvestment can diminish farmers', communities', and governments' abilities to meet the threshold levels of capital needed to transform farming systems in response to long-term climate shifts; for example, to change from a rice system to wheat or small grains. The combination of failing household risk management and failure to adapt to progressive climate change might entrench poverty traps and food insecurity. Farming systems and farmers will differ enormously in their capacities to respond to climate change. Differentiated adaptation strategies and enhanced climate risk management support to agriculture and farming households are critical to counter the impacts of climate change.

At the same time, our climate is being influenced by GHG emissions *from* agriculture, which is responsible for an estimated 10-12 percent of total GHG emissions,[9] or as much as 30 percent when considering land-use change, including deforestation driven by agricultural expansion for food, fiber, and fuel. The sector is responsible for 47 percent of the world's methane (CH_4) and 58 percent of its nitrous oxide (N_2O) emissions (see Figure 1.1). Methane contributes 3.3 Gigatonnes (Gt) of carbon dioxide equivalent (CO_2e) per year, primarily from enteric fermentation in livestock, and nitrous oxide contributes 2.8 Gt CO_2e per year, mainly as emissions from soils as a result of application of nitrogen fertilizers and as nitrogen excreted in livestock feces and urine. Carbon dioxide (CO_2) accounts for only a small proportion of agricultural emissions. Agricultural soils both emit and absorb large fluxes of carbon dioxide, resulting in a small net emission of 40 megatonnes (Mt) CO_2-eq, less than 1 percent of global anthropogenic CO_2 emissions.[10]

[9] Smith, *et al*. IPCC. 2007. FN 3.

[10] Ibid. FN3.

Figure 1.1: Direct emissions in the agriculture sector[11]



1.3 What Makes Agriculture Special?

Agriculture produces food and contributes to basic needs of people. The sector is therefore characterized by low price elasticity of demand and limited price responsiveness of both demand and supply. Agriculture is the number one provider of employment and livelihood in developing countries. Whereas the sector supports millions of smallholders, its global supply chains are dominated by highly integrated industrial producers and traders.

Agriculture is highly site- and context-specific. When it comes to climate change, practices and technologies that may be synergetic in one context may have significant detrimental effects in another due to differing climatic or agricultural conditions. It is therefore challenging to formulate generally applicable mitigation or adaptation priorities, express the mitigation potential of agriculture in marginal abatement cost curves, or define global indices for climate vulnerability.

Agriculture affects and is directly affected by climate change. However, the sector has great potential for synergies among the objectives of mitigation, adaptation, food security, and poverty reduction. At the same time, there is the potential, and sometimes the necessity, for trade-offs across these objectives. How to maximize the synergies and minimize the trade-offs is

[11] Ibid. FN 3.

an increasingly pressing challenge that both policy makers and farmers are being called upon to address.

When climate change threatens food production and supply, adaption measures become essential. Consequently, one of the most important areas where trade-offs might occur in the next decades in the field of agriculture is between mitigation and food security. Agricultural production will need to grow in order to meet increased demand for food. This growth will almost inevitably lead to an increase in GHG emissions and in the sector's relative contribution to climate change. With food security at stake, many see this trade-off as necessary and one that should not be altered in favor of increased mitigation.

The agricultural sector's mitigation potential is predominantly in sequestration of carbon. Even while providing for food security, world-wide agricultural production offers considerable mitigation possibilities that—with an estimated potential of 5.5-6 Gt CO_2–eq per year—is almost equal to its current total annual emissions (5.1-6.1 Gt CO_2–eq). Estimates show that up to 89 percent of technical mitigation potential by 2030 could be achieved through soil carbon sequestration,[12] although there is still contention over how much of this is ultimately feasible.[13]

Agriculture brings complex links among the issues of climate change, food security, and trade. Climate change will likely affect agricultural production, distribution and supply of food and alter food prices leading, in turn, to significant changes in global trade flows. In the absence of enhanced investments in agriculture, in a matter of only decades, regions that used to be net exporters of food may become net importers and vice versa. Some net importing regions may see their imports double or triple. The concentration of food production in a small number of countries exporting to the rest of the world may be problematic from a food security and vulnerability perspective. Mitigation actions in agriculture could also affect the distribution and availability of food in the world market.

At the same time, there are linkages between agriculture and attempts to reduce emissions from deforestation. Agriculture is one of the principle drivers of deforestation. Intensification of agriculture, depending on the context and policies used, could reduce or increase pressure on forests. Improved governance, land tenure reform, enhanced regulatory frameworks,

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[12] Ibid. FN 3.

[13] Baker, J.M., T.E. Ochsner, R.T. Venterea, and T.J. Griffis. 2007. Tillage and soil carbon sequestration – What do we really know? *Agriculture, Ecosystems and Environment* 118 (2007): 1-5; Govaerts, B., N. Verhulst, A. Castellanos-Navarrete, K.D. Sayre, J. Dixon, , and L. Dendooven. 2009. Conservation agriculture and soil carbon sequestration: Between myth and farmer reality. *Critical Reviews in Plant Science,* 28: 97-122; Luo, Z., E. Wang, and O.J. Sun. 2010. Can no-tillage stimulate carbon sequestration in agricultural soils? A meta-analysis of paired experiments. *Agriculture, Ecosystems and Environment* 139 (2010): 224-231.

compliance mechanisms, and more integrated policies and planning (e.g., integrated land-use strategies) may be used in managing trade-offs and creating synergies across land uses.

1.4 Agriculture under the Convention and the Kyoto Protocol

Policies and measures promoting adaptation and mitigation in the agricultural sector may require support mechanisms, especially in developing countries. Financing and technology transfer as well as capacity building supported under the Convention may assist in overcoming financial and nonfinancial barriers to the adoption of agricultural practices that increase climate-resilience, mitigate GHG emissions, and enhance food security. The types and extent of such barriers depend on the context, culture, and capabilities of countries, regions, or even farming systems, and on labor availability. Financial support related to covering only incremental or abatement costs is unlikely to trigger changes in agricultural practices; support is more likely to be effective if it improves adaptation while maintaining production. Agricultural practices that result in increased yields and resilient agricultural systems are likely to be favored by farmers. Once adopted, such practices are unlikely to be reversed and emission reductions are likely to be permanent. However, a lack of data and capacities to estimate and monitor emissions and carbon stock changes may potentially delay the application of international performance-based incentive mechanisms.

The Convention places obligations on Parties that could directly or indirectly affect agricultural activities. The linkage between climate change and agriculture is addressed directly in Article 2 of the treaty which states:

> *stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system… 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.*

Under Article 4 of the Convention, developed countries have the specific obligation to "adopt national policies and take corresponding measures on the mitigation of climate change by […] protecting and enhancing its greenhouse gas sinks and reservoirs."[14] Preambular paragraph 4 of the Convention also mentions the role and importance of sinks and reservoirs of GHGs in terrestrial ecosystems. When formulating Party obligations, the Convention, rather than focusing on specific mandatory obligations, focuses on general preparatory measures, such as to:

[14] UNFCCC, Art. 4, para. 2.

- Promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of GHGs in all relevant sectors including […] agriculture.
- Promote sustainable management, and to promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of greenhouse gasses […] including biomass.
- Cooperate in preparing for adaptation to climate change; develop and elaborate appropriate and integrated plans.[15]

The Kyoto Protocol refers to policies and measures, including promoting sustainable forms of agriculture, as a way for developed countries to achieve their emissions reductions and limitations.[16] In addition, developed countries have the option of using net "direct human-induced" changes in GHG emissions and removals by sinks to meet their emission reduction targets.[17] At the same time, the clean development mechanism (CDM), the mitigation crediting mechanism for developing countries, maintains a general focus on emission reductions rather than removals, and has so far limited eligible sequestration activities to afforestation and reforestation project activities.[18] The primary mitigation opportunities to enhance soil carbon stocks through cropland or rangeland management, opportunities that are especially important for small farmers in developing countries,[19] are excluded.

In the context of negotiations on a future climate regime, agriculture has been discussed in the context of the Ad-Hoc Working Group on Long-Term Cooperative Action (AWG-LCA). The Cancun Agreements, the outcome of the sixteenth session of the Conference of the Parties (COP) of the UNFCCC and of the sixth session of the COP serving as the meeting of the Parties to the Kyoto Protocol (COP/MOP), do not contain any sections dedicated to agriculture. A decision on agriculture that had been part of the draft negotiating text relating to cooperative sectoral approaches and sector-specific actions in agriculture[20] was not included in the final text, apparently due to it being coupled with text about bunker fuels and to disagreement on trade-related issues.

Although there is no decision or work program dedicated to agriculture, the Cancun Agreements allow for consideration of agriculture as a driver of deforestation and thus can be

[15] Respectively UNFCCC, Art. 4, para. 1, (c), (d) and (e).
[16] Kyoto Protocol, Art. 2, para. 1.
[17] Under Kyoto Protocol, Art. 3.4, developed countries elect to report on carbon stocks in existing forests (forest management) and carbon stocks in agricultural soils, which is optional. Only a few countries have elected to do so.
[18] UNFCCC Decision 16/CMP.1, para. 13.
[19] FAO (UN Food and Agricultural Organization). 2007. *The State of Food and Agriculture*. Rome: FAO, www.fao.org/docrep/010/a1200e/a1200e00.htm.)
[20] FCCC/AWGLCA/2010/14, Chapter IX.

considered under adaptation actions.[21] Agriculture already figured prominently in national adaptation programmes of action (NAPAs) formulated by least-developed countries (LDCs). NAPAs are now to inform the new national adaptation plans, which, in accordance with the Cancun Agreements, are to be prepared by developing countries.[22] Also, following the fifteenth session of the COP, a number of developing countries indicated their intention to undertake nationally appropriate mitigation actions (NAMAs) related to agriculture (see **Annex 1**). [23]/[24] Agricultural activities mentioned in this regard include: the restoration of grasslands, fodder crop production, introduction of combined irrigation and fertilization techniques to increase the efficiency of fertilizer application, and methane capture in livestock and chicken farms.[25]

While international negotiations on the details of financing and support mechanisms, means, modalities, methodologies, and measurement continue, countries could lead with "early national actions" to increase their capacities, confidence, and knowledge to engage in agricultural adaptation and mitigation in nationally appropriate ways that safeguard food security and enhance development. Policy makers could identify practices that enable agriculture to contribute simultaneously to climate change, food security, and development goals. They may also integrate agriculture into coordinated land-use planning strategies building coherence across climate change, development and food security policy, and investment priorities. The example of reduced emissions from deforestation and forest degradation (REDD+)[26] shows that countries can enter into voluntary partnerships to build capacities and institutions that support climate activities, even before international frameworks and mechanisms have been formally adopted (see Chapter 5, Table 5.6 for lessons from REDD+ for agriculture).

[21] UNFCCC Decision 1/CP.16, Chapter II and Chapter III under C.

[22] FCCC/CP/2010/7/Add.11/CP.16 , para. 16

[23] See UNFCCC NAMA registry at http://unfccc.int/meetings/cop_15/copenhagen_accord/items/5265.php.

[24] FCCC/AWGLCA/2011/INF.1; FAO (UN Food and Agricultural Organization). 2010. *"Climate Smart" Agriculture, Policies, Practices and Financing for Food Security, Adaptation and Mitigation*, (Prepared for The Hague Conference on Agriculture, Food Security and Climate Change) Rome: FAO, http://www.fao.org/fileadmin/user_upload/newsroom/docs/the-hague-conference-fao-paper.pdf .

[25] FAO (UN Food and Agricultural Organization). 2010. Agriculture, food security and climate change in post-Copenhagen processes: An FAO information note, http://foris.fao.org/static/data/nrc/InfoNote_PostCOP15_FAO.pdf.

[26] The full scope of REDD+ includes reduced emissions from deforestation and forest degradation, and the role of conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks.

2. Agricultural Production and Food Security

2.1 Introduction

Food security figures high on global and national agendas. Pressing issues include both price volatility and long-term responses to increased demand for food as populations grow and dietary habits change. The globally accepted definition of food security, agreed at the 1996 World Food Summit, is that "food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life."[27] From this definition, four dimensions of food security emerge (**Box 2.1**) that need to be fulfilled simultaneously.

Box 2.1: Characteristics of food security

Food security is understood to have four dimensions:

1. *Availability* of food: the physical "supply side" of food security, determined by the level of food production, stock levels and net trade.
2. *Access* to food: physical and economic entitlements to food, through markets or non-market channels, usually dependent on incomes, expenditure, market governance and prices.
3. *Utilization* of food: how the human body absorbs and utilizes nutrients, dependent on food quality, dietary diversity, food hygiene and safety, and cultural preferences for food types and cooking.
4. *Stability* of availability, access and use: year-on-year ability to maintain nutritional status, dependent on sustainable food systems and on management of multiple risk factors such as adverse weather conditions, political instability, or economic drivers (unemployment, rising food prices).

Source: FAO. 2008. An introduction to the basic concepts of food security. Food Security Information for Action Practical Guidelines. Food and Agriculture Organization of the United Nations, Rome, Italy (URL: http://www.fao.org/docrep/013/al936e/al936e00.pdf).

[27] FAO (UN Food and Agriculture Organization). 1996. Final report of the 1996 World Food Summit. Rome: FAO.

The Convention addresses mitigation and adaptation in the agricultural sector and makes specific reference to food security when it confirms that climate change mitigation should be achieved within a time-frame sufficient to ensure, among other things, that *food production* is not threatened, ecosystems can adapt naturally, and economic development is pursued in a sustainable manner (Art 2 UNFCCC). Agriculture provides nonfood products, jobs, incomes, livelihoods, environmental services, nutrition and health, cultural identities, rural development, landscapes, and ways of life. Farming is still the primary occupation globally and contributes to food security not only via agricultural production but also through provision of livelihoods and incomes to many millions of small-scale, resource-poor farmers. Policy objectives for agriculture are likely to be multifaceted in most countries, rather than geared primarily toward maximizing food production. However, in line with Article 2 of the Convention, the main consideration in this chapter will be food production (a necessary element for achievement of food security). Food security in its wider sense is addressed in other venues (see Annex 2).

2.2 Food Production and Climate Change Mitigation

Achieving mitigation in agriculture without compromising food security is a policy challenge, both nationally and globally. For some countries, future food security may be increasingly dependent on trade (see also Chapter 4). For many other countries, future food security will require greater food production, which might, in turn, lead to more agricultural emissions. Given the need for growing food production, a completely "carbon-neutral" agriculture may not be possible and it may be more appropriate to focus policy interventions on achieving future growth in food production without commensurate increases in emissions. Nonetheless, there is substantial mitigation potential within the agricultural sector, which may be achieved both through greater efficiency in agricultural production (thereby leading to fewer emissions per unit of product, e.g., per liter of milk, kilogram of meat) and in some cases through absolute reductions in GHG emissions, including removal through sequestration in agricultural soils and biomass. The good news is that many options can simultaneously increase food productivity and reduce the emissions per unit of output (emissions intensity).

Emissions reductions associated with food will be enhanced by mitigation action in agriculture as well as actions across the food chain.[29] In the IPCC's fourth assessment report, Smith *et al.*[30]

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[28] FAO. (UN Food and Agriculture Organization). 2008. An introduction to the basic concepts of food security. Food security information for action practical guidelines. Rome: FAO, http://www.fao.org/docrep/013/al936e/al936e00.pdf

[29] For example, through reducing post-harvest losses and waste in the retail, catering, and consumer segments of the supply chain. Roughly one third of the food produced in the world for human consumption every year — approximately 1.3 billion tonnes— gets lost or wasted. FAO (UN Food and Agriculture Organization). 2011. *Global food losses and food waste*, Rome: FAO.

[30] Smith, et *al.* IPCC.2007. FN3.

distinguish seven broad sets of options for mitigating GHG emissions from agricultural ecosystems:

- *Cropland management,* including nutrient management; tillage and residue management; water management (irrigation, drainage); rice paddy management; agroforestry; set-asides; crop rotations; and land-use change
- *Grazing land management and pasture improvement,* including grazing intensity, increased productivity (e.g., fertilization), nutrient management, fire management, and species introduction (including legumes)
- *Management of organic soils,* including avoiding drainage of wetlands
- *Restoration of degraded lands,* including erosion control, organic amendments, and nutrient amendments
- *Livestock management,* including improved feeding practices, dietary additives, longer-term structural and management changes, and animal breeding
- *Manure management,* including improved storage and handling, anaerobic digestion, and more efficient use as a nutrient source
- *Bioenergy,* including energy crops (solid, liquid, biogas, and residues)

The potential for synergies among these land-based agricultural mitigation actions that promote food security is particularly high for specific practices such as adopting improved crop varieties (e.g., with higher water-use efficiency), breeding livestock to increase sustainable productivity of meat or milk, avoiding bare fallow land and changing crop rotations to incorporate food-producing cover crops and legumes, adopting precision fertilizer management, improving forage quality and quantity on pastures, expanding energy-efficient irrigation and water conservation techniques (e.g., in rice systems), and implementing agroforestry that does not take significant amounts of land out of food production.

Specific interventions, however, only make sense within a broader, holistic approach to agricultural management. There may not be any net mitigation effect if greater on-farm efficiency displaces emissions to other parts of the landscape or food chain. Similarly, one might want to avoid emissions reductions at the expense of, for example, biodiversity conservation.

Another key point is that the most cost-effective and appropriate mitigation options can probably not be identified *a priori* at the global level. Technical options for mitigation in agriculture need to be locally appropriate. For example, although land management presents the major opportunity for mitigation in the agricultural sector globally, other interventions, such as improved livestock breeding and feeding, or manure management, may be more effective for particular countries, farming systems, or agro-ecological zones.[31] Many of the most effective options are likely to build on, or scale up, current practice; however, in some cases technically sophisticated innovations may be required (e.g., enteric fermentation). A diversity of mitigation options provides flexibility, but also raises challenges in measuring, reporting, and verification (for more details on measurement, reporting, and verification (MRV), see Chapter 6).

Some of the biggest potential for mitigation lies in reducing the footprint of agriculture on forests.[32] Agriculture in all its forms – subsistence, commercial cropping, ranching, and intensive feedlots based on extensive grain production – is currently the major cause of deforestation. Policies to reduce deforestation must be context-specific, related to the type of agriculture taking place in the forest landscape. The implication at the international level is to aim for close coordination among mechanisms for forest protection and improved agricultural practice, for example by creating incentives for REDD+. Equally, or even more, relevant are national policy considerations, which are summarized in Chapter 3.

2.3 Food Production and Climate Change Adaptation

Effective adaptation policies should increase the capacity of farming and food systems to adapt to climate change while maintaining or increasing food production. Climate change entails both long-term changes in the baseline climate (shifts in mean temperatures and precipitation) and increasing variability within and between seasons. Greater climatic variability means higher frequencies of extreme events such as droughts, floods, hailstorms, and heavy snows. Furthermore, the future direction and degree of change in baseline climate is moderately to highly uncertain for many of the world's agricultural areas.

Given current uncertainties, there are strong arguments for "no regrets" policy interventions that deliver on agricultural and rural development to build local capacity and resilience in a general sense, regardless of the future direction and severity of climate change impacts (see **Chapter 3** on Early Action). Many of the most effective interventions will build on current practices and technologies, because farmers and their input and service providers have many generations of experience in managing climatic risks.

Better management of the risks associated with climate variability presents an immediate opportunity to build future capacity to adapt to climate change. Many of the projected impacts of climate change are amplifications of the substantial challenges that climate variability already

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[31] Smith, P., D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kumar, B. McCarl, S. Ogle,F. O'Mara, C. Rice, B. Scholes, and O. Sirotenko, M. Howden, T. McAllister, G. Pan, V. Romanenkov, U. Schneider, S. Towprayoon, M. Wattenbach, and J. Smith. 2008. Greenhouse gas mitigation in agriculture. *Philosophical Transactions of the Royal Society* B 363: 789-813.

[32] DeFries, R. and C. Rosenzweig. 2010. Toward a whole-landscape approach for sustainable land use in the tropics. *Proceedings of the National Academy of Sciences* 46: 19627–19632.

imposes on agriculture, particularly for rainfed cropping and livestock systems. Enhanced risk management needs to be coupled, however, with building preparedness for long-term climatic shifts, for example, through accelerated development of varieties suitable for projected future climates, or building capacity in support of future transformation of farming systems in certain agroecological zones (e.g., from cropping to livestock).

The IPCC distinguishes between *autonomous adaptation*, which is the ongoing implementation of existing knowledge and technology in response to the changes in climate experienced, and *planned adaptation*, which is the increase in adaptive capacity created by mobilizing institutions and policies to establish or strengthen conditions favorable for effective adaptation as well as investment in new technologies and infrastructure.[33] Both farm-level adaptation options and higher-level policies and investments to enable their adoption will be necessary for effective agricultural adaptation.[34]

In addition to agricultural measures, there is considerable scope for agricultural adaptation throughout the food chain, for example, better post-harvest storage and distribution of food, to ameliorate the gap between good and poor years. Easterling *et al*.[35] describe a range of options, at the level of autonomous adaptation, for cropping and livestock systems:

- *Different varieties or species* with greater resistance to heat or water stress, or adapted phenology (maturation times and responses)
- *New cropping practices*, including adjustments in timing and locality of crop production, and changed water and fertilizer management to maintain yield quality and quantity
- *Greater use of water conservation technologies,* including those to harvest water and conserve soil moisture, or, in flood-prone areas, water management to prevent waterlogging, erosion, and nutrient leaching
- *Diversification* of on-farm activities and enhancement of agrobiodiversity, with greater integration between livestock and cropping systems
- *Adapted livestock and pasture management*, including rematching stocking rates and timing with pasture production, new varieties and species of forage and livestock, updated fertilizer applications, and using supplementary feeds and concentrates

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[33] Easterling, W.E., P.K. Aggarwal, P. Batima, K.M. Brander, L. Erda, S.M. Howden, A. Kirilenko, J. Morton, J.-F. Soussana, J. Schmidhuber, and F.N. Tubiello. 2007. Food, fibre and forest products. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Cambridge, U.K.: Cambridge University Press, 273-313.

[34] Easterling et *al.* 2007. FN33

[35] Ibid. FN33.

- *Improved management of pests, diseases and weeds,* for example, through integrated pest management, new crop and livestock varieties, improved quarantine, and sentinel monitoring programs
- Better use of short-term and seasonal climate forecasting to reduce production risk (see Box 2.2)

Box 2.2: Agro-meteorology for managing climate risk in Mali

Mali's national meteorological service launched a pilot project in 1982 to provide climate information to rural people, especially farmers. The project was the first in Africa to supply climate-related information directly to farmers, as well as to help them measure climate variables themselves, so that they could incorporate it into their decision making.

Over the years, the project has evolved into an extensive and effective collaboration among government agencies, research institutions, media, extension services, and farmers. More than 2,500 farmers have participated. Climate information is collected from diverse sources, including the World Meteorological Organization, the African Centre of Meteorological Application for Development, the national meteorological service, extension workers and farmers themselves, who are supplied with rain gauges and feed back their data to their nearest meteorological office. The data is processed and forecasts provided for three periods: three-days, ten-days, and seasonal. The forecasts include information on the state of crops, water resources, and weather conditions, as well as crop health issues, pastoral issues and agricultural markets.

Multidisciplinary working groups at local and national levels provide iterative improvement to the system by identifying farmers' needs, analyzing technical aspects of data and products, developing recommendations related to agricultural production, disseminating information, and building capacity. Data collected by the national meteorological service, as well as farmer testimonies, indicate significantly higher yields and incomes (up to 80 percent higher for participating farmers). Farmers report that they feel they are exposed to lower levels of risk and are therefore more confident about purchasing and using inputs such as improved seeds, fertilizer, and pesticides. The Malian model has long-term sustainability and potential for scaling up, and strong future prospects for enhancing farmers' capacities to adapt to climate change.

Source: Hellmuth, M., D.Z. Diarra, C. Vaughan, and R. Cousin. 2010. Increasing food security with agrometeorogical information: Mali's national meteorological service helps farmers manage climate risk. In *World Resources Report*, Washington D.C.: World Resources Institute, http://www.worldresourcesreport.org/files/wrr/papers/wrr_case_study_increasing_food_security_mali.pdf.

As with mitigation measures, there are no globally applicable priorities among the general set of adaption measures. Interventions need to be locally appropriate and locally selected. There are also limitations to many of the practices; for example, more heat-tolerant crop or livestock varieties often give lower mean productivity.

Cross-site and cross-country transfer of best practices will be critical to effective adaptation. However, scaling out will be limited by a number of factors, including possible nonlinearity of climate impacts and the complexity of agricultural decision making within contrasting economic and cultural settings. Therefore, much investment in adaptation needs to be geared towards effective learning processes and capacity building over and above development of specific technologies and practices.

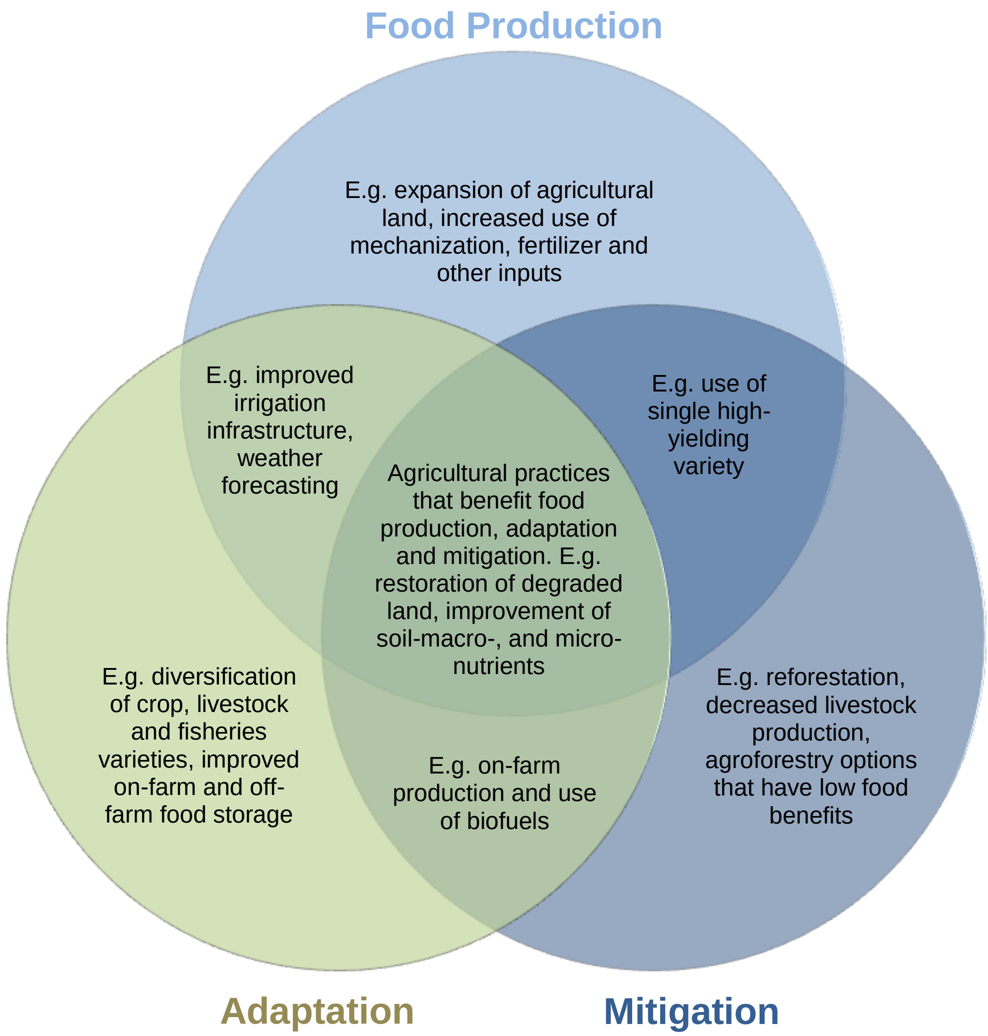
Investments in infrastructure (irrigation and rural roads) and in extension, research, and development are also likely to be critical to increasing productivity under climate change in countries that are prone to food insecurity.[36] New understandings of agriculture, such as appraisals of how urban agriculture or trends in retail affect food security, could help direct investments effectively. The most successful interventions to support adaptation in agriculture are likely to be those that adopt a holistic approach, those that work to support the multiple ways in which agriculture and food systems contribute to livelihoods, incomes, and food security.

2.4 Synergies and Trade-Offs: Food Production, Adaptation, and Mitigation

Policy has to balance potential synergies and trade-offs in agricultural systems to meet multiple objectives for food production, adaptation, and mitigation in farming and food systems. Figure 2.1 shows the range of possible trade-offs and synergies among these three objectives. Specific practices and policy options may be able, in particular contexts, to achieve all three objectives. Other practices may achieve only one or two objectives, while possibly compromising others. Prioritization among the three objectives is an issue for the national and subnational policy level; choices should reflect biophysical and socioeconomic contexts, climate change impacts, objectives for agricultural development, and associated responses to climate change.

[36] Nelson, G.C., M.W. Rosegrant, J. Koo, R. Robertson, T. Sulser, T. Zhu, C. Ringler, S. Msangi, A. Palazzo, M. Batka, M. Magalhaes, R. Valmonte-Santos, M. Ewing, and D. Lee. 2009. *Climate change: Impact on agriculture and costs of adaptation.* Food Policy Report #19. Washington, D.C.: International Food Policy Research Institute (IFPRI), http://www.ifpri.org/sites/default/files/publications/pr21.pdf.

Figure 2.1: Potential synergies and trade-offs among food production, mitigation, and adaptation



Several caveats apply to this figure:

(1) Examples are illustrative, not comprehensive; furthermore the examples will not apply to all countries, farming systems or agro-ecological zones.

(2) The size and overlay of the circles do not represent either relative potential or degree of overlap.

(3) The term "adaptation" here, and throughout the report, refers to approaches and capacities within agriculture, and does not include "getting out of farming", which may be the most effective adaptation to climate change for farmers in particularly vulnerable contexts

Box 2.3: Synergies in rice production: Mitigating methane emissions, adapting to water scarcity and enhancing food security in Bohol, Philippines

The waterlogged and warm soils of rice paddies make this production system a large emitter of methane. Irregular rainfall, drier spells in the wet season (damaging young plants), drought and floods, and higher temperatures, particularly night temperatures, have a severe effect on yields.

Bohol Island is one of the biggest rice-growing areas in the Philippines' Visayas regions. Before the completion of the Bohol Integrated Irrigation System (BIIS) in 2007, two older reservoirs were unable to ensure sufficient water during the year's second crop (November to April), especially for farmers who live farthest downstream from the dams. This problem was aggravated by the practice of unequal water distribution and a preference by farmers for continuously flooded rice.

In the face of declining rice production, the National Irrigation Administration created an action plan for the BIIS. The plan included construction of a new dam (funded by a loan from the Japan Bank for International Cooperation) and the implementation of a water-saving technology called Alternate Wetting and Drying (AWD), which was developed by the International Rice Research Institute in cooperation with national research institutes.

The visible success of AWD in pilot farms, as well as specific training programs for farmers, dispelled the widely held perception of possible yield losses from non-flooded rice fields. Ample adoption of AWD facilitated an optimum use of irrigation water, so that the cropping intensity could be increased from about 119 percent to about 160 percent (related to the maximum of 200 percent in these double-cropping systems). Moreover, AWD potentially reduces methane emissions by 48 percent compared to continuous flooding of rice fields. AWD therefore generates multiple benefits: methane emission reduction (mitigation), reduced water use (adaptation), and higher productivity and incomes (food security).

Source: World Bank, 2010 *Opportunities and Challenges for a Converging Agenda: Country Examples*, Washington, D.C. (prepared for the 2010 The Hague Conference on Agriculture, Food Security and Climate Change.

There are extensive opportunities for synergies among food production, adaptation, and mitigation within agriculture. These opportunities include conserving soil moisture, reducing soil degradation and leaching, increasing the diversity of crop rotations, and reducing temperature extremes by providing shade and shelter. [37] Numerous options deliver adaptation and productivity, with co-benefits for efficiency in GHG emissions. For example, increasing the

[37] Smith, P. and J.E. Olesen. 2010. Synergies between the mitigation of, and adaptation to, climate change in agriculture. *Journal of Agricultural Science* 148: 543-552.

quality of livestock feed can provide three-way benefits. These synergies can be delivered both by wider adoption of well-established, often low-tech, good practices and by take-up of agricultural innovations. Many of the interventions have additional co-benefits, such as greater biodiversity, higher incomes to farmers, and better animal welfare. Box 2.3 presents an example of a synergistic intervention in rice paddy management.

Conversely, there are trade-offs and limitations associated with mitigation and adaptation options in agriculture. Reducing rice paddy methane emissions through periodic drying (Box 2.3), for instance, could also increase nitrous oxide emissions. Some mitigation actions can have negative impacts on the adaptive capacity of farming systems; for example, the removal of crop residues for biofuels can deplete soil carbon. Adaptation strategies employed by farmers may also increase GHG emissions. For example, rice and wheat farmers may try to maintain two cropping cycles as the growing season becomes shorter, but this practice involves increasing irrigation (driving up energy use) and burning stubble (releasing GHGs and changing air quality). There are also time-related factors. Some mitigation options may lose their efficacy as the climate changes.[38] For other options, short-term impacts may be negative, whereas long-term impacts are expected to be positive for increasing both the average and stability of production levels. For example, reducing grazing pressure may foster more resilient systems in the future, but at the cost of income and food security in the short term.[39]

Trade-offs are more likely when mitigation options take land out of production, either temporarily or permanently. Restoration of degraded lands often requires that the land not be used for production at least in the short term, whereas avoiding draining of or restoring wetlands would take the wetlands out of production permanently.[40] These trade-offs again point to the critical interface between agriculture and landscape management, and hence the need for coordination of forestry and agricultural policies, including REDD+. Similarly, coordination of actions across the food supply chain from producers to consumers can maximize synergies and avoid perverse incentives. Many options designed to deal with the resilience of the whole food system and to enhance food security (e.g., improved post-harvest storage, reduced wastage, strategic grain reserves, crisis management and response) have the potential to make the food system more efficient, and thus indirectly cut down on emissions from agriculture.

Since synergies and trade-offs tend to be local to farming systems and agro-ecological zones, planning needs to occur at the national and subnational levels rather than through selection from a ranked list of global options. Nonetheless, there are some general principles. A wealth of

[38] Parry, et *al*, IPCC 2007. FN5.

[39] FAO. 2010. FN 24; World Bank. 2010. Opportunities and challenges for a converging agenda: Country examples. (Prepared for the 2010 The Hague Conference on Agriculture, Food Security and Climate Change). Washington, D.C. : World Bank.

[40] FAO. 2009. *Food security and agriculture mitigation in developing countries: options for capturing synergies*. Rome: FAO.

recent evidence-based policy recommendations for agriculture use terms such as sustainable agriculture, conservation agriculture, climate-smart agriculture, eco-efficient agriculture and agro-ecology.[41] While these practices differ in specifics, they all advocate a holistic approach to management of land and other resources that balances short-term and long-term interests. They recommend provision for the multiple dimensions of agriculture (e.g., affordable food, jobs, environmental services, and GDP earnings) at the national and international policy levels, and attention to stewardship of nutrients, energy, and water cycles at the level of landscapes and farms. These approaches need to be underpinned by policies and institutions that provide for secure individual and collective property rights, legitimate farmers' organizations, and accessible finance for agriculture.

2.5 Main Messages

The following points highlight issues around food security and agricultural production that should be considered within further elaborations of agriculture within the Convention and related international policy processes.

Multidimensions of agriculture and maximization of synergies. The critical role of food security in human survival and development suggests distinct treatment of agriculture in the context of the Convention. To achieve harmony among the multiple functions of agriculture within climate change (as a source and a sink, and in both adaptation and mitigation) and more broadly (not only as food production, but including incomes, revenues, environmental services and cultural value) agriculture may require a unified approach rather than separate treatment in different negotiating streams (e.g., mitigation, adaptation, technology transfer).

Scope for synergies among food production, adaptation, and mitigation. Agriculture offers a wealth of technical and institutional opportunities to deliver simultaneously on food production, adaptation, and mitigation, while benefiting wider environmental services and farming incomes, and hence food security. Many of these options use practices, technologies, and systems that are already available and affordable. However, interactions are complex, may involve trade-offs, and need to be tailored to specific contexts.

[41] Foresight. 2011. *The future of food and farming*. Final Project Report. London: The Government Office for Science; Garnett, T. 2011. Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? *Food Policy* 36, http://www.bis.gov.uk/foresight/our-work/projects/current-projects/global-food-and-farming-futures/reports-and-publications; Hoffman, U. 2011. *Assuring food security in developing countries under the challenges of climate change: Key Trade and development issues of a fundamental transformation of agriculture.* United Nations Conference on Trade and DevelopmentUNCTAD discussion paper 201, http://www.unctad.org/en/docs/osgdp20111_en.pdf; De Schutter, O. 2011. *Agro-ecology and the right to food*. Report presented at the Sixteenth Session of the United Nations Human Rights Council [A/HRC/16/49], March 8, 2011, http://www.srfood.org/index.php/en/component/content/article/1174-report-agroecology-and-the-right-to-food.

Coordinating agriculture and forestry land uses. Although land-use change is not counted within GHG emissions from agriculture, agriculture is the primary driver of conversion of forests, grasslands, and wetlands. Agricultural intensification can free up land for carbon storage, but perverse incentives and externalities can arise, which need to be avoided through policy coordination. Forestry and agricultural perspectives need to come together to stimulate synergies between food security and mitigation, as well as building the adaptive capacity of these land-based activities.

Joining up climate change with food security. There are considerable options for adaptation throughout the food system that will improve the links between food production and food security. As many of these options involve improving efficiency, they may also have positive impacts on mitigation. At the international level, there may be benefit in stronger exchange between international deliberations on food security and those on climate change. This could increase the likelihood that climate change actions assure availability, accessibility, and utilization of food, and that food security interventions take full account of climate change impacts and options.

Appropriate incentives, governance, and institutions to deliver multiple objectives. There are limits to a simple cost-abatement logic in selecting best-bet options in agriculture to deliver on food production, adaptation, and mitigation. Options are locally specific, costs of and incentives for different options are interrelated (e.g., agriculture and REDD+). Even the implementation of immediate win-win-win options is deterred by a range of financial, cultural, knowledge, and policy barriers. A mix of instruments and governance arrangements that include both positive incentives on the one hand and safeguards, regulations, and sanctions on the other will be needed to achieve the multiple objective of food security, climate change adaptation, and mitigation. Internationally, negotiations on trade, measurement, finance, technology transfer, and capacity development will be important to achieving a balance among the various objectives of agriculture.

3. Early Action Opportunities in Agriculture

3.1 Introduction

Despite recognition that the challenges of food security and climate change are closely linked within the agriculture sector,[42] policy, institutional arrangements, and funding channels for climate change, food security, and rural development are poorly coordinated at international, and, in many cases, national levels. Early action in agriculture allows countries to take the lead in preparing for near- and long-term agricultural adaptation and mitigation actions, closely linked with national food security and development efforts, while negotiations continue in the context of the Convention on Climate Change and its Kyoto Protocol. This chapter identifies a number of early action options that countries may wish to consider.

3.2 Climate-Smart Agriculture

Climate-smart agriculture seeks to maximize benefits and minimize negative trade-offs across the multiple objectives that agriculture is being called on to address: food security, development, climate change adaptation, and mitigation (see Figure 2.1 for an illustration of synergies and trade-offs and Box 5.1 for an example of a climate-smart agricultural project). Key elements include increasing productivity and resilience, reducing GHG emissions or enhancing sequestration, and managing interfaces with other land uses.[43] Climate-smart agricultural options will in many cases be sustainable agriculture practices that take into account the need for climate change adaptation and mitigation (and may need additional financial resources).

Although it is expected that aggregate emissions from agriculture will increase to meet the food demands and development needs of a growing global population, climate-smart agricultural options should not be viewed solely through a mitigation lens, given the importance of climate change adaptation to food security as well as to livelihoods, employment, and the overall economy. Increasing productivity and the resilience of agricultural systems to climate change impacts, both from extreme events and slower-onset changes, as well as enhancing agricultural adaptation by altering exposure, reducing sensitivity, and increasing adaptive capacity, are considered fundamental to the continued viability of agriculture in many areas.[44] However,

[42] FAO. 2009. FN40.

[43]FAO. 2010. FN24; World Bank. 2010. *Opportunities and challenges for a converging agenda: Country examples.* (Prepared for the 2010 The Hague Conference on Agriculture, Food Security and Climate Change). Washington, D.C.: World Bank.

[44] OECD (Organization for Economic Co-operation and Development). 2010. *Climate change and agriculture: impacts, adaptation and mitigation,* Paris: OECD.

exploring opportunities for lower emissions, compared with business-as-usual scenarios, is also seen as important in curbing potentially catastrophic climatic change, which may occur beyond 2050.[45]

3.3 Options for Early Action on Climate-Smart Agriculture

Drawing on national policy instruments, countries could decide to identify climate-smart agricultural practices and policies as well as map their testing and implementation in the context of sustainable agricultural development. Early action might be funded domestically or through international climate financing, including fast-start financing, as well as other bilateral and multilateral channels.

National early-action policies and measures might include: building a country-specific evidence base that could generate the required information, data, and knowledge to identify climate-smart agricultural practices as well as constraints to their adoption; more integrated and innovative policy design to overcome adoption barriers; institutional and financing arrangements; and formulation of implementation strategies. These activities should also contribute to capacity building, consolidation of country ownership, and confidence-building; they could all benefit from consultation with stakeholders.

There is no blueprint for climate-smart agriculture and the specific contexts of countries and communities would need to shape if and how it is ultimately implemented. The specific conditions, circumstances, and capacities within countries will define opportunities and barriers to implementation, and hence policy choices. Some countries may find that adaptation (due to country-specific impacts and vulnerabilities), food security (due to chronic food deficits or impacts of food price volatility), or productivity increases (required for livelihoods and economic growth) may be the most appropriate entry point, while others may wish to contribute to mitigation. Climate-smart agriculture and other more narrowly focused adaptation and mitigation activities are not mutually exclusive and could proceed in parallel. Most countries are not starting from zero and have already undertaken relevant activities that can be a foundation for further action.

3.3.1 Building an Evidence Base: Country-Specific Information and Data

The knowledge base for making strategic choices that can help maximize benefits and minimize trade-offs among adaptation, mitigation, and food security is often nonexistent or weak, particularly given that these choices vary by specific agro-ecological and farming systems.

[45] IPCC. 2007. *The Fourth Assessment Report of the United Nations Intergovernmental Panel on Climate Change* ("Synthesis Report,"). Geneva: IPCC.

Climate change, by increasing uncertainty and the need for rapid and accurate response, augments the necessity for timely and accurate spatial and scale-relevant information.[46]

Countries with a large share of their population engaged in agricultural production, high rates of food insecurity and poverty, and adverse impacts from extreme climate events are often obliged to take urgent and difficult policy decisions based on insufficient evidence. Narrowing knowledge and data gaps through use of existing data and the collection, analysis, and modeling of new information and data can be an important step in allowing practices, policies, and strategies to be informed by the best possible evidence that is relevant to specific country contexts.

Improving the use of climate science data for agricultural planning can be useful in assessing vulnerability and risks, reducing uncertainties generated by climate change, and improving early warning systems (for an example see Box 3.1). The access to data can increase the capacity of farmers and agricultural planners to take decisions and allocate resources effectively to reduce risks. There is also a need to close the divide between science and field application that can assist communities and planners in understanding the implications of planning decisions (e.g., scenario simulation).[47] A better understanding of farmer decision making in adoption of practices and technologies possibly based on risk aversion, low investment capacity, tenure security, or social customs and the introduction of new information dissemination technologies could also be useful in the design of policies to facilitate adoption.

Box 3.1: Modelling System for Agricultural Impacts of Climate Change (MOSAICC)

Among the range of emerging models and assessments of impacts of climate change on crop production and food security is a toolbox developed by the World Bank and FAO. The toolbox, called the Modelling System for Agricultural Impacts of Climate Change (MOSAICC), is being tested in Morocco. It comprises four software components for processing global climate model output data, estimates of irrigation water resources, estimates of crop yields, and a simulation of the effect of changing agricultural yields on national economies.

In 2011, the system and related capacity-building activities will be fully tested in Morocco before being exported to other countries. MOSAICC is based on a study conducted by FAO, together with the World Bank and Moroccan national institutions, to assess the impact of climate change on Moroccan agriculture. The study covers 50 crops, major agro-ecological zones, and several climate change scenarios. For further information visit:
www.fao.org/nr/climpag/pub/FAO_WorldBank_Study_CC_Morocco_2008.pdf

[46] FAO. 2010. FN24.
[47] Stockholm Environment Institute. 2008. Climate change and adaptation in African agriculture, Stockholm.

There is ample scope for sharing lessons learned from national experiences. Investment in agricultural research, for example, by Brazil, China, and New Zealand, has been an engine for more sustainable increases in production and enabled a rapid response in addressing agricultural adaptation and mitigation challenges. Mexico and Brazil, among others, have developed or are developing climate legislation that includes managing different land uses under climate change. A number of African countries (e.g., Lesotho, Malawi, and Zambia) have experimented with conservation agriculture that promotes tillage and residue management practices that potentially favor greater productivity, mitigation, and adaptation. In Brazil, low-emission agriculture is already part of efforts to reduce GHG emissions.

Table 3.1: Options for collecting and analyzing information and data
Identification, by agro-ecological systems, of agricultural practices where there are potential synergies and trade-offs among food security and agricultural adaptation and mitigation
Identification and analysis of household-level and institutional constraints that need to be addressed in order to secure synergies and/or manage trade-offs
Assessment of climate change impacts, vulnerability, and adaptation needs of agriculture
Assessment of GHG emissions and mitigation potential from agriculture
Development of weather, crop, and pest/disease forecasting, including mechanisms for data collection, and mechanisms for delivery of information and services to farmers, agricultural planners, and other actors
Utilization of national research institutes and national universities to review existing data and information and collect, analyze, and model new data and information
Agreements on arrangements for the exchange of knowledge and experiences

3.3.2 Designing National Policies to Enable Adoption of Practices

Policies on food security, development, and climate change adaptation and mitigation tend to be formulated separately, with little thought given to linkages across these policy areas. They are also often influenced by policies outside these areas, such as those relating to environmental and energy issues or finance and trade. Better aligned policies could help to overcome policy fragmentation and encourage more coordinated action that is required for synergy building, management of difficult trade-offs,[48] and avoidance of perverse outcomes, which climate-smart agriculture seeks to address.

Agricultural sector policies and programs are often linked to broader policy frameworks, such as national development plans, national poverty reduction strategy papers (PRSPs), national food security strategies (NFSS) or, in the case of Africa, to the Comprehensive African Agriculture Development Programme (CAADP) compacts and their investment plans. These could be screened for policy consistency with climate-smart agricultural approaches, policy coherence across these instruments, and assessment of the potential for integrated policy formulation.

It will also be important for policy, using incentives and regulatory measures as appropriate, to address the barriers to uptake of climate-smart practices by farmers, which may relate to risk aversion, an inability to cover upfront transaction costs or investments, or land tenure issues. A better understanding of how farmers make decisions will be essential in the design of policies that enable them to adopt practices and technologies.

Meeting increasing demand for food, fuel, and carbon storage in forest biomass and soils are closely linked and cut across bioenergy, food security, and agricultural and forest policies. National policy makers will be challenged to formulate more integrated policies to manage potential trade-offs and potentially perverse outcomes arising from policies with a compartmentalized view of land use.

Agriculture is a major driver of deforestation and the draining of wetlands, due to positive returns to farmers from conversion to agriculture. Financial incentives to conserve and sustainably manage forest lands or wetlands would need to provide at least the same level of income or benefits to agricultural land users to be effective in reducing agricultural expansion into these carbon-rich areas. Intensification of agricultural systems, or the increase in agricultural production per unit of inputs (which may be labor, land, time, fertilizer, seed, feed, or cash) could potentially reduce the need for agricultural expansion into forests and wetlands.

However, in some circumstances, increasing productivity and income from agricultural lands could act as an incentive to expand agricultural lands even more, often at the expense of forests. Intensification of agriculture could thus potentially increase the costs for REDD+ and wetland conservation, while policies and measures that take these lands out of production could potentially increase the cost of land. These interlinkages underline the importance of considering the dynamic opportunity costs that farmers and forest communities may face by

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[48] FAO. 2009. FN40.

foregoing agricultural production on forested and wetland areas.[49] In addition, intensification may result in an increase in indirect emissions from higher use of inputs (e.g., on-farm use of fossil fuels, increased fertilizer use, certain types of animal feeds and certain irrigated rice systems).

Box 3.2: Examples of integrated approaches to land-use and multiple objectives

Canada's integrated landscape management uses planning and managing approaches at the landscape scale to address trade-offs, explore risk, and consider best options within the context of socioeconomic and environmental priorities over time, space, and jurisdictions, in order to promote policy development.

Australian Heartlands and LandCare initiatives also use integrated management approaches to land use. **Brazil**'s National Plan on Climate Change, issued in 2008, led to the successful reduction of deforestation, while the country was able to increase economic growth, reduce hunger and transition to low-emission agriculture. More than 80 percent of Brazil's commitment for the reduction of emissions (made at COP15) relates to agriculture and deforestation, which constitute the bulk of its domestic emissions. Brazil manages competing land uses, *inter alia,* through its agro-ecological sugar cane zoning law, and through key policy documents such as the environment agenda within the National Plan, the Sustainable Amazon Plan, and the National Water Resources Plan, which prohibit the cultivation of sugar cane in Amazon, Pantanal, and other protected areas, An agro-ecological palm oil zoning law allows palm cultivation in degraded areas.[1] These laws aim to address multiple objectives at the inter-sectoral level and within targeted sectors such as agricultural lands, forests, water, and energy. See Brazil Federal Government, *Brazil – A country that builds the present, while preserving the future, 20*10.

The impact of bioenergy production is context-specific and will vary according to feedstock, technology, land conversion (especially of carbon-rich land), and country characteristics. Bioenergy production from crops can compete with food crops for land and water resources or may divert food to fuel, resulting in potentially negative impacts on food availability. Also, using agricultural residues to produce bioenergy may divert them from use as soil amendments, contributing in some areas to reduced soil fertility or water retention capacity (with lower adaptive capacity to some climate change impacts). However in countries where, for example, the availability of land, water, and food is not a constraint, bioenergy production could have a

[49] Angelsen, A. and D. Kaimowitz. 2001. *Agricultural technologies and tropical deforestation*, Bogor: Center for International Forestry Research.

negligible impact on food security and a beneficial impact on energy security, livelihoods, and income of farmers, including smallholders.[50]

Integrated land-use planning and landscape approaches, which attempt to holistically integrate multiple goals or targets within spatial planning, are still in their infancy (see Box 3.2 for examples). Such approaches are likely to become important planning tools by which trade-offs and synergies across multiple objectives can be considered and managed.

Table 3.2 Options for designing coherent and coordinated national policies
Review existing national policies related to agricultural sector development, food security and climate change (including bioenergy and REDD), with analysis of the extent to which current policies are aligned or are in conflict with each other
Screen existing national policy instruments and frameworks (e.g., agriculture sector policies, PRSPs, CAADP instruments, FSS, NAPAs, and NAMAs where they exist) for consistency across the policy areas concerned to see how they might be usefully integrated to heighten effectiveness
Identify policy options that enable adoption of climate-smart practices, drawing on data collection on barriers to adoption
Consider possible measures to enforce compliance
Build capacity of policy makers and planners to formulate and coordinate coherent policies across multiple policy areas relating to climate-smart agriculture, including the use of integrated land-use planning, landscape and ecosystem approaches, and scenario simulation for different policy choices

3.3.3 Developing Supportive National Institutional Arrangements

Climate-smart agriculture involves multiple objectives that cut across separate institutions at national and international levels. Innovative institutional arrangements, making full use of existing structures to the extent possible, can contribute to improved coordination and integration of capacity across institutions (e.g., facilitated inter-ministerial dialogue, creation of

[50] It is important to take measures to avoid the potential negative impacts of biofuels on food security in certain national contexts and globally, and to enhance potential positive impacts. Assessing the potential food security, environmental and development implications of biofuels can be a useful first step. FAO has developed an analytical framework to assist national decision makers in considering the complex linkages between bioenergy and food security in the context of formulation of national bioenergy policies and strategies, as well as assessment of investment opportunities (http://www.fao.org/docrep/013/i1968e/i1968e.pdf).

inter-disciplinary communities of practice across relevant ministries, research institutes, planning units, and farmer unions; joint planning exercises, and multi-stakeholder consultation). Improved coordination could lead to more coherent institutional support horizontally across government and vertically from national to local level.

Institutional mechanisms to link farmers with information, inputs, and incentive or payment schemes are often weak or nonexistent. In many countries, agricultural extension systems, the main vehicle for disseminating information for agricultural development, have been completely or partially eroded due to declining external and domestic investment in agriculture. In many cases, Ministries of Agriculture, national research institutes, and extension systems need to be built back. Recently, nongovernmental organizations (NGOs) and private sector entities have tried to fill the "extension void" in some countries. The effectiveness of this outsourcing of extension has not yet been comprehensively reviewed. Existing mechanisms, such as farmer field schools, producer organizations, and farmer unions also offer possibilities in this regard. More effective systems of use and access rights (both formal and informal) to natural resources (land, water, forests, genetic resources) are also likely to be important.

A national mechanism, existing or new, to capture and analyze national experiences with regard to early action could enable countries to feed these experiences back into the discussion of international policy on food security, agriculture, and climate change, particularly discussions on the design and functioning of enabling mechanisms. This feedback could be extremely useful in helping to ensure greater responsiveness of such mechanisms to the specificities of agriculture and its diversity in terms of country needs and contexts.

Table 3.3 Options for developing supportive national arrangements
Review existing institutions and analysis of their capacities and potential for greater integration
Explore possibilities for innovative mechanisms (using to the extent possible existing channels) that allow institutions to contribute to more integrated work that can support the synergy building and trade-off management required for climate-smart agriculture (e.g., mechanisms for inter-ministerial dialogue, linking national policy and community-based action, joint planning exercises across institutions)
Strengthen formal and informal agricultural extension and research systems, including through alternative and innovative mechanisms for extension, aggregation, and collective action
Create, designate, or integrate national and regional knowledge networks or platforms for the identification and dissemination of climate-smart agricultural practices and technologies
Create a feedback loop between experiences and lessons learned in national early action and international policy fora, including UNFCCC and the Committee on World Food Security

3.3.4 Accessing Financing and Investment

For agriculture to be part of the solution to climate change, while continuing to contribute to development and food security, it needs to (1) be eligible to receive resources from existing and future climate financing mechanisms, (2) have its specificities taken into account for effective allocation and use of resources and (3) allow rewards for agricultural producers who adopt practices that generate multiple benefits for climate change, development, and food security. Early action programs and projects can lead to an improved understanding of the feasibility of climate-smart agricultural programs, the costs of measuring results and the effectiveness of different investment/financing options.

Coordination across different financial sources is needed to mobilize the scale of finance required to meet agricultural production and climate change challenges. Such coordination could involve blending climate financing for adaptation and mitigation with domestic resources or official development assistance (ODA) to finance programs to support climate-smart agriculture, where appropriate. Countries could also consider adopting national policies to encourage appropriate private and public investment for achieving synergies across different financing sources and in spreading risk across private and public investors.

National funds, such as Brazil's Amazon Fund, the Indonesian Climate Change Trust Fund or the proposed national Mexican Green Fund, provide opportunities for national ownership while also securing better integration with national policies and programs. Some countries, such as China and Brazil, to a large extent, have, used domestic resources for agricultural adaptation and mitigation activities. Countries may wish to measure the performance and benefits derived from climate-related activities in the agricultural sector, especially if they intend to seek international support for these activities (see Chapter 6).

Smallholder farmers have often been unable to adopt agricultural practices and technologies, from which they stand to benefit, due to barriers such as limited capital or capacities, including the ability to take risks required for innovation and diversification. These same barriers, unless overcome, could prevent them from effecting changes that heighten the resilience of their agriculture-based livelihoods and the food systems to which they contribute and on which they depend or that pave the way for lower emission development. Financial incentives, investment policies, institutional arrangements, tenure security and aggregating mechanisms, as well as innovative ways of sourcing and delivering support, are likely to be important in overcoming adoption barriers.[51]

Reaching numerous and geographically spread smallholders, as well as encouraging and sustaining adoption in cases where benefits are generated over the medium-to-long-term, will

[51] FAO. 2010. FN24.

not be easy. Fortunately, there are a number of experiences on which climate-related financing can draw and which can be tested through demonstration pilots. These include:

- Index insurance transfers risk against an objectively measured index, such as a rainfall deficit. Index insurance programs can be managed through social safety net programs or commercial financial institutions.[52]
- Safety nets are a form of social insurance, which includes programs supported by the public sector or NGOs that may provide cash transfers, food distribution, seeds and tools distributions, and conditional cash transfers to prevent the poor from falling below a recognized poverty level.[53]
- Payments for environmental services (PES) are a potential source of alternative financing for agricultural transition.[54] Mitigation of climate change is an environmental service that smallholders can provide and that can be synergistic with improvements to agricultural productivity and stability. PES relies on (1) formal and informal institutional arrangements for aggregation among a large number of smallholders; (2) coherent policies in the agriculture, financial, and environmental sectors that encourage the flow of public and private financing to farmers; (3) capacity building, including on accessing financing mechanisms; and (4) an agreed system for payments to farmers.[55]

It is not clear at this time whether existing or envisaged financing mechanisms, including fast-start financing or the Green Climate Fund (see Chapter 5 for context and details), will be capable of adequately addressing the specificities of agricultural mitigation and adaptation, including ways of rewarding policies and measures that capture synergies between adaptation and mitigation in the agricultural sector, or whether a dedicated financial mechanism would be beneficial. The extent to which agriculture could attract climate financing will depend on better recognition of the importance of agriculture's adaptation to climate change in order to ensure food security and development, its mitigation potential, and its role as a driver of deforestation, as well as the costs and feasibility of implementing actions and measuring results. These questions could benefit from both international and national consideration. Financing of early actions could add to the body of knowledge underpinning decisions in this regard.

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[52] Hansen, J.W., F.J. Meza, D. Osgood. 2008. Economic value of seasonal climate forecasts for agriculture: Review of ex-ante assessments and recommendations for future research, *Journal of Applied Meteorology and Climatology* 47:1269-1286; Stockholm Environmental Institute (SEI). 2008. FN47.

[53] Devereaux, M. 2002. Can social safety nets reduce chronic poverty ? *Development Policy Review* 20 (5): 657-675.

[54] FAO (UN Food and Agriculture Organization). 2007. *The state of food and agriculture: Paying farmers for environmental services*, Rome: FAO.

[55] FAO. 2010. FN39.

Table 3.4 Options for financing climate-smart agriculture
Strengthen or formulate national policies on investment and financing that ensure appropriate access to climate financing for climate smart agriculture
Identify financing streams that might be optimally combined to give greater flexibility and required resource levels for relevant activities in the agriculture sector
Strengthen national financial institutions, including where relevant national funds, that reward synergies across agricultural adaptation and mitigation and food security
Explore the possibility of new business models for agricultural adaptation and mitigation
Conduct cost-benefit analysis of candidate financing delivery mechanisms and related policies that reach farmers (PES, index insurance, safety nets)
Design financing that addresses delayed returns on investment and "bridges" the loss of income over the short term (e.g., land taken out of production or reduction in stocking rates)
Develop performance and benefit-measurement schemes, assessing their costs and potential institutional and capacity-building requirements

3.3.5 National Strategies and Implementation Frameworks

As part of early action, countries could develop a strategy to guide future action on climate-smart agricultural transformation. The strategy could draw on readiness work undertaken to build an evidence base on practices and barriers to their adoption, policies to overcome these barriers and promote integrated approaches, institution-strengthening to enable greater coordination across entities dealing with food security, development and climate change, and formal and innovative ways of linking finance and climate-smart agriculture. This work could form the basis for a strategy, which would summarize policies and measures, as well as identify necessary enabling means, for implementation beyond early action. Such a strategy might include:

- Costing (including opportunity costs associated with transformation pathways and investment costs), prioritizing and sequencing implementation of promising climate-smart agricultural practices and policies
- Identifying the potential and modalities for innovative financing of action-generating synergies across agricultural adaptation, mitigation, and food security in the agriculture sector
- Identifying other enabling needs (capacity building, technology transfer)

- Monitoring and measuring results
- Drawing on broad stakeholder consultation and determining whether to have a stand-alone strategy or whether relevant elements would be integrated into broader existing strategy(ies).

Table 3.5 Options for an institutional implementation framework
National implementation frameworks, dedicated to climate-smart agriculture, created by unilateral action and funded from national resources
National implementation frameworks dedicated to climate-smart agriculture, funded from both national and external resources
National implementation frameworks for climate change and/or frameworks decided in Cancun (e.g., NAMAs, National Adaptation Plans) into which climate-smart agricultural activities are integrated
Integration of climate-smart agricultural activities into development implementation frameworks
A global partnership arrangement (similar to the Interim Partnership on REDD+[56]) that coordinates national efforts and donor support
Integration of agriculture into a broader REDD+ strategy
Integration of climate-smart agricultural activities into agricultural sector or food security frameworks
A framework for addressing integrated land-based activities, within which climate smart agriculture and REDD+ are placed

3.3.6 Demonstration Activities

Demonstration activities, selected by countries and undertaken as part of early action, could provide opportunities for learning-by-doing or, alternatively, partially implement prioritized activities contained in an eventual national strategy. Activities would be highly dependent on country contexts, thus it is difficult to identify a generic list of options. Categorization or typologies of activities may also not be useful because holistic or integrative approaches are needed to capture synergies and manage trade-offs across different policy areas and institutions.

[56] Meridian Institute. *2009*. Reducing Emissions from Deforestation and Forest Degradation (REDD*): An Options Assessment* Report. Prepared for the Government of Norway.

3.4 Main Messages

Transforming agriculture. Agricultural production systems will often be expected first and foremost to increase productivity and resilience to support food security and agricultural development. However, there is potential for developing lower-emission options without compromising development and food security goals. Transformation of agriculture in this direction may be assisted by climate-smart agriculture that seeks to build synergies and manage trade-offs across the multiple objectives of food security, climate change adaptation and mitigation, and other closely related land uses in the context of sustainable agricultural development.

Learning-by-doing, while negotiations continue. National early action can offer opportunities for confidence, capacity, experience, and knowledge building for more climate-smart agricultural production systems. Such learning-by-doing can help countries clarify their choices and sharpen their capacities and skills for long-term action, while negotiations continue in the context of the Convention.

Ensuring agriculture can benefit from new enabling mechanisms. It is important that envisaged enabling mechanisms being developed in the context of the Convention (NAPs, NAMAs, Adaptation Fund, Green Climate Fund, technology mechanisms) are inclusive of and take into account the specificities of agriculture. A key issue will be how these mechanisms might prioritize and reward options delivering multiple benefits.

Competing land uses addressed in an integrated way. Countries will have to address competition for land (and other natural resources), driven by increasing demands for food, fuel, and carbon storage from agriculture and other land uses. Integrated approaches (land-use planning, landscape, and ecosystem approaches), for example in REDD+ strategies, are likely to be of relevance in looking holistically at multiple goals or objectives within spatial planning exercises.

Technology will not suffice. The existence of suitable climate-smart agricultural practices or technologies with multiple benefits will not *per se* bring about desired transformation of agricultural production systems. Technology adoption has remained a persistent challenge. Adoption of promising technologies and practices might be enhanced by:

- Being part of broader national platforms for action
- Appropriate policies and measures, incentive and regulatory systems, and supportive institutional arrangements
- Capacity building and information dissemination
- Access to appropriate financing, financing instruments, and investment that encourage uptake and overcome barriers to adoption

4. Trade

4.1 Introduction

Feeding the world's population in a context of climate change will require a gradual and significant expansion of transborder exchanges of agricultural products. Hence, it is imperative to ensure a mutually supportive approach to the interface between climate change and trade policies as they relate to agriculture. Regardless of the venue, dealing with these critical issues will benefit from a prompt, informed, and evidence-based approach. Yet the complexities of the interface between trade and climate change have not been comprehensively dealt with—let alone resolved—in any forum, leaving the door open for isolated or plurilateral responses and unilateral action. This chapter intends to provide an objective analysis of the most salient issues at the intersection of trade, agriculture, food security, and climate change.

4.2 Trade and Climate Change Adaptation in Agriculture

4.2.1 The Role of Trade in Agricultural Adjustment to Climate Change

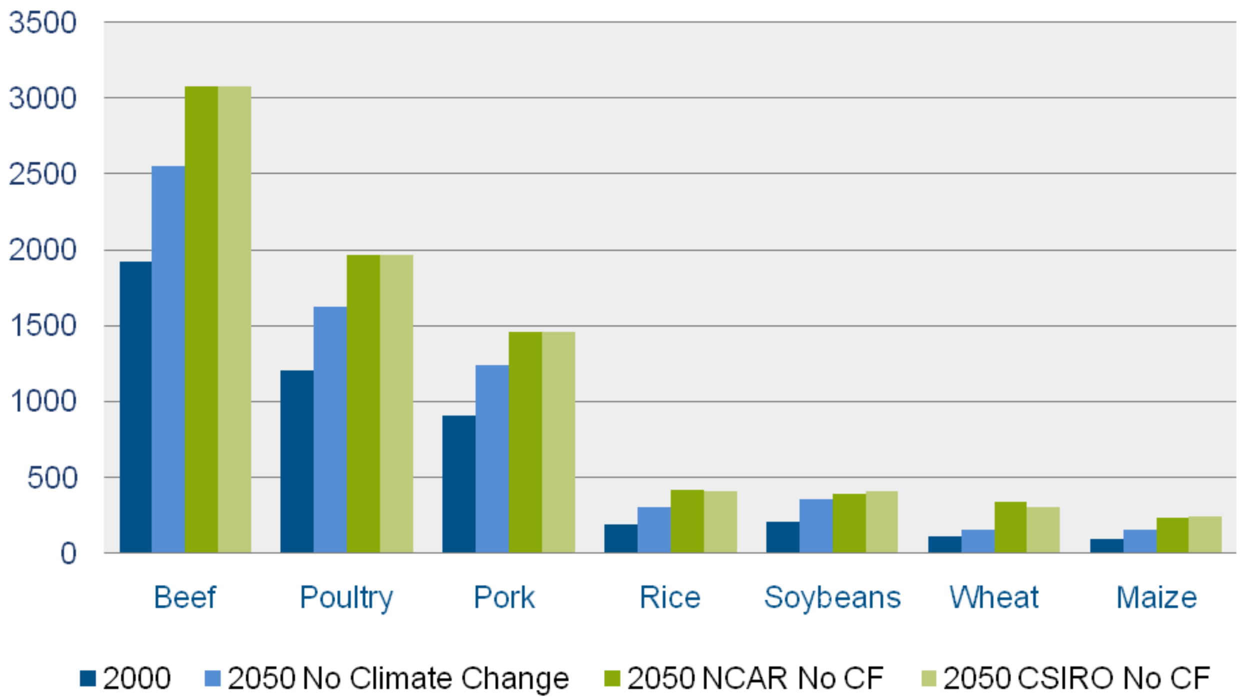
Exports of agricultural goods through international markets enable the availability of grains and other agricultural commodities that may be otherwise unavailable or scantily accessible through domestic production. The biophysical impacts of changes in climate patterns will alter crop and animal productivity and ultimately affect availability of agricultural products through trade flows. Assessing the scope and magnitude of these changes is challenging, not least of all because of the large uncertainties regarding future climatic conditions and their effects on production. Bearing in mind these limitations, a 2009 study by Nelson *et al.* of the International Food Policy Research Institute (IFPRI) estimated climate change effects on yields, world prices, and trade.[57] Because such simulations are inherently uncertain, the study uses two climate models developed by the U.S. National Center for Atmospheric Research (NCAR) and Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) to simulate future climate, using the A2 scenario of the IPCC Fourth Assessment Report.[58]

[57] For a detailed description of the models used, see Nelson, G., A. Palazzo, C. Ringler, T. Sulser and M. Batka, 2009, *The Role of International Trade in Climate Change Adaptation*. ICTSD-IPC Platform on Climate Change, Agriculture and Trade, Issue Brief No 4. Geneva: International Centre for Trade and Sustainable Development and Washington DC: International Food & Agricultural Trade Policy Council.

[58] IPCC. 2007. FN45. For information on the NCAR model, see http://ncar.ucar.edu/. For further information on the CSIRO model, see http://www.csiro.au/.

Figure 4.1 shows the evolution of prices between 2000 and 2050, first without climate change and then under the CSIRO and NCAR scenarios without CO_2 fertilization (No CF). Even in the absence of climate change, prices are expected to increase significantly as population and income growth surpass productivity and increases in agricultural land Climate change further exacerbates this trend, with wheat prices increasing by an additional 94–111 percent and maize by 52–55 percent.

Figure 4.1: World prices of selected crop and livestock products under different scenarios[59] *(constant 2000 US$/tone)*



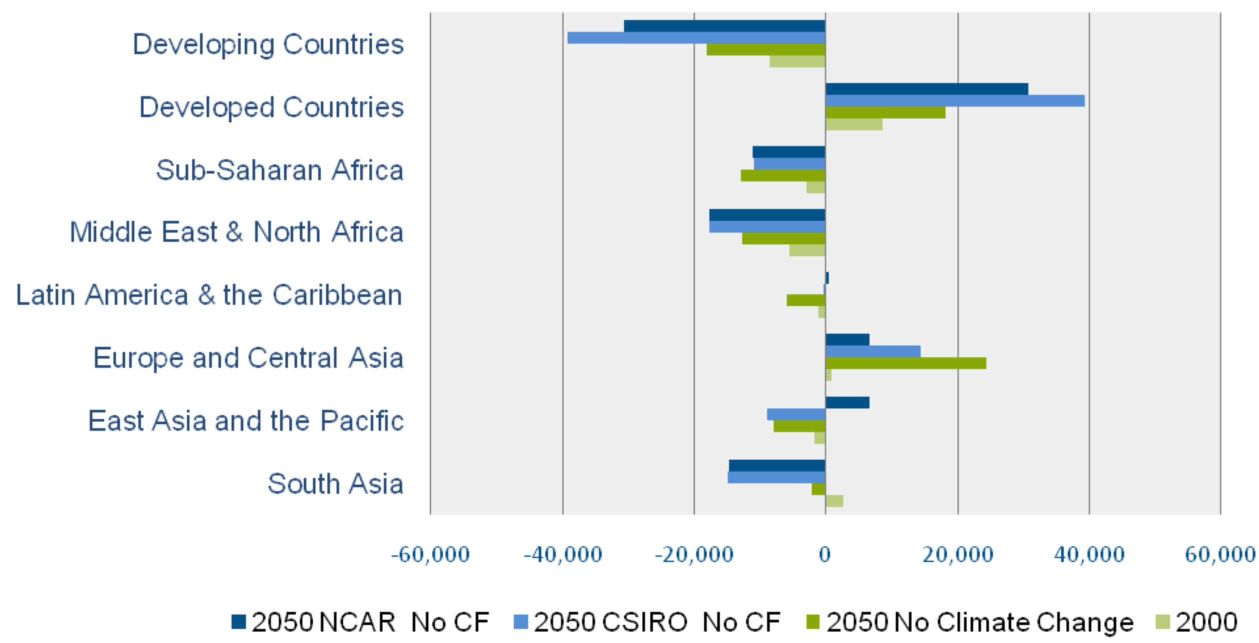
Estimated trade flow adjustments resulting from changes in prices and production are shown in Figure 4.2. The graph shows the net difference between balance of trade (exports minus imports) in a base scenario compared with balance of trade with climate change impacts factored in (without fertilization). It is worth noting that changes in the value of imports and exports are generally more dramatic than changes in production because of the climate-change effect on prices described above.

Overall, developing countries' agricultural imports are expected to double due to climate change. This evolution is mirrored by a similar increase in developed-country exports. Whereas

[59] Nelson *et al*. 2009. FN36.

South Asia was a net exporter of cereals in 2000, it is projected to become a net importer under the no climate change scenario in 2050. With climate change, South Asia's imports are projected to increase by another 550 percent. Sub-Saharan Africa's imports are estimated to increase by about 270 percent depending on the scenario, compared with 2000 levels. Finally, Latin America and the Caribbean countries would see their imports significantly reduced or may even become net exporters of cereals.

Figure 4.2: Value of net cereal trade (rice, wheat, maize, millet, sorghum, and other grains) by region in 2000 and 2050 under different climate scenarios[60] (million US$)



These changes will affect individual countries differently depending on the extent to which they rely on agricultural trade as part of their food security and development strategy. Countries that import a large share of agricultural products will face significantly higher food bills because of both productivity declines at home and higher world food prices. Similarly, countries that rely heavily on commodity export earnings to import food and feed might suffer from lower productivity at home and higher prices of staple food.

[60] Ibid. FN36.

4.2.2 Trade Policy Implication

Trade flows in agriculture depend on the interaction between comparative advantages determined by climatic conditions and resource endowment, as well as a wide range of trade-related policies. To address future imbalances in supply and demand that may result from productivity decline, many have argued that an open and undistorted trading system at the regional and international level would be the best guarantee to ensure that food will remain available, particularly in regions where production has been affected by climate change.[61] Others have argued that enhanced investment in agriculture combined with appropriate flexibilities in liberalization of agreements are needed to deal with cases of market failures and imperfect institutions, particularly in those developing countries where livelihoods are intricately related to farming.[62] This section examines a range of national and regional policies that currently affect trade in agriculture.

Farm productivity has remained low in many developing countries partly as a result of implicit and explicit taxation of agriculture along with weak infrastructure and low levels of investment, but also as a result of trade policies. For years, independent analysts , the World Bank, the UN Food and Agriculture Organization (FAO) and a number of countries and coalitions at the World Trade Organization WTO, have argued that the sustained provision of trade-distorting subsidies to the agricultural sector in several country markets has affected competitiveness and undermined incentives for investment in agriculture elsewhere, sending wrong economic signals in countries where enhanced investment to cope with climate change is urgently needed. Conversely, countries providing massive agricultural support point to the multifunctional role of agriculture and argue that in the absence of subsidies, production would not be economically sustainable with current farm structures.

Trade-distorting agricultural subsidies in the United States amounted to US$13 billion in 2008[63] while Japan's, according to its most recent notification to the WTO, amounted to ¥679 billion in 2006.[64] In the European Union, successive reforms of farm support policies have delinked payments from production levels, leading to a sharp decline in trade-distorting payments from

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[61] Blandford, D., and T. Josling. 2009. *Greenhouse gas reduction policies and agriculture: Implications for production incentives and international trade disciplines, ICTSD–IPC platform on climate change, agriculture and trade*, Issue Brief No.1. Geneva: International Centre for Trade and Sustainable Development, and Washington D.C., International Food and Agricultural Trade Policy Council.

[62] See, for example, UNCTAD. 2011. *Assuring Food Security in Developing Countries under the Challenges of Climate Change: Key Trade and Development Issues of a Fundamental Transformation of Agriculture*. Discussion Paper No 201 (Geneva: UNCTAD).

[63] WTO. 2010. *Committee on Agriculture. Notification. United States. Domestic support. WTO /G/AG/N/USA/77* , Geneva. This quoted amount, as well as other similar figures, is taken directly from each country's own latest notification to the WTO Committee on Agriculture. Such notifications are only available in local currencies and no official exchange rate conversion is available from the WTO to make them comparable; they are offered here for illustrative purposes.

[64] WTO. 2008. *Committee on Agriculture. Notification. Japan. Domestic subsidies.* WTO/G/AG/N/JPN/137, Geneva.

roughly €60 billion in 2004 to €19.9 billion in 2007–2008.[65] This reduction was accompanied by a similar increase in payments that are decoupled from production and may be considered nontrade distorting.

Negotiations in the context of WTO's Doha Round are aimed at cutting trade-distorting subsidies in a series of gradual instalments by imposing stricter ceilings for future spending. However, no cuts or ceilings are expected on support that countries "decouple" from production, such as direct income support payments, environmental payments, or investment aids on the grounds that these types of payments cause minimal distortion of trade or production. Known as "green box" support at the WTO, these payments allow countries to promote specific public goods such as the environment. They reached US$81 billion in the United States in 2008 and €63 billion in the European Union in 2007–2008.[66] Some developing countries have recently introduced schemes of support along these lines.

Improved market access for exports from all countries, but particularly those from developing countries, could enable or enhance countries' capacities to respond to climate-change-induced productivity declines. Although average tariffs in many developed countries are low, tariffs on a number of key products remain unusually high. The European Union already grants duty-free, quota-free market access to least-developed countries and former colonies in African, Caribbean, and Pacific countries. It also provides preferential market access to other developing countries through its generalized system of preferences, but maintains relatively higher tariffs on "sensitive products" such as beef, pork, dairy products, rice, and processed cereal grains. The proposed Doha Round deal at the WTO could cut tariffs for such products from an average of 85 percent to closer to 45 percent.[67] Although the United States has fewer such products, the draft WTO accord is expected to reduce the maximum tariff permitted on them from an average of 29 percent to around 18 percent.[68] Developing-country tariff structures vary significantly: on the whole, developing countries tend to have fewer unusually high tariff peaks, but average agricultural tariffs tend to be higher than in developed countries.[69]

Importing countries, particularly the poorest ones, will need to ensure that their adaptation strategies take into account the needs of small farmers in poor communities whose livelihoods and food security may be at risk in the event of rapid and far-reaching trade liberalization. In

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[65] WTO. 2011. *Committee on Agriculture. Notification. European Union. Domestic support. WTO/* G/AG/N/EEC/68, Geneva.
[66] WTO. 2010. FN63 and WTO. 2011. FN65.
[67] Jean, S., T. Josling, and D. Laborde. 2008. *Implications for the European Union of the May 2008 draft agricultural modalities*, International Centre for Trade and Sustainable Development (ICTSD), Geneva.
[68] Blandford, D, D., Laborde, and W. Martin. 2008. *Implications for the United States of the May 2008 draft agricultural modalities*, International Centre for Trade and Sustainable Development (ICTSD), Geneva.
[69] Tariff barriers are not the only impediment to exports from developing countries. Market and transportation infrastructure, as well as countries' capacity to meet sanitary and phytosanitary requirements in export markets also plays a critical role. Initiatives such as the Aid for Trade can help countries overcome their supply-side constrains.

many parts of the developing world, small farmers are unable to compete with large-scale industrialized agriculture. A mechanism to deal effectively with products that are critical to food security, livelihoods, and rural development is currently under negotiation in the WTO, allowing developing countries to modulate liberalization to their needs by cutting tariffs more gently than other countries.[70]

4.3 Transfer of Technology and Trade

4.3.1 Intellectual Property Rights and Technology Diffusion

Technologies for adaptation and mitigation play a key role in enabling a wide range of developing countries cope with the effects of climate change. As countries seek to access new productivity-enhancing and climate-resilient crops, while safeguarding farmers' traditional rights to use, save, and share seeds that may be particularly well suited to local conditions, the debate on technology transfer and trade-related intellectual property rights (IPRs) has been particularly controversial.[71] There seems to be a generalized view among countries that IPRs play an essential role in promoting innovation in clean technologies. However, up to the sixteenth session of the COP in 2010, some developing countries had argued that IPRs constituted a possible barrier to technology transfer by increasing the cost of technology acquisition. In this context, a polarized debate has ensued in which a meaningful discussion based on evidence rather than rhetoric had little chances of taking place. As a result, all the language on IPRs remains bracketed and there is no reference to IPRs in the Cancun Agreements.

Recent reports have documented an increase in patenting of climate-change-adaptation crops[72] (e.g., drought resistant seeds) leading to concerns about whether farmers and communities in developing countries will have access to the seeds. Most patent landscaping studies in relation to climate change technologies have focused on energy rather than agriculture. Hence, a gap persists in data and analysis on patenting and licensing trends in the development of new crops and seeds for climate change adaptation, as well as on the effects of IPRs on access to new climate-appropriate plant varieties. Overall, the role of patents in impeding access to agricultural technologies is less clear than in other sectors such as the pharmaceutical sector.[73]

[70] See ICTSD (International Centre for Trade and Sustainable Development). 2005. *Special products and the special safeguard mechanism: Options for developing countries.* Issue Paper No 6, Geneva.

[71] For more detail on the role of technology under the Convention, see Chapter 5.

[72] *Washington Post.* 2008. "Firms Seek Patents on 'Climate Ready' Altered Crops", March 13, 2008, Washington, DC. http://www.washingtonpost.com/wp-dyn/content/article/2008/05/12/AR2008051202919.html.

[73] Lybbert, T., D. Sumner. 2010. A*gricultural technologies for climate change mitigation and adaptation in developing countries: Policy options for innovation and technology diffusion, ICTSD–IPC platform on climate change, agriculture and trade*, Issue Brief No.6, 17. International Centre for Trade and Sustainable Development (ICTSD), Geneva.

Not all the new varieties currently protected by IPRs are valuable for smallholder resource-constrained farmers. Furthermore, much of the needed improvement in agricultural production can be achieved through enhanced practices and may not require the latest biotechnology.

4.3.2 Trade Liberalization and Technology Diffusion in Agriculture

The WTO's 2001 Doha Ministerial Declaration[74] calls for reduction of tariff and nontariff barriers on environmental goods and services. In this context, several members have put forward proposals focusing specifically on climate change. By reducing costs of climate-friendly products the negotiations aim to contribute to the diffusion of carbon and energy-efficient technologies. In this context, many countries, particularly developing economies, have expressed interest in "environmentally preferential products" (EPPs). EPPs are distinct from pollution-control goods and technologies in the sense that environmentally beneficial effects arise during the course of their production, use, or disposal. Some developing countries, including India and Brazil, have supported inclusion of organic products and fertilizers, jute, sisal, and other textile fibers. A prominent example of an EPP is bioenergy. Brazil – a major producer of carbon and energy-efficient ethanol that faces major access barriers to export markets – has proposed that biofuels be considered as environmental goods. Australia, the European Union, and the United States have opposed this designation, as have some developing countries, such as Cuba, while others, such as Peru, have supported it. At this stage, discussions and negotiations remain inconclusive.

4.4 Mitigation in the Agricultural Sector and Trade

4.4.1 Agriculture Trade and Competitiveness

Various concerns have been expressed regarding how measures aimed at reducing GHG emissions in agriculture could affect trade performance or accessibility and availability of food in the future. The top 25 food-exporting countries currently produce 82 percent of all the food that is traded globally.[75] At the same time, they account for more than 70 percent of agricultural GHG emissions. Countries like Argentina, New Zealand, Thailand, Uruguay, and Vietnam, which tend to rely heavily on agricultural trade for employment generation and economic development, also generate a considerable share of their emissions through agriculture: 36 percent in Vietnam, 38 percent in Argentina, nearly 50 percent in New Zealand, and more than 80 percent in Uruguay.[76] Unless they manage to reduce their emissions without affecting

[74] WTO (World Trade Organization). 2001. Doha Ministerial Declaration, para. 31 (iii)
[75] See Climate Analysis Indicators Tool (CAIT), http://cait.wri.org/.
[76] Ibid.

production, they will have to make difficult trade-offs between mitigation and export revenues. At the other end of the spectrum, in the European Union, Japan, and the United States, for example, agriculture exports play a limited role as a share of GDP. In these countries the sector also represents a relatively low share of total GHG emissions (2.6–10 percent, even though the amount of emissions is high in absolute terms).[77]

Overall, countries that heavily rely on agricultural exports have raised concerns regarding the consequences of mitigation measures taken by their trading partners. Similarly, in countries considering emissions reduction in agriculture, exporters and importers are concerned about losing competitiveness *vis-à-vis* foreign providers as a result of more stringent domestic environmental regulations.

4.4.2 Economic and Social Consequences of Mitigation Measures

Some of the climate change mitigation (response) measures that have emerged in recent years, depending on how they are designed, may pose challenges to existing trade agreements. The following sections focus on four salient types of policy measures: Carbon standards and labeling; subsidies for reducing GHG emissions; border tax adjustments; and free emission allowances under cap-and-trade schemes.

Carbon standards and labeling initiatives that affect both sourcing and decision making within agricultural supply chains are rapidly growing. These schemes entice producers to measure and monitor their embedded carbon, and provide consumers with the option of decreasing their personal carbon footprints. Examples of early initiatives involved supermarket chains, with companies such as the United Kingdom's Tesco that offer an increasing number of products carrying carbon labels. France has new legislation under development that would make carbon labeling mandatory for a range of products.[78] At the global level, the International Standards Organization (ISO) plans to launch an international carbon footprint standard, ISO 14067, by the end of 2011. In the absence of a standardized methodology to calculate GHG emissions, initiatives vary considerably in design and scope.[79] The first experiments on private labeling focused narrowly on transport-related emissions and thus ended up disadvantaging small fruit and vegetable exporters from Africa and countries in regions located far from markets. Currently, more sophisticated schemes, based on life-cycle analysis, are emerging, such as the European-wide sustainability criteria for biofuels, which contains requirements linked to the

[77] Ibid.

[78] Steenblik, R ., and E. Moise. 2010. *Counting the Carbon Emissions from Agricultural Products: Technical Complexities and Trade Implications*. Policy Brief. Washington: International Food and Agriculture Trade Policy Council. France's draft law (Grenelle II, Article 85), http://www.nosdeputes.fr/loi/2449/article/85
http://www.nosdeputes.fr/loi/2449/article/85.

[79] For a discussion on measurement of GHG emissions in agriculture, see Chapter 6.

product's carbon footprint, but also specifies which types of land may be used to produce feedstock. Still, debate is ongoing as to the discriminatory or protectionist effects of any such standard, particularly when developing country producers are not involved in the design and setting of such standards.

Although these schemes could provide opportunities for positive product differentiation, they have also raised concerns related to equity and cost of compliance for developing countries confronted with a multiplicity of standards. Nonstatutory schemes, such as private sector labeling initiatives have raised particular concerns. Although such schemes can hurt their exports, developing countries have little room to maneuver, given that WTO rules governing standards essentially bind member countries but not private agents.

Subsidies are not necessarily inconsistent with WTO rules, but their application is strictly circumscribed by the Agreement on Subsidies and Countervailing Measures and the Agreement on Agriculture (AoA). Overall, support decoupled from production, such as environmental payments or policies that restrict current activities (e.g., taking land out of production via subsidies for sequestration), are unlikely to encounter problems from a trade perspective. Conversely, policies that subsidize particular practices, such as improvement in animal nutrition or subsidies for minimum tillage, might be qualified as trade distorting if they encourage production or exports.[80]

Environmental payments

The AoA makes explicit provisions for direct environmental payments in agriculture. The largest user of this provision, the European Union, spent €6.3 billion on its environmental programs in 2007–2008, the United States spent US$43.9 billion in 2008, and Japan, ¥170 billion in 2006.[81] These payments administer a variety of programs, from wetlands preservation in the United States to pasture lands in the European Union. The WTO's conditions for direct environmental payments specify that transfers cannot be related to production, must be part of a clearly defined government environmental program, and cannot exceed the extra costs or loss of income involved in complying with the program. In practice, however, some programs do not contain strict environmental objectives defined in measurable and verifiable outcomes, which could raise concerns of overcompensation and, ultimately, make the payments potentially

80 Blandford, *et al*. 2009. FN61.

81 Figures quoted from the most recent notifications of the respective countries to the WTO Committee on Agriculture in currencies originally used. WTO. 2010. *Committee on Agriculture. Notification. United States. Domestic support. WTO /G/AG/N/USA/77* , Geneva, WTO. 2008. *Committee on Agriculture. Notification. Japan. Domestic Subsidies. WTO/G/AG/N/JPN/137*, Geneva. WTO. 2008. *Committee on Agriculture. Notification. China. Domestic support. WTO/ G/AG/N/CHN/17*, Geneva, WTO. 2011. *Committee on Agriculture. Notification. European Union. Domestic support. WTO/ G/AG/N/EEC/68*, Geneva.

subject to challenge in the WTO.[82] This reality highlights the importance of establishing appropriate indicators and performance monitoring systems (see also Chapter 6).

Subsidies for energy crops

Governments increasingly support fuels from renewable organic feedstocks that are low in GHGs as part of climate-change-mitigation efforts. Estimates of subsidies for biofuels place the United States at the head of the pack with US$8.1 billion spent in 2007. Total transfers associated with the policies of the European Union and its member states amounted to €3.01 billion in 2008.[83] However, as of 2009, the Common Agricultural Policy no longer provides direct support to biofuels at the community level. Support can be provided at different levels of the supply chain from the production and distribution of biomass to the consumption of blended (or unblended) fuel. In Brazil, for example blending mandates have been accompanied by a host of supporting policies, including retail distribution requirements, subsidized credit for ethanol storage, and tax preferences for vehicles.[84] Overall, support measures for production and distribution are more likely to be challenged under WTO rules than consumer and research subsidies. Some subsidies could be considered as providing indirect support to the production of feedstock (e.g., corn or oilseeds) and therefore fall under the category of trade-distorting subsidies. Others might be considered as minimally trade distorting if feedstock was a waste product or cellulosic material that is not a "marketable agriculture product."

Governments taking climate change mitigation actions, and thereby imposing a carbon cost, are generally concerned that their economies will experience fierce competition from foreign firms that do not face a similar carbon cost. As a result, market shares could be lost and a relocation of production, and thus of emissions, to regions with a lower carbon price could take place. The two measures, although not the only ones, under the most discussion to deal with these competitiveness and carbon leakage concerns, are the application of border carbon adjustments (BCAs), and the allocation of emission allowances free of charge under an emissions trading scheme. These two measures, although sharing similar rationale, have very different economic and legal consequences.

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[82] Blandford, et *al*. 2009. FN61.

[83] See Koplow, D. 2007. *Biofuels - At what cost? Government support for ethanol and biodiesel in the United States: 2007 update*. One of a series of reports addressing subsidies for biofuels in selected OECD countries, IISD Global Subsidy Initiative, International Institute for Sustainable Development , Geneva; Jung, A., P. Dörrenberg, A. Rauch, and M. Thöne. 2010. *Biofuels at what cost? Government support for ethanol and biodiesel in the European Union - 2010 update*, International Institute for Sustainable Development, Geneva, Global Subsidy Initiative.

[84] Hebebrand, C, and K. Laney. 2007. *An examination of U.S. and EU government support to biofuels: Early lessons,* IPC Issue Brief, International Food & Agricultural Trade Policy Council, Washington DC.

The prospect of border carbon adjustments in the agricultural sector

The legality of BCAs under WTO law is disputed.[85] BCAs would entail an extra charge at the border and thus might disrupt trade, affecting the income or competitiveness of exporting countries. Even if the carbon charge were low, it would entail administrative costs, and possibly delays at the border, which could pose a problem for perishable agricultural goods. There have been proposals on BCAs, but so far these measures have not been implemented. The United States discussed two comprehensive climate change bills with such provisions, the Waxman-Markey and Kerry-Lieberman bills.[86] However, these bills are currently off the table. The European Union has discussed the concept but has never considered an actual proposal. With respect to agriculture, the U.S. proposals and the E.U. discussion focused on a few heavy-emitting industries—including fertilizers—but so far have excluded agriculture products.

Free allowances in the agricultural sector

Agriculture is not presently included in the few emissions trading schemes in effect around the world. However, New Zealand will incorporate agricultural emissions in its trading scheme beginning in 2015. In so doing, it will also extend its program of free allocation of allowances to the sector. From a trade perspective, free allowances, depending on the way they are allocated, could constitute a subsidy, from both an economic and a legal point of view, and might be challenged if they distort trade or generate serious prejudice to other WTO members.

4.5 Pending Issues under the Convention

Climate change adaptation and mitigation policies and measures related to agricultural trade remain ungoverned by the Convention. While trade policy may support these ends, it may not be designed for it. Overall, good-faith climate -change policies are unlikely to breach existing multilateral trade rules, either because they would not be discriminatory or because, if they are, they may be covered by the general exception under WTO's Global Agreement on Tariffs and Trade (GATT) Article XX. [87] Many potential conflicts can be avoided if international consensus on a climate change framework is reached. In the absence of a global agreement, countries might apply unilateral or plurilateral measures, which may lead to trade disputes. When and if

[85] For a legal analysis of BCAs, see WTO-UNEP. 2009. *Trade and climate change: WTO –UNEP report*, WTO Publications, Geneva.

[86] Waxman-Markey bill refers to the American Clean Energy and Security Act, HR 2454, 2009. Kerry-Lieberman bill to the American Power Act. O:\END\END10540.xml.

[87] "Subject to the requirement that such measures are not applied in a manner which would constitute a means of arbitrary and unjustifiable discrimination between countries where the same conditions prevail, or a disguised restriction on international trade, nothing in this agreement shall be construed to prevent the adoption or enforcement by any contracting party of measures: …(b) necessary to protect human, animal or plant life or health;…(g) relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption;… "General Agreement on Tariffs and Trade (GATT 1947), Article XX: General Exceptions. The WTO Agreement. 1995. World Trade Organization, Geneva.

conflicts arise, governments may have to leave these matters to existing applicable regulatory frameworks (i.e., WTO dispute settlement) for resolution. Several countries have suggested that trade issues cannot be solved in the UNFCCC negotiations and should be left to the trade community. At the same time, WTO members have adopted a "wait and see" approach, expecting a signal from the UNFCCC negotiations before engaging formally on those issues. This section suggests possible avenues, both in the UNFCCC process and in the multilateral trading system, to advance discussions on trade and climate change. These options do not reflect consensus among countries and are not mutually exclusive.

4.5.1 Options under the UNFCCC Process

Paragraph 90 of the AWG-LCA text of the Cancun Agreements echoes language of Article 3.5 of the Convention which states that "measures taken to combat climate change, including unilateral ones, should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade."[88] This language draws from the text of the chapeau of GATT Article XX. By using similar language, negotiators have sought consistency between the two regimes. It may also imply that in case of conflict, the WTO dispute settlement would ultimately apply.

The extent to which climate change negotiations may want to tinker or go beyond such language is a matter for negotiation among Parties. In theory, the climate regime itself could act multilaterally to create norms on trade and climate change; for example, by agreeing on principles for the use of trade measures for climate change, which could be taken into consideration by WTO dispute procedures if a conflict should arise.

Alternatively, Parties to the Convention may call on the WTO to address a set of critical issues at the interface between trade and climate change. It could send a strong signal to the trade community and encourage the establishment of a formal discussion within the multilateral trading system.

Whereas trade negotiations in agriculture may be left to the WTO, there might be merit in exploring selected trade- and climate-change- related issues in the context of a work program on agriculture under the Subsidiary Body of Scientific and Technical Advice (SBSTA) and/or the Subsidiary Body for Implementation (SBI). These explorations could range from simple exchange of information, experiences, or policies through methodological and conceptual aspects (e.g., in the design of carbon standards and regulations) to broader political concerns around the potential trade impact of different policies and measures to address climate change.

[88] See UNFCCC. 2010. Cancun Agreements: Outcome of the work of the Ad Hoc Working Group on Long-Term Cooperative Action under the Convention. FCCC/CP/2010/7/Add.1.

Given the high level of sensitivity associated with trade issues, one option might be to create a dedicated forum outside the formal negotiating process. This forum could follow the model provided under paragraph 93 of the AWG-LCA text of the Cancun Agreements, but with a specific focus on trade. Such a proposal would be along the lines of the submission by Argentina to the AWG-LCA in April 2010, suggesting the establishment of a mechanism to share information and explore concrete ways to minimize negative economic and social consequences of response measures by developed countries in particular on international trade.[89]

4.5.2 Options in the WTO

Some analysts have suggested that key WTO members could negotiate a code or a plurilateral agreement on trade and climate change among themselves.[90] A recent paper by the World Economic Forum emphasizes the need for WTO members to negotiate a "green space" to allow for enactment of national measures to combat climate change, prohibit fossil fuels subsidies, and encourage the development of green technologies.[91] These proposals would probably go a long way in responding to new challenges.

In parallel with efforts to conclude the Doha Round, WTO members could initiate a dialogue process to examine emerging policies designed to combat climate change, identify possible areas of conflict, and consider ways in which WTO rules may need to be clarified and possibly amended. Such a process would not require a new institutional framework and could be initiated under the current mandate of the WTO´s Committee on Trade and Environment (CTE). In this respect, Singapore has recently made a submission to the regular session of the CTE to embark on work examining the relationship between the possible application of BCAs and the WTO.[92]

Some observers have suggested that WTO members should agree on a time-limited moratorium in the application of trade-related measures in the context of their climate change legislation. This moratorium would, for example, suspend the application of border measures on imports

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[89] UNFCCC. 2010. *Ad Hoc Working Group on Long-Term Cooperative Action. FCCC*/AWGLCA/2010/MISC.2, April 30, Preparation of an outcome to be presented to the Conference of the Parties for adoption at its sixteenth session to enable the full, effective, and sustained implementation of the Convention through long-term cooperative action now, up to and beyond 2012. Submissions from Parties.

[90] Hufbauer, G.C. and J. Kim. 2009. *The WTO and climate change: Challenges and options*, Washington, D.C.: Peterson Institute for International Economics,

[91] See: Ad Hoc Working Group on Trade and Climate Change. 2010. *From collision to vision: Climate change and world trade*. Discussion paper, Geneva: World Economic Forum.

[92] See: WTO. 2011. WT/CTE/W/248: Promoting Mutual Supportiveness between Trade and Climate Change Mitigation Actions: Carbon-Related Border Tax Adjustments. Communication from Singapore, March 30, 2011, World Trade Organization.

and other extra-territorial controls, while UNFCCC and WTO negotiations are under way.[93] The main advantage of such an option is that it would buy time while international consensus is reached.

A related proposal informally tabled by New Zealand is to establish a "peace clause" for a period of five to seven years once a global agreement on emissions reductions is reached under the UNFCCC process. Such a clause would commit WTO members to refrain from using WTO dispute settlement procedures that might challenge certain core climate change policy tools.[94] The proposal would explicitly rule out unilateral BCAs, but could apply to "grey areas," such as the extent to which free allocations of emissions units might constitute a subsidy, and if so whether they would be WTO compatible.

4.6 Main Messages

Impact of climate change on trade patterns. Climate change will affect comparative advantages in agriculture. Trade patterns are likely to change as a result of variations in yields and prices. Climate change will likely further drive up food prices, which in turn might lead to significant changes in global trade flows.

Role of international trade in adaptation and food security. Trade combined with increased investment in agriculture production, can help address imbalances of supply and demand and make food available in world markets by offsetting climate-induced production decreases in certain regions. As a response to future imbalances in supply and demand that may result from productivity decline, many have argued that an open and undistorted trading system at the regional and international level is the best guarantee to ensure that food will remain available, particularly in regions where production has been affected by climate change. Others suggest that appropriate flexibilities in liberalization agreements combined with productivity-enhancing measures are needed to deal with market failures and imperfect institutions in countries where livelihoods are intricately related to farming.

Impact of mitigation policies. Mitigation measures in agriculture could affect agricultural exporters and ultimately the availability of food in the world market. Some measures (e.g., subsidies for mitigation, border tax adjustments) may also pose challenges to existing trade agreements depending on how they are designed and implemented. However, overall, good-faith climate-change policies are unlikely to breach existing multilateral trade rules, either

[93] Hufbauer *et al*. 2009. FN90.

[94] Transcript of a speech delivered by the Hon. Tim Groser, Trade Minister and Associate Climate Change Minister, New Zealand, "Trade and Climate Change: A Negotiator's Perspective," speech delivered December 8, 2009 at Chatham House, London, http://www.chapmantripp.com/publications/Pages/Carbon-border-taxes-and-Grosers-peace-clause.aspx.

because they would not be discriminatory or because, if they are, they would be covered under the general exceptions of WTO's General Agreement on Tariffs and Trade (GATT) Article XX. Many potential conflicts could be avoided if consensus on a global climate change framework is reached.

WTO and UNFCCC offer venue options. Possible avenues to advance discussions on trade and climate change can be explored in both the UNFCCC and/or in the multilateral trading system. Such options range from maintaining the current status quo, through establishing dedicated discussion fora outside of existing negotiating tracks, to clarifying or designing new principles or multilateral disciplines in the WTO to address the trade and climate change interface.

5. Finance, Technology, and Capacity Building

5.1 Introduction

Adopting agricultural practices that are able to withstand changes in climate and contribute to the reduction of GHG emissions requires the application of new technologies, the modification of existing ones, and changes to relevant laws and policies, as well as additional capacity at the farm, policy, and scientific levels to implement such measures. Technology deployment and related capacity building in agriculture comes with significant costs, for which developing countries, in particular, need financial support. Therefore, finance, technology transfer, and capacity building are essential focus areas for the successful implementation of climate change mitigation and adaptation activities.[95]

5.2 Finance

5.2.1 Agricultural Financing Needs

Over the past three decades, agricultural commodity prices sank to all-time lows (in real terms), along with yield growth in both developed and developing countries.[96] New pressures on the sector are redrawing this picture. The two factors that are likely to be the most important in defining long-term agricultural demand are population and income (measured as GDP per capita). More people earning higher incomes (and consequently shifting toward resource-intensive foods), along with surging bioenergy demand, tight food supplies, and little spare production capacity, are likely to lead to an increase in demand for the foreseeable future.

Large private and public agricultural investments are required to meet projected agricultural demand. FAO estimates investment needs of US$9.2 trillion by midcentury (US$210 billion annually from 2005– 2050),[97] a number that does not even account for climate change impacts or other constraints.[98] About 60 percent (US$5.5 trillion) of the total will be required to replace existing capital stocks. The remainders (about 40 percent or US$3.6 trillion) will be used to meet

[95] This is in line with the Cancun Agreements that discuss all three subjects under a common header. Decision 1/CP.16, chapter IV (AWG-LCA text).

[96] Foresight. 2011. FN41; Garnett, T. 2011, FN41.

[97] Schmidhuber, J., J.Bruinsma, G. Boedeker. 2009. *Capital requirements for agriculture in developing countries to 2050.* Rome: UN Food and Agriculture Organization, Economic and Social Development Department, ftp://ftp.fao.org/docrep/fao/012/ak974e/ak974e00.pdf.

[98] US$210 billion gross if accounting for replacement costs of depreciating capital goods; all estimates in constant 2009 U.S. dollars.

the additional agricultural product demand. Mechanization represents the single largest investment (about 25 percent) within primary agriculture in developing countries, along with expansion of irrigation systems (about 20 percent).[99] Of the total US$9.2 trillion, 57 percent, is dedicated to primary agriculture and the remainder for support services such as storage, processing, milling, and marketing facilities or services.[100] **Table 5.1** illustrates the net investment (after depreciation) and gross investment (absolute capital replacement and productivity) needed through 2050 for specific applications.

Table 5.1: Total annual investments in agriculture required in developing countries[101]

		Net	Gross
Crop production	Land development, soil conservation and flood control	139	161
	Expansion and improvement of irrigation	158	960
	Permanent crops establishment	84	495
	Mechanization	356	1,312
	Other power sources and equipment	33	482
	Working capital	94	94
	Total	**864**	**3,505**
Livestock	Herd increases	413	413
	Meat and milk production	1,101	1,269
	Total	**1,514**	**1,683**
Downstream support services	Cold and dry storage	277	797
	Rural and wholesale market facilities	410	959
	First stage processing	570	2,231
	Total	**1,257**	**3,986**

[99] Investment to replace existing assets/capital stock accounts for the 60 percent, or US$5.5 trillion, of total investment.
[100] Schmidhuber *et al*. 2009. FN97.
[101] Ibid. FN97.

Asia accounts for the largest part of global investment needs (57 percent); China and India alone account for some 40 percent. Latin America would absorb about 20 percent and sub-Saharan Africa and the Near East and North Africa region account for the remaining 23 percent of capital needs.[102] Private and public investments in the agricultural sector are crucial to meet the GHG emission reductions goals identified by the IPCC, to execute REDD+ strategies,[103] and to secure adaptation. Nelson *et al.* (2010), drawing on the IMPACT model, estimate annual investments of US$7 billion will be needed for developing countries through 2050,[104] considering only the cost categories presented in Table 5.2 and Table 5.3. However, cost estimates remain uncertain because nonlinear risks and innovation are hard to accurately incorporate into future projections, and a great deal of uncertainty remains about how (and whether) adaptation measures for the current state of the climate will function under future conditions.[105]

Table 5.2: Breakdown of spending for agricultural sector to offset climate change impacts[106]

	Total	R&D	Irrigation Expansion	Irrigation Efficiency	Rural Roads
Developing	392	65	30	93	208
South Asia	78	10	14	35	19
East Asia and Pacific	52	10	2	29	11
Europe and Central Asia	13	6	-	7	0
Latin America and Caribbean	62	12	3	13	35
Middle East and North Africa	16	12	-	3	4
Sub-Saharan Africa	171	15	12	7	138

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102 Ibid. FN97; Msangi, S., S. Tokgoz, M. Batka, and M. Rosegrant. 2009. Investment requirements under new demands on world agriculture. Feed with the world with bioenergy and climate change. Presented at FAO expert meeting, How to Feed the World in 2050, June 24-26 ,2009, Washington, D.C.

103 The primary drivers of tropical forest loss in Indonesia, Brazil, and many countries in Africa are biofuel plantations and the expansion of low-productivity farming and grazing.

104 Nelson, G.C., M.W. Rosegrant, A. Palazzo, I. Gray, C. Ingersoll, R. Robertson, S. Tokgoz, T. Zhu, T.B. Sulser, C. Ringler, S. Msangi, and L.You. 2010. *Food security, farming, and climate change to 2050: Scenarios, results, policy options.* Washington D.C.: International Food Policy and Research Institute.

105 Thornton, P.T., P.G. Jones, P.J. Ericksen, and A.J. Challinor. 2011. *Agriculture and food systems in sub-Saharan Africa in a 4°C+ world*, Philosophical Transactions of the Royal Society, January 13, 2011 vol. 369 no. 1934: 117-136.
For example, as many as a quarter of African countries could see climatic conditions over today's farmland with "no current analogues" suggesting few resources will be readily available to adapt to these new conditions.

106 Msangi et al. 2009. FN102.

Table 5.3: Increase in spending over baseline levels for adaptation[107] *(in percent)*

	Total	R & D	Irrigation Expansion	Irrigation Efficiency	Rural Roads
Developing	66	34	30	133	89
South Asia	78	43	38	115	190
East Asia and Pacific	50	29	30	151	26
Europe and Central Asia	33	21	0	157	19
Latin America and Caribbean	44	21	35	116	53
Middle East and North Africa	56	55	0	638	178
Sub-Saharan Africa	94	69	27	146	123

The agricultural sector also involves cost-efficient mitigation potential.[108] However, such potential is limited by the fraction that is feasible or economical compared with nonagricultural options. Economic global mitigation potentials based on opportunity costs from the IPCC diverge widely. In order for global abatement through agricultural practices to increase and for continuing net agricultural production at the same volume, simply meeting opportunity costs may not be enough. Effective climate policy has to lift numerous political, implementation, and financial barriers (see the policy options outlined in Chapter 3).

5.2.2 Financial Flows and Investments

The lion's share of agricultural capital needs is likely to be covered by private domestic sources.[109] The public spending on agriculture can be as low as 4 percent in agriculture-based countries with a high share of agricultural GDP.[110] However, the public sector is financing 94 percent of all agricultural research and development[111] and plays an important role in helping link, pool, and promote private investment flows.[112] For the past three decades, the rate of

[107] Ibid. FN102.
[108] Larson, D.F., A. Dinar, J.A. Frisbie. 2011. *Agriculture and the Clean Development Mechanism*, Policy Research Working Paper 5621. The World Bank, Development Research Group, April 2011, http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2011/04/04/000158349_20110404091922/Rendered/PDF/WPS5621.pdf.
[109] Schmidhuber *et al*. 2009. FN97.
[110] World Bank. 2007. *World development report 2008: Agriculture for Development*. Washington D.C.: The World Bank.
[111] Ibid. FN110.
[112] Schmidhuber *et al*. 2009. FN97.

agricultural investment has declined amid low and stable world food prices. The growth of agricultural capital stock fell from 1.1 percent between 1975 and 1990 and to 0.5 percent between 1991 and 2007 along with developing countries' budgets and ODA for agriculture.[113] Recent years have seen a rapid rise in investment in agriculture triggered by a series of price shocks and supply constraints.[114]

Asset growth in the agricultural sector, although increasing in absolute terms for developed and developing countries, has steadily fallen as a percentage of overall economic value as countries industrialize (measured as gross capital formation), particularly outside of sub-Saharan Africa.[115] This trend is also reflected in global income figures: agriculture accounted for 3 percent of global GDP between 2003 and 2007: less than 2 percent in developed countries, 7 percent in transitional economies,[116] and more than 10 percent in developing countries.[117]

Private

Agriculture attracts billions of dollars in new private investments. The private sector contributes about two thirds of global investment and financial flows, both through local investments and through foreign direct investment.[118] A 2010 survey conducted for the Organization for Economic Co-operation and Development (OECD) estimates about US$14 billion of private capital has been committed to farmland and agricultural infrastructure investment globally among more than 50 firms active in this area. Capital flowing into the farmland and agricultural infrastructure asset class is expected to grow two to three times beyond the current level (US$28 to US$42 billion annually) within five years, and as high as US$150 billion beyond 2015.[119]

Precise figures for specific investments are difficult to obtain. UN statistics show foreign direct investment (FDI) in global agricultural production tripled between 1990 and 2007 to US$3 billion annually from less than US$1 billion.[120] Although this represents an absolute increase, the rate of

[113] Ghanem, H. 2009. World food security and investment in agriculture, *International Economic Bulletin*, Weekly Economic Commentary and analysis from the Global Think Tank, http://www.carnegieendowment.org/ieb/?fa=show&id=23850.
[114] UNCTAD (United Nations Conference on Trade and Development). 2009. *World Investment Report: Transnational corporations, agricultural production and development.* New York, and Geneva; HighQuest Partners, United States. 2010. *Private financial sector investment in farmland and agricultural infrastructure* OECD Food, Agriculture and Fisheries Working Papers, No. 33. OECD Publishing.
[115] Gross capital formation is measured by the total value of the gross fixed capital formation, changes in inventories and acquisitions less disposals of valuables for a unit or sector.
[116] Southeastern Europe and former Soviet republics.
[117] UNCTAD. 2009. FN114.
[118] The most recent FAO estimates are that about 30 percent of the total agricultural investments come from the public sector, while private investment accounts for 70 percent. Schmidthuber *et al.* 2009. FN97.
[119] HighQuest Partners, 2010, FN114.
[120] Ibid. FN114.

growth and relative share of total FDI (already small) declined.[121] Agricultural FDI from developing countries was as significant as FDI from the developed world. For productivity investments, land is a primary asset class. The geographic focus of investment activity is centered on South America (led by Brazil) and increasingly Africa, while investors in the European Union and North America are generally wealthy individuals (and increasingly hedge funds, endowments, and pension funds).[122] Inflation hedging is among the primary drivers for investment commitments. These private investments are being deployed for an array of agricultural activities including:[123]

- 83 percent in production of major row crops (soft oilseeds, corn, wheat, and feed grains)
- 13 percent invested in livestock production
- 4 percent for permanent crops such as sugar cane and viticulture

Empirical studies show, however, that much of the land acquired through sales or long-term leases has not subsequently been developed.[124] Additional private finance is being invested in agricultural infrastructure (primarily on-farm storage), water rights, or other value chain assets (distribution of crop inputs or storage, transportation, and primary processing of food. Interest is also growing for investments like transportation and logistics infrastructure that expand market access.

Public

In line with an overall increase in agricultural investments (see Table 5.4), the share of agriculture in ODA, which declined from 19 percent in 1980 to 3 percent in 2006, is increasing again and amounted to about 6 percent in 2009.[125] FAO estimates that in developing countries through 2050, about US$60 billion of the US$210 billion estimated to be needed annually may be provided by public sources, both foreign (ODA) and domestic. These public expenditures are expected to include rural infrastructure, knowledge generation, and ensuring access to food and

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[121] FDI has historically declined amid low or stable world food prices during the last three decades. Growth rate of agricultural capital stock fell from 1.1 percent in 1975–1990 to 0.50 percent in 1991–2007, mirroring the decline in domestic agricultural budgets among developing countries and ODA provided by donor countries. Ghanem, H. 2009. FN114.

[122] HighQuest Partners, 2010. FN114.

[123] Ibid. FN114.

[124] Cotula, L., S. Vermeulen, R. Leonard, and J. Keeley. 2009. *Land grab or development opportunity? Agricultural investment and international land deals in Africa.* Rome: International Institute for Environment and Development, UN Food and Agriculture Organization and International Fund for Agricultural Development, Rome.
World Bank. 2010. *Rising global interest in farmland: Can it yield sustainable and equitable benefits?* World Bank, Washington D.C..

[125] FAO (UN Food and Agriculture Organization). 2009. The Investment imperative. Paper from the FAO High Level Conference on World Food Security: The Challenges of Climate Change and Bioenergy, Rome: FAO.

markets.[126] Public expenditures in the agricultural sector are also likely to provide finance for support services as well as research and development.[127] Subsidies are another major expenditure on agricultural products (see Chapter 4).

Table 5.4: Agricultural expenditures[128]

	2000 (US dollars, billions)					Percentage of GDP from agriculture			
	1980	1990	2000	2005		1980	1990	2000	2005
North Africa	4.35	4.20	6.29	5.20		14.76	8.71	10.97	7.96
Sub-Saharan Africa	3.00	3.64	4.24	8.67		4.09	3.73	3.67	6.42
Asia	71.14	103.00	127.46	201.63		9.57	8.63	7.87	10.22
Latin America	30.31	12.19	18.93	25.46		14.18	5.77	9.12	9.40
TOTAL	**108.80**	**123.03**	**156.93**	**240.96**		**10.27**	**7.93**	**7.84**	**9.86**

Historically, agricultural research and development (R&D) expenditures have increased in absolute terms between 1981 and 2000, but declined as a percentage of agricultural GDP (along with growth rates for new R&D investment) since the 1990s, particularly in developing countries.[129] IFPRI's Agricultural Science and Technology Indicator initiative estimates total global public agricultural investment in R&D in 2000 was US$25.2 billion.[130] The primary funders of R&D were governments (81 percent), with 14 percent derived from domestic funds and donors (loans and grants, mostly in highly donor-dependent countries).[131] Brazil, China, India, and South Africa account for the bulk of R&D spending in developing countries.[132]

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[126] Schmidhuber, *et al*. 2009. FN97.
[127] Ibid. FN97.
[128] Shenggen F., B. Omilola, M. Lambert. 2009. *Public spending for agriculture in Africa: Trends and composition.* Regional Strategic Analysis and Knowledge Support System (ReSAKSS) Working Paper No. 28. April, www.resakss.org/index.php?pdf=42375.. Calculated using data from International Monetary Fund (IMF) Government Financial Statistics Yearbook (various issues).
[129] Msangi, S. 2009. FN102.
[130] 2005 PPP dollars for a 171-country revised sample in 2000, http://www.asti.cgiar.org/.
[131] Beintema, N.M. and G.J. Stads. 2010. Public agricultural R&D investments and capacities in developing countries: Recent evidence for 2000 and beyond. Note prepared for Global Conference on Agricultural Research and Development (GCARD) 2010.
[132] Pardey, P.G., J.M. Alston, and R.R. Piggott, eds. 2006. *Agricultural R&D in the developing world: Too little, too late?* Washington DC: International Food Policy Research Institute.

5.2.3 Financing for Agriculture under Convention

Under the Cancun Agreements, developed countries committed to mobilize new and additional resources approaching US$30 billion for the period 2010–2012 and US$100 billion annually by 2020.[133] There is significant uncertainty about how the precise finance channels and mechanisms could evolve between now and 2030. As a result of the limitations of the financial mechanism of the Convention and of the clean development mechanism (CDM), there has been a persistent call to reform existing mechanisms, and to develop new mechanisms that can scale up investment for emission-reduction projects in developing countries. This issue is particularly pertinent given the current negotiations on the architecture of the framework post-2012 and the scale of financial flows envisaged for 2020. In the context of agricultural mitigation and adaptation, the following financing channels may be considered:

The Global Environment Facility (GEF) Trust Fund. The GEF operates the current financial mechanism of the Convention. For the period 2010–2014, a total of US$4.25 billion has been pledged, of which about US$1.35 billion is expected to be delivered to mitigation projects.[134] Although these figures are considerably lower than the funding generated under the CDM and the sums are expected to flow through the Green Climate Fund (see below), the GEF Trust Fund remains one of the largest sources of grant-based finance for mitigation.[135]

UNFCCC and Kyoto Protocol linked funds. The GEF also operates two other funds under the Convention: the Special Climate Change Fund, which focuses mainly on adaptation, and the Least Developed Countries Fund, which assists least-developed countries in preparing and implementing their NAPAs. Both funds provide adaptation funding for agriculture-related projects. Under the Kyoto Protocol, the Adaptation Fund supports projects and program in developing countries and is financed through a 2 percent levy on the share of proceeds from CDM project activities. Most of the projects accepted and proposed for funding to date have agriculture as a component.[136]

The Green Climate Fund. The Cancun Agreements established the Green Climate Fund (GCF) as a financial mechanism under the Convention, with the World Bank serving as an interim trustee subject to a review three years after the fund begins operations. It is likely that the GCF will be set up by 2012, although it remains unclear where the resources for the GCF will come from and how much time it will take until the GCF starts receiving and channeling these funds to developing countries. It is also not clear to what extent the GCF will replace the GEF as the financial operating entity under the UNFCCC. The fact that Parties agreed that a significant

[133] UNFCCC Decision 2/CP.15, para 8.
[134] UNFCCC. http://unfccc.int/press/news_room/newsletter/items/5563.php
[135] World Bank. *Making the most of public finance for low-carbon growth*. 2009, http://www.oecd.org/dataoecd/15/0/43684020.pdf.
[136] See http://www.adaptation-fund.org/node/794

share of adaptation funding will flow through the GCF shows that they expect a stronger role for the GCF in climate funding, at least with respect to finance for adaptation measures.

Relevant mechanisms to channel mitigation finance for agriculture into developing countries include the CDM, NAMA, and finance and support for REDD+ action:

A reformed CDM. The CDM allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol to acquire emission reductions from mitigation projects in developing countries. Such projects can earn certified emission reductions, which can be counted toward meeting Kyoto targets. In the current CDM, the mitigation crediting mechanism for developing countries limits the eligibility of carbon sequestration to afforestation and reforestation, while excluding primary mitigation opportunities (especially for smallholders) to enhance soil carbon stocks through cropland or rangeland management. See Box 5.1 for an example of a carbon project developed in the context of the voluntary carbon market.

The CDM is currently undergoing a number of changes as a result of the review of the Kyoto Protocol. In the gradual evolution of the CDM, programmatic approaches are also gaining more traction. Programs of activities under the CDM and could be seen as a stepping stone to other forms of accounting for and incentivizing GHG reductions in developing countries (e.g., subregional or sectoral government-led policies and programs).

Developing-country NAMAs. Although there is no definition of the term, NAMAs are generally interpreted as voluntary mitigation actions by developing countries in the context of sustainable development goals and objectives that reduce emissions below the business-as-usual baseline. From country submissions so far, it seems that NAMAs may comprise a diverse set of activities, ranging from capacity building to conventional command-and-control regulations and including sectoral and nonsectoral emissions trading schemes. Internationally supported NAMA actions will be subject to international measurement, reporting, and verification.

Reduced emissions from deforestation and forest degradation (REDD+). Support for REDD+ is likely to finance a range of activities including national strategy or action plans, forest reference levels, forest monitoring systems, and other issues affecting REDD+ , such as drivers of deforestation, land tenure issues, and forest governance issues. Agriculture is an important driver of deforestation and will, therefore, have to be considered in country strategies that address drivers of deforestation. For a comparison between relevant incentive mechanisms for REDD+ and agriculture see Table 5.5 and for lessons learned from REDD+ see Table 5.6.

Box 5.1 Climate financing to restore grasslands and increase productivity

- The FAO's Three Rivers Project, situated in the Qinghai province of Northern China is a pilot project using carbon financing to facilitate grassland restoration and increase livestock productivity. Potential benefits are to expected to be greater resilience to droughts and floods from improved soils and less degraded grasslands, emission removal through soil carbon sequestration, and emission reduction (per unit of product) through greater efficiency and productivity and greater productivity and food security through improved livestock management practices.

- Carbon finance from a voluntary scheme will be used to compensate costs and foregone income during a transition period and to increase productivity. The pilot offers a combination of grassland-restoration zoning and stocking-rate management in an incentive-based system. Given the current overstocking rates of about 45 percent, considerable reductions in income are expected during the first years of the project, for which herders will receive compensation. In the following years, as incomes are expected to grow in response to increased livestock productivity (and possibly other small business support measures), compensation will decrease progressively until year ten. Overall, after the first decade of the project, households will have fewer but more productive livestock.

- From years 10–20, herds can be increased beyond the level of the first 10 years, without the risk of overgrazing. Increased availability of forage will enable higher incomes and higher levels of production over the long term, providing an incentive for long-term sustainable land management. The improvement of animal production from better(e.g., feeding, winter housing, and breeding, as well as the development of processing activities and marketing associations, will be aimed at improving the livelihoods of herders. It is hoped that this model can break the vicious cycle of overstocking and land degradation and demonstrate sustainable management options, while generating a reduction of approximately 500,000 tons of CO_2–equivalent, over 10 years. It also aims to address some of the key barriers to smallholder access to carbon finance, which include the lack of appropriate baseline methodologies and cost-effective measuring, reporting, and verification.

Table 5.5: Incentive framework for REDD+ compared with agriculture

Category	REDD+	Agriculture
Establishment	National incentive framework covering the forest sector established in Cancun Agreements.	No dedicated decision, no discussion of particular incentive mechanism yet.
Purpose	REDD+ is negotiated as mitigation instrument.	Multiple-objective focus (adaptation, food security, mitigation) is more appropriate.
Mitigation potential	Perception of cost-efficient mitigation potential.	Mitigation potential limited by growing demands for food driven by population increase and change in diets.
Measurement	Measurement of emission reductions against national and, as appropriate, subnational reference (emissions) levels.	Establishment of national reference levels would be extremely difficult due to data limitations, capacity constraints, and heterogeneity in territory and practices.
Incentives	Incentive system expected to compensate for opportunity costs.	Reflecting the multiple aspects of agriculture, incentives need to reflect adaptation and mitigation benefits.
Permanence risk	Permanence risk significant, but measurable.	Permanence risk smaller, but actual reversal is often difficult to detect and measure.
Coverage	Incentive mechanism limited to developing countries.	Negotiations on agriculture cover both developed and developing countries.
Data collection	Growing comfort about the ability to measure forest carbon with existing MRV techniques and technologies.	Lagging behind in collecting, analyzing and publishing carbon data.
Safeguards	Strong emphasis on safeguards.	Safeguards are essential to ensure food security and avoid adverse effects of mitigation and adaptation measures.
Implementation	Phased approach in implementing REDD+ action starting with capacity building and institutional strengthening (Phase 1); policy reform and demonstration activities (Phase 2); and full scale national implementation (Phase 3).	Even before an incentive framework is defined, readiness is important to increase data and knowledge base and inform negotiators on the national and international level.
Importance of agriculture	SBSTA addresses drivers of deforestation, including agriculture.	Agriculture is an important factor for success in REDD+ action.

Table 5.6: Relevant lessons learned from REDD+ for agriculture

REDD+	Lessons Learned
Process started in 2005 through the building of support outside the UNFCCC negotiations; REDD+ Interim Partnership and pilots launched parallel to consideration in AWG-LCA and SBSTA.	Building support outside the UNFCCC negotiations was essential to drive and maintain the momentum in REDD+ negotiations.
Driven by the Coalition of Rainforest Nations under the leadership of Papua New Guinea.	Developing country leadership and the demonstrated willingness of developing countries to contribute to GHG emission reductions provided appropriate incentives and led to constructive negotiations on REDD+.
Norway announces the contribution of up to US$2.5 billion for REDD+ in 2009 (COP13); other donors joined with additional pledges in 2010 (COP15).	Norwegian funds demonstrated donor commitment and enabled the testing of partnership agreements between Norway and developing countries; financing facilitates start up and continuing progress.
REDD+ is enshrined in the Bali Action Plan and in the Cancun Agreements. SBSTA considers technical/methodological issues, at same time AWG-LCA considers policy issues.	Dedicated negotiations and a separate agenda item facilitated a focused discussion that allowed REDD+ to move ahead of other negotiation items.
Social and environmental safeguards are backed by a system for reporting information on how safeguards are being implemented.	International consideration of safeguards leads to increased accountability, transparency, and stakeholder involvement.
Forest Carbon Partnership Facility of the World Bank and UN-REDD support a country's readiness, the REDD+ Interim Partnership enhances policy coordination.	Dedicated funds and programs enable building of nationally led capacities; multilateral fora allow the building of consensus on implementation-related matters outside of the UNFCCC negotiations; REDD+ pilots support learning-by-doing to build country capacity and confidence to implement projects, which takes time.
Significant interest of private sector in voluntary carbon markets, progress in developing methodologies to account for REDD+ at the project scale.	Bottom-up initiatives involving multiple NGOs and private actors signal private sector interest and the potential of investment and finance once a mechanism has been set up.
Subnational partnerships in the context of the Governors' Task Force lead by California.	Progress on all levels of governance allows testing and mobilizing finance beyond national donor pledges.
Active stakeholder involvement on all governance levels and in various policy fora.	Wide consultation and transparent processes help avoid adverse effects of REDD+; they also build support among civil society.

Although international climate finance is likely to be scaled up in the future, it is unlikely to address the investment needs for adaptation and mitigation in developing countries. It is, therefore, of essence to use public funds strategically to remove investment barriers and facilitate private investment. With adaptation being a clear priority for agriculture, developing countries may identify financing and technology needs in the relevant planning and assessment processes encouraged under the Convention. Mitigation finance may complement adaptation finance, especially in supporting activities that combine adaptation and mitigation benefits. Over the next few years, countries will have to develop appropriate MRV tools to measure performance in reducing emissions and enhancing removals from agricultural activities (see Chapter 6).

5.3 Technology Development and Transfer

Concerns about mitigation and adaptation to climate change are generating new research and innovation priorities in agriculture. This is particularly the case in developing countries where the mitigation potential is larger and where adaptation is closely related to food and livelihood security. Although new traits, varieties, and crops will play an important role in climate change mitigation or adaptation, the range of relevant practices and technologies is much broader, including water management, production practices, post-harvest technologies, information and forecasting, and insurance. Table 5.7 provides examples of technology needs for agricultural mitigation and adaptation as indentified by developing countries.[137] The extent to which these needs apply to a given country depends on the country's relevant capacities and circumstances. Where countries have not yet engaged in a prioritization of technology needs for agriculture, they may do so as part of strategic planning on early action (see Chapter 3).

Impediments to the diffusion of relevant technologies can occur at different stages, from inception to uptake of agricultural innovations by resource-poor farmers. Constraints to innovation can be overcome if private or public sectors provide appropriate incentives. The most binding constraints often occur at the adoption stage: poorly functioning input and output markets, weak local institutions and infrastructure, or inadequate extension systems, missing credit and insurance markets often prevent smallholder from accessing and using new technologies and practices.[138]

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[137] UNFCCC Secretariat. 2009. *Second synthesis report on technology needs identified by Parties not included in Annex I to the Convention - Note by the secretariat*; FCCC/SBSTA/2009/INF.1, 2009.

[138] Lybbert, T., and D. Sumner. 2010. *Agricultural technologies for climate change mitigation and adaption in developing countries: Policy options for innovation and technology diffusion: ICTSD-IPC platform on climate change, agriculture and trade*, Issue Brief no.6, Geneva: International Centre for Trade and Sustainable Development and Washington D.C. International Food and Agricultural Trade Policy Council.

Table 5.7: Developing country technology needs[139]

Examples of Technology Needs for Mitigation in Agriculture	Examples of Technology Needs for Adaptation in Agriculture
• Crop waste gasification • Improved cultivation methods • Production and management of soil nutrients • Rational application of fertilizer • Drip irrigation • Biodigesters (manure management using digesters) • Better land management • Solar (photovoltaic) and wind water pumps • Solar energy for processing of agricultural products • Modification of livestock feed	• Tolerant/resistant crop varieties (to drought/heat, salt, insects/pests, improved seeds) • Efficient water utilization and improved irrigation systems (drip irrigation, creation of networks of reservoirs and water resource management) • Low-density planting, adjustment of sowing dates and crop rotation • Land management • Improved drainage • Integrated pest management • Sustainable grazing and herd management • Heat-tolerant livestock breeds • Networks of early warning systems

5.3.1 Technology Development and Transfer under the Convention

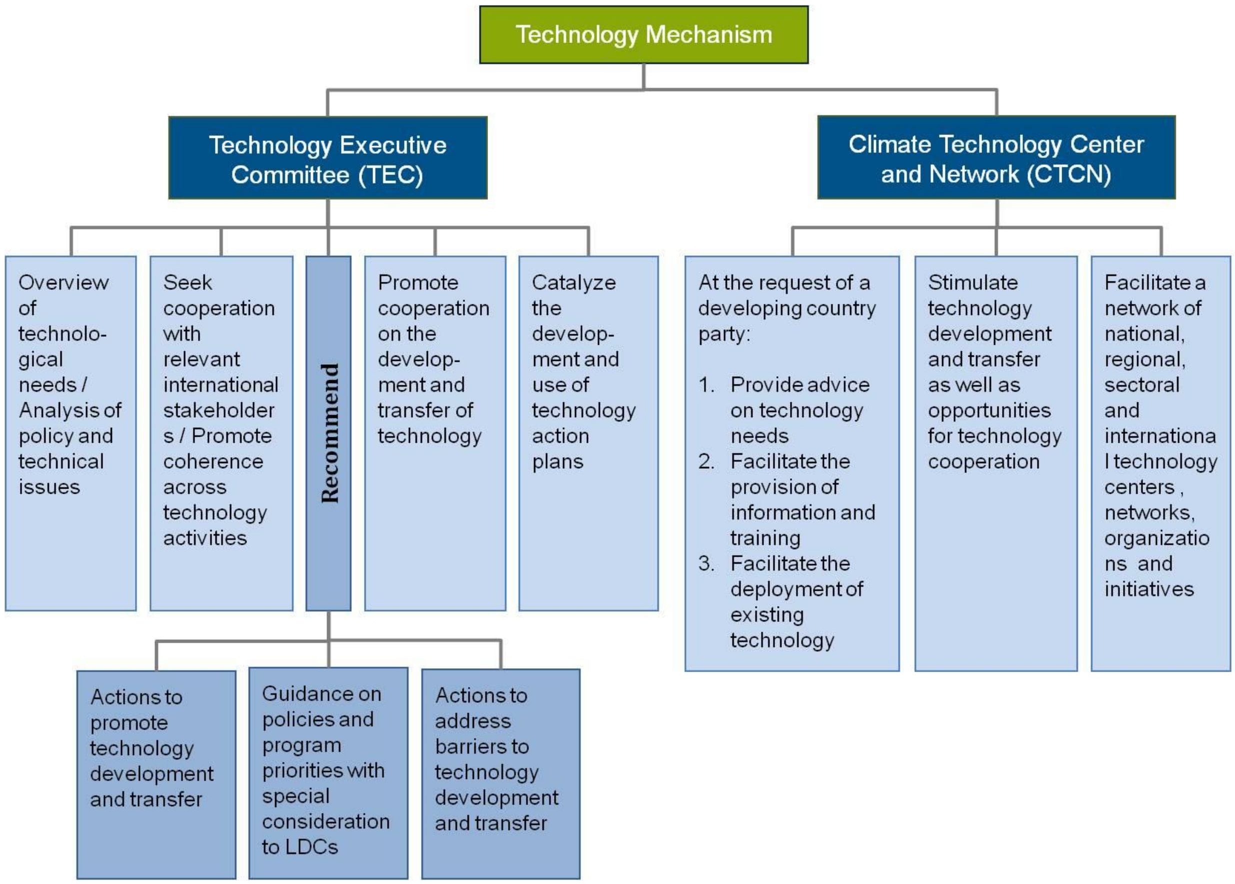
In the context of the Cancun Agreements, Parties decided to create a technology mechanism to accelerate the development and transfer of climate friendly technologies, in particular to developing countries, to support action on climate mitigation and adaptation.[140] The technology mechanism consists of two bodies: a Technology Executive Committee (TEC) and a Climate Technology Centre and Network (CTCN). Figure 5.1 provides an overview of their main functions.[141]

[139] UNFCCC Secretariat. 2009. FN137.

[140] UNFCCC Decision 1/CP.16

[141] ICTSD. 2011. *The climate technology mechanism: Issues and challenges*, International Centre for Trade and Sustainable Development (ICTS), Information Note No.19, Geneva.

Figure 5.1: Technology Mechanism under the UNFCCC[142]



The functions of the TEC and of the CTCN are general in nature. The TEC's primary focus is to service the Convention and its Parties, particularly by making recommendations and providing an overview of technological needs. The CTCN is the operational arm that will provide services to developing countries and facilitate a network of national, regional, sectoral, and international technology centers.

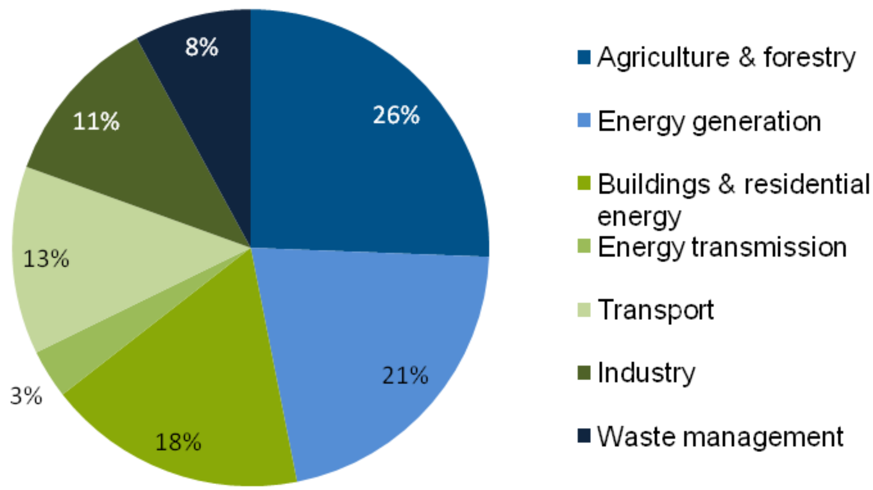
Although the Cancun Agreements defined the broad architecture and functions of the Technology Mechanism (TM), they did not provide the specifics on how these two bodies should operate, what their precise priorities should be or how their activities would be funded. No specific sectors are mentioned in the mandate of the TM or among the functions of the TEC and the CTCN.[143] The only priority area specifically mentioned that has a strong relevance for agriculture adaptation is, "improved climate change observation systems and related

[142] Ibid. FN141.
[143] UNFCCC Decision 1/CP.16, para. 121.

information management."[144] However, there is ample scope for including agriculture in the priories and activities to be undertaken by the TEC and the CTCN, if countries wish to do so.

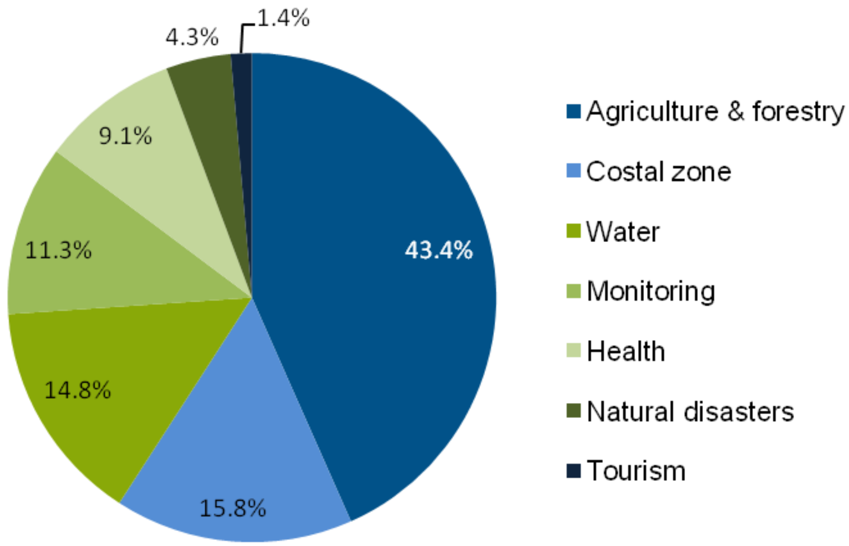
In this regard, the national Technology Needs Assessments (TNAs) undertaken by developing countries are a valuable source of information. According to the identified technology needs of developing countries identified in 70 TNAs, 26 percent of mitigation technologies and 43.4 percent of adaptation technologies relate to agriculture and forestry.[145] In both cases, agriculture and forestry are the most important sectors identified for mitigation and adaptation technologies. Figure 5.2 and 5.3 provide an overview of these findings.

Figure 5.2: Mitigation technologies identified in 70 TNAs[146]



[144] UNFCCC Decision 1/CP.16, para. 120.
[145] UNFCCC. 2009. FN137.
[146] Ibid. FN137.

Figure 5.3: Adaptation technologies identified in 70 TNAs



Harnessing the potential of the technology mechanism to accelerate action consistent with international obligations, demonstration, deployment, diffusion, and transfer of technology in support of action on mitigation and adaptation in the agricultural sector requires mapping possible options and points of intervention in current discussions about the operationalization and institutional set-up of the TM.

For instance, at a workshop held at the 2011 UNFCCC talks in Bangkok (April 4-5, 2011) discussing the operationalization of the TM some delegations suggested that the technology networks to be facilitated by the CTCN should be arranged thematically and that one network should be specifically devoted to agriculture.[147] These networks are poised to play a key role in addressing the needs of developing country parties and promoting innovation and technology diffusion.

5.4 Capacity Building and Institutional Strengthening

Lack of knowledge and capacity of farmers, weak national and international institutional structures, unavailability of finance and insurance, insecurity of land tenure, limited access to markets and basic services, and the absence of capable local research institutions are barriers to

[147] Jonathan Pershing. 2011. Considerations on the climate technology centre and network, http://unfccc.int/files/meetings/ad_hoc_working_groups/lca/application/pdf/linkages_within_the_technology_mechanism_and_with_other_institutional_arrangements.sa.pdf)

the deployment of agricultural practices and technologies. Capacity building and institutional strengthening are, therefore, essential to enable individuals, communities, institutions, and other entities to make effective use of available knowledge, resources, and technologies to successfully respond to the challenges posed in the field of agriculture, and increasingly by climate change.

5.4.1 Needs of Farmers, Communities, and Local Farmers' Associations

Farmers' needs in the field of climate change cannot be separated from their overall needs in agriculture: successful adaptation to the effects of climate change often equals taking measures that ensure continued productivity. However, farmers' needs are not related merely to productivity.

A number of these needs can be addressed through targeted capacity building, extension activities, awareness raising, communication, trainings, and workshops. However, capacity building needs to be seen in a broader context: the foundation for building adaptive capacity in agriculture for climate change is better knowledge management. Relevant knowledge includes the likely future scenarios for agriculture in different localities, better forecasting for the forthcoming season so that practices can be tailored to likely conditions and extremes, understanding of how farming systems (and their associated support systems) may have to shift in the next decade, and better understanding of what works where – for policies, approaches, practices, and technologies. In some cases, appropriate practices and technologies are available to farmers or their associations, but there is a lack of knowledge and guidance on how to use them or there are other impediments, such as poorly functioning input and output markets, weak local institutions and infrastructure, inadequate extension systems, or missing credit and insurance markets. In other cases, farmers lack the access to practices and technologies that enable adaptation to changed climate conditions and ensure stable or increased yields (for more detail, see Chapter 3).

A number of these needs can be addressed through targeted capacity building. Farmers can, for example, be assisted through expert advice in the field on how to use another variety of seeds or alternative cropping practices.[148] Creative ways of improving knowledge management may include: regional knowledge management networks; enhanced use of cell phones through public-private partnerships for receiving relevant weather forecasts; and farmer field schools that involve farmer-to-farmer exchanges that give a vision of warmer worlds (e.g., by visits to so-called analogue sites, which are two degrees warmer than the current locations, see **Box 5.1** for an example).

[148] For more examples, see: Easterling *et al.*, 2007, FN33.

Examples of institutional support to farmers that responds to these needs include setting up a legal and policy framework that ensures access and secures tenure to resources and land (e.g., in case of competing land or resource claims), protects water-use rights, allows brokering long-term contractual arrangements, commercial out-grower schemes, or farmer cooperatives,[149] and provides investments in agricultural infrastructure to expand farmers' access to markets.

Funding and technological support are often a precondition for capacity development. Farmers, their communities, and local farmers' associations need to be aware of opportunities for financial support and once they have access to such finance, use it efficiently and allocate it equitably within the community to enhance stakeholder involvement, trust, and sense of ownership (see Section 3.3. for examples on how to provide farmers with access to financing).[150]

Box 5.2 Capacity Building in Bangladesh

Bangladesh, due to its geophysical position and socioeconomic context, is prone to regular natural hazards and the impacts of climate change. In 2005, FAO initiated a project at the request of the Bangladesh government that was designed to improve the adaptive capacities of rural populations and their resilience to drought and other climate change impacts. It was also to inform service providers and policy makers of its findings to improve support for adaptation processes.

Community-based actions started with:

- Characterizing livelihood systems
- Profiling vulnerable groups
- Assessing past and current climate impacts
- Understanding local perceptions of climate impacts,
- Identifying local coping capacities and adaptation strategies

Based on these findings, the project promoted institutional and technical capacity building within key agencies and among farmers associations and groups to provide demand-responsive services needed by farmers to better adapt. The project has developed, and is constantly updating, a menu of diversified good-practice adaptation options, which guides field testing of locally prioritized adaptation practices. Participatory extension is key and includes demonstrations, orientation meetings, field days, farmer field schools, and community rallies.

For further information see:
http://www.fao.org/docs/eims/upload/286580/CommunityBasedAdaptationActionBangladesh.pdf

[149] IAASTD (International Assessment of Agricultural Knowledge, Science and Technology for Development). 2009. *Agriculture at a crossroads,* Synthesis Report, Washington D.C.: IAASTD, p. 27 .
[150] Ibid. FN149, Global summary for decision makers.

5.4.2 Needs at the Institutional Level

To successfully tackle climate change in the long run, the capacity of national and local institutions, such as agricultural ministries and research institutes, must be simultaneously enhanced in the development of national policies and programs. They also need the of resources to create such policies and programs, as well as the capacity to spend the resources effectively, efficiently, and equitably. Increasing the capacity of policy-makers to better align policies across multiple policy areas and coordinate policy formulation horizontally across national government entities and vertically from local to national levels could help produce multiple win solutions. Section 3.3 in Chapter 3 summarizes options on how to address institutional needs through the design of national policies and implementation frameworks, and reviews the mandates of national institutions and some processes that allow effective policy reform.

The exchange of information and training among research institutions and between research institutions and policy makers at the national level (e.g., coming from the agricultural, environment, trade, and transport ministries) and among policy makers of developing and/or developed countries, can be a tool for policy and program development that supports the above-mentioned needs.[151] Such cooperative approaches can be further supported by international programs supporting policy analysis and strategy development. International discussions and national strategies around climate change adaptation and mitigation have triggered a number of consultative and strategic processes at the national level. More than 40 countries are in the process of developing their readiness to participate in a REDD+ technical mechanism; other countries are evaluating low carbon/low emission and resilient development options. These and other processes may inform formulation and implementation of action around agriculture and climate change.

5.4.3 Needs in Research and Extension

In many countries, agricultural research and extension services need greater capacity to enable responses to climate change, including adequate funding and policy support for requisite expertise in climate science and agricultural science, as well as the broader contextual issues of trade, economics, and political science. National institutions may need significant investments in research capacity, especially to understand agriculture under climate change in the specific context of their countries. In producing national inventories, activity data often derive from various sources, such as national statistics, industry or stakeholder organizations, and national experts, which may be supplemented by new surveys.[152] The agricultural sector presents a

[151] UNEP. 2002. Briefs on economics, trade and sustainable development, UNEP's capacity-building activities on environment, trade and development, http://www.unep.ch/etu/publications/UNEP_Capacity.pdf
[152] IPCC. 2006. *Guidelines for national greenhouse gas inventories*, chapter 2: Approaches to data collection , Geneva: IPPC, http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_2_Ch2_DataCollection.pdf).

greater challenge than many other sectors in inventory compilation, especially for developing countries, mainly due to a lack of reliable activity data at the national level.

Partnerships with international or national research organizations may help. But with agricultural practices often highly context specific and based on and informed by new, traditional, general, and local knowledge, local agricultural science and research need to fit specific national characteristics.

Another major gap globally is in extension services to agriculture, particularly small-scale farmers. Decreasing budgetary allocations to the agricultural sector over the past several decades have led to the erosion of public extension services in many countries, with only partial, and not always satisfactory, replacement by private extension (see also Chapter 3, Section 3.3). The new challenges and opportunities brought by climate change reinforces the pressing need for revitalization of a holistic extension system that can help farmers make locally appropriate innovations and balance between sustainable food production and delivery of environmental services. FAO, in a 2010 report, concluded that in order to provide effective support, a broader perspective on extension systems should be promoted, including a more important role for farmer organizations in setting the agenda for extension and research institutions. Developing such capacities could lead to better coherence among poverty alleviation, market orientation, food security, and climate change goals that are being pursued in rural development.[153]

5.5 Capacity-Building Initiatives

5.5.1 Existing Capacity-Building Initiatives

To date, a range of agricultural capacity-building frameworks and initiatives coexist, initiated by different international, national, public, and/or private entities. A number of these include capacity building with regard to climate-change-specific issues.

One example of agricultural capacity building can be found at the International Fund for Agricultural Development (IFAD).[154] IFAD provides assistance for farmers on a range of topics, including improved natural resource management (e.g., assisting farmers in adopting soil and water conservation techniques) and in economic diversification as responses to climate change.[155]

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[153] FAO (UN Food and Agriculture Organization). 2010. *Mobilizing the potential of rural and agricultural extension*. Rome: FAO.

[154] See http://www.ifad.org/climate/index.htm

[155] See IFAD website for examples: http://www.ifad.org/climate/ifad.htm.

FAO has its own capacity-development portal, providing a wide range of capacity building activities in agriculture, including "improved responses to environmental challenges," which also covers adaptation to climate change (see B**ox 5.2** for an FAO project).[156] Capacity- building activities in agriculture are also undertaken by other UN organizations and multilateral development banks.[157]

Capacity-building initiatives in agriculture and climate change are also implemented by private entities with a more commercial focus, such as private banks or large agribusinesses. For example, the Dutch Rabobank, with the Banque Populaire du Rwanda, has initiated a capacity-building program in the Rwandan rice sector in tandem with a financing program. This capacity-building program aims to help leaders of agricultural cooperatives professionally organize their cooperatives so they will have fewer difficulties attracting the loans needed for storage capacity, mechanization, and other investments that help farmers earn more money by improving yields and reducing post-harvest losses.[158]

Technical mechanisms for exchanging lessons learned include cooperation initiatives among developing countries (e.g., Brazil has been particularly active),[159] and organizations at many levels including global (e.g., Global Research Alliance on Agriculture, see **Box 5.2**), multilateral (numerous knowledge and research networks, ranging from the CGIAR to issue-specific networks of other international organizations), bilateral (Canada, United States, European Commission, and others), and regional (e.g., facilitated by regional organizations). Demonstration activities aimed at reducing emissions from deforestation also offer relevant lessons from the country level. However, more systematic collection and dissemination of lessons learned relating to climate-smart agricultural practices and policies would be useful.

[156] FAO. 2010. FN153.
[157] Just to list one of many examples: IDB area of action: Modernization of agricultural services, http://www.iadb.org/en/topics/agriculture/investment-in-agricultural-services,2343.html
[158] See http://www.rabobank.com/content/about_us/rabodevelopment/rwanda.jsp.
[159] See for example the Africa-Brazil Agricultural Innovation Marketplace which aims to enhance interaction between Brazilian and African research and development experts and institutions and to develop cooperative projects. (URL: http://www.africa-brazil.org/home/about).

Box 5.3 Cooperation in Research and Transfer of Knowledge

The **Global Donor Platform for Rural Development** is a network of 34 bilateral and multilateral donors, international financing institutions, intergovernmental organizations, and development agencies created in 2003 to increase and improve the quality of development assistance in agriculture and rural development. Its working group on climate change has formulated the following objectives:

- Advocate for the inclusion of climate-smart, pro-poor agriculture in the emerging climate regime through international forums.
- Ensure a better reflection of agriculture's potential for climate change adaptation and mitigation in the UNFCCC.
- Share knowledge between stakeholders to ensure that climate change investments are consistent with aid and development effectiveness.

For more information visit: URL: http://www.donorplatform.org/

The **Global Research Alliance on Agricultural Greenhouse Gases** brings countries together to find ways to grow more food without growing greenhouse gas emissions. It was launched in December 2009 and will initially focus on three broad areas of work—paddy rice, croplands, and livestock—and two key issues that span these areas: soil carbon and nitrogen cycling and inventories and measurement.

For more information visit: ULR: http://www.globalresearchalliance.org.

Another example of cooperation is the **Adaptation Learning Mechanism (ALM),** facilitated by UNDP in cooperation with UNFCCC, the United Nations Environment Programme (UNEP), The World Bank, and FAO. ALM seeks to provide stakeholders with a common platform for exchanging information, experiences, and expertise and develops tools and resources to support:

- Adaptation practices
- Integration of climate change risks and adaptation into development policy, planning and operations
- Capacity building so people become equipped for adapting to climate change

For more information visit: http://www.adaptationlearning.net/

5.5.2 Capacity Building under the Convention

In 2001, at COP7, two frameworks for capacity building (one for developing countries, the other for economies in transition), were agreed upon in the context of the UNFCCC. The purpose of these frameworks was to provide guidance to the GEF and other bilateral and multilateral climate funds on capacity building.[160] They confirm that the effectiveness and coordination of existing capacity-building efforts should be promoted across a wide range of actors and institutions including governments at all levels, international organizations, civil society, and the private sector. In addition, synergies between the Convention and other global environmental agreements should be promoted and the coordination and effectiveness of existing efforts improved wherever possible using existing institutions and bodies and building on existing processes and endogenous capacities.[161]

The first comprehensive review of these capacity-building frameworks was made available in 2004. For the developing-country framework, this review led to the identification of "key factors" to take into account in the further implementation of the framework. The key factors include the promotion of exchange of best practices, enhanced financial and technical resources, and improved donor coordination. [162] A second review of the UNFCCC capacity-building frameworks was initiated in 2008; the results of this review are not yet ready and no information is available on whether any improvements were achieved with regard to the key factors identified in 2004.

Recently, the Cancun Agreements confirmed the relevance and validity of capacity building, stressing the importance of strengthening endogenous capacities at the subnational, national, and regional levels, including relevant institutions, networks, and stakeholder participation as well as communication, education, training, and public awareness at all levels.[163] The Agreements explicitly refer to developed countries and "other Parties in the position to do so" providing financial resources for enhanced action on capacity building in developing countries. They also invite both the funding parties and those receiving funding to report to the UNFCCC on progress in this area.

5.6 Main Messages

Creation of enabling conditions: Finance, technology, and capacity are essential to motivate large-scale emission reductions from the agricultural sector and to enable this sector to harness itself effectively against the effects of climate change. However, the current incentive frameworks for agricultural mitigation and adaptation under the Convention do not take account of the special characteristics of the agricultural sector and often fail to provide appropriate support and incentives.

160 UNFCCC Decision 2/CP.7 and decision 3/CP.7.
161 UNFCCC Decision 2/CP.7 and decision 3/CP.7
162 UNFCCC Decision 2/CP.10, para. 1.
163 UNFCCC Decision 1/CP.16, Chapter IV, sub. C.

International mechanisms may facilitate mitigation and adaptation action: New and emerging mechanisms, such as an expanded CDM and funding for NAPAs and NAMAs, may help countries, in the short term, engage in climate change mitigation and adaptation. It is important to engage in the development of appropriate needs assessments and funding proposals as agriculture is competing with other sectors for limited funds.

Technology transfer can support a change in agricultural practices toward more sustainable activities: The process of transferring agricultural innovation across agro-ecological zones is often subject to agronomic constraints and slow adaption rates. Technology transfer can support a change in agricultural practices toward more sustainable activities. The newly established TM responds to needs of developing countries as set forth in national TNAs. A significant portion of these relate to agriculture and forestry. Harnessing the potential of the TM toward promoting technology transfer for agriculture requires continued identification of agriculture as a “need” by Parties and as a “priority area” by the TEC and the CTCN.

Capacity building and institutional strengthening needs to support implementation: To adapt to climate change and contribute to mitigation in the agriculture sector, innovation is needed in farming and food systems. Farmers and their supporting agencies, especially extension and research, need greater capacity to apply new farming approaches effectively and efficiently. Building farmer capacity could be part of a larger effort to build the capacity of local governmental institutions and local R&D and in finding ways to make capacities mutually reinforcing. Financing dedicated capacity-building programs as well as improving coordination between existing and emerging programs can help address gaps in skills, knowledge, staffing, and management systems.

6. Performance and Benefits Measurement

6.1 Introduction

Countries may wish to measure the performance and benefits derived from climate-related activities in the agricultural sector, especially if they seek international support for these actions. They may choose to invest in systems that measure[164] adaptation and mitigation benefits in a balanced, integrated, and comprehensive manner in accordance with the principles and provisions of the Convention. This chapter analyzes the different options and implications for measurement of both adaptation and mitigation actions.

Performance and benefits measurement in the context of the Convention has several different functions (**see Table 6.1).** The functions of MRV systems and the ways in which these functions are performed determine the information needs at multiple levels (e.g., international, national, subnational, local), obligations of Parties as established within the UNFCCC framework, and the capacity needs for MRV among Parties and stakeholders.

Table 6.1: Functions of performance and benefits measurement in agriculture

Functions	Examples
Tracking progress	• Enable transparent party-specific and collective-action progress • Inform implementation status of specific actions
Ensuring accountability	• Ensure support is provided • Link developing country actions to support • Assess compliance with domestic or international targets • Ensure effectiveness of program or project expenditures
Supporting learning	• Help identify new potential mitigation and adaptation actions • Enhance action by providing an opportunity for expert inputs • Create credibility and trust in collective action • Enable comparisons among countries and sectors
Generating knowledge	• Identify and share best practices among countries • Create and share knowledge on the impacts of interventions • Increase understanding of context-specific outcomes and impacts

[164] The term measurement in this paper refers to the terminology of the Bali Action Plan, but is technically misleading since proxies and estimation procedures are widely used to determine mitigation and adaptation benefits.

6.2 Performance and Benefits Measurement under the Convention

The Convention formulates requirements for performance and benefits measurement for both mitigation and adaptation. Reporting on vulnerability and adaptation occurs through national communications, in relation to NAPAs in least-developed countries, and in the operations of the Adaptation Fund. For measurement of vulnerability or adaptation, there is no consensus on indicators, frameworks, or methods, but emerging practice indicates that results-based frameworks[165] are a preferred and suitable approach to track progress in implementing specific adaptation actions and ensuring accountability for the use of adaptation funds.

Approaches to measure mitigation impacts in agriculture already exist at international, national, programmatic, and project levels. The Convention mandates the use of various guidelines[166] to measure and report agricultural emissions at the national level, and these guidelines inform current measurement approaches at subnational and project levels. Although there is relatively strong consensus on agricultural GHG accounting frameworks, measurement of agricultural mitigation actions is hampered by inherent variability in agricultural emissions and removals and, in many countries, by a lack of available data and limited capacities for measurement. Areas of emerging practice include strengthened capacities, guidelines for accounting at programmatic and project levels, and increasing recognition of the relevance of approaches to measure increased GHG emission efficiency (i.e. decreased emissions intensity) along the food chain. [167]

[165] Rajalahti, R., Woelcke, J., Pehu, E. 2005. Monitoring and Evaluation for World Bank Agricultural Research and Extension Projects: A Good Practice Note Agriculture and Rural Development Discussion Paper 20. World Bank.
[166] IPCC (Intergovernmental Panel on Climate Change). 1997. *Revised 1996 IPCC guidelines for national greenhouse inventories.* J.T. Houghton, L.G. Meira Filho,B. Lim, K.Tréanton, I. Mamaty, Y. Bonduki, D.J. Griggs, and B.A Callander, (eds). Paris:IPCC, IPCC/OECD/IEA; IPCC. 2000. *Good practice guidance and uncertainty management in national greenhouse gas inventories*. J. Penman, D. Kruger, I. Galbally, T. Hiraishi, B. Nyenzi, S. Emmanuel, L. Buen ia., R. Hoppaus, T. Martinsen, J. Meijer, K. Miwa, and K.Tanabe (eds). Hayama, Japan :IPCC/OECD/IEA/IGES; IPCC. 2003. *Good practice guidance for land use, land-use change and forestry*. J. Penman, M. Gytarsky, T. Hiraishi, T. Krug, D. Kruger, R. Pipatti, L.Buendia, K. Miwa, T. Ngara, K. Tanabe, and F. Wagner (eds). Hayama, Japan: IPCC/IGES,. The *2006 IPCC guidelines for national greenhouse gas inventories* are also widely used but not yet adopted under the Convention.
[167] Foresight. 2011. FN 41; Garnett, T. 2011. Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? *Food Policy* 36 (in press).

6.3 MRV for Adaptation

6.3.1 Adaptation Performance and Benefit Measurement

Implementation agencies have a strong interest in measuring the effectiveness of adaptation actions and measuring progress towards adaptation. Governments also require data to report on vulnerability and adaptation in national communications[168] and to measure and compare the effectiveness and efficiency of supported adaptation actions. Assessing adaptation progress is also essential to identify, prioritize, and select the most effective adaptation actions.[169]

However, measurement of adaptation is currently a debated topic and there is no consensus on indicators, frameworks, or methods. A great deal of research by academia and civil society is ongoing, much of which falls into one of two general approaches: (1) approaches to measure vulnerability or adaptation,[170] and (2) approaches to measure functions that indicate adaptive capacity.[171] There are both theoretical and practical reasons why there is no single approach to measuring adaptation or adaptive capacity, or their inverses, such as vulnerability.[172] Measurement of adaptation (or vulnerability) in general is hampered by difficulties in defining the concept to be measured and the interaction of multiple factors that vary geographically, at different scales, and over time. Developing countries' national adaptation plans often form part of broader development approaches. Although this inclusion benefits implementation, it makes it difficult to measure the impact of specific actions as opposed to the performance of the whole system. Given the complexity of factors influencing systems and the multiple levels (sector, regional, or national) involved, even developed countries are just beginning to develop measurement approaches and their utility and effectiveness still needs to be tested. For example, the United Kingdom is devising a flexible and multidimensional approach to measuring adaptation.[173] The British system will build on recent departmental adaptation plans and

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[168] UNFCCC. 2003. *Reporting on climate change: User manual for the guidelines on national communications from non-annex I parties,* November, Bonn, http://unfccc.int/resource/userman_nc.pdf

[169] However, since this report focuses on MRV of adaptation performance and benefits, ex-ante measurement approaches are not dealt with in this chapter. Various climate vulnerability indices and prioritization and ranking procedures have been used at the national level for planning adaptation actions. See e.g. Wheeler, D. 2011. *Quantifying vulnerability to climate change: Implications for adaptation assistance*. CGD Working Paper 240. Washington, D.C.: Center for Global Development, http://www.cgdev.org/content/publications/detail/1424759

[170] Kelly P.M., W.N. Adger. 2000. Theory and practice in assessing vulnerability to climate change and facilitating adaptation. *Climate Change* 47: 325-352; Eriksen, S., and P. Kelly. 2006. Developing credible vulnerability indicators for climate adaptation policy assessment. *Mitigation and Adaptation Strategies for Global Change* 12 (4):495-524.

[171] World Resources Institute. 2009. *The National Adaptive Capacity Framework: Key institutional functions for a changing climate*. Washington D.C.: WRI.

[172] Hinkel, J. 2011. Indicators of vulnerability and adaptive capacity: Towards a clarification of the science–policy interface. *Global Environmental Change* 21: 198–208

[173] Department for Environment Food and Rural Affairs (DEFRA). 2010. *DEFRA's climate change plan 2010*. London.

existing data sources used by line agencies and local governments for other measurement and reporting purposes. Given the inherent uncertainty about future climate change and the expectation that the national risk assessment will change over time, the system is designed to be flexible; however, its utility will be assessed against its fitness for its purpose as a tool for guiding decision making to enhance adaptation across government and society.

When the systems to be monitored are well defined and the purpose of monitoring is driven by specific questions, results-based frameworks can be applied. A results-based management framework is "a management strategy focusing on performance and achievement of outputs, outcomes, and impacts."[174] The core of the framework is a chain that specifies the logical connections and steps assumed to be necessary to achieve the stated objectives of an intervention, beginning with inputs, which support activities that generate outputs, through outcomes, and eventually impacts. This approach is typified by the logical framework, or "logframe." Results-based frameworks are widely used by international organizations and are the main approach used by the GEF (for an example see **Box 6.1).**[175] Despite their wide use in donor programs, little systematic analysis of actual monitoring and evaluation practices in developing-country extension systems has been conducted. Furthermore, measuring impacts of agricultural interventions is complex, and impact evaluations are relatively underemphasized and underfunded.[176]

[174] OECD. 2008. *Emerging good practice in managing for development results*. Sourcebook 3rd edition, http://www.mfdr.org/Sourcebook.html

[175] See http://www.thegef.org/gef/project_cycle, and guidance issued by GEF in relation to accessing each adaptation fund.

[176] CGD (Center for Global Development). 2006. Will we ever learn? Improving lives through impact evaluation. Report of the Evaluation Gap Working Group, Washington D.C.: CGD; de Janvry, A., A. Dustan, E. Sadoulet. 2010. *Recent advances in impact analysis methods for ex-post impact assessments of agricultural technology: Options for the CGIAR*. University of California at Berkeley, http://impact.cgiar.org/sites/default/files/images/deJanvryetal2010_0.pdf)

Box 6.1. Project case study: Adaptation to coastal erosion in vulnerable areas in Senegal

The Adaptation Fund has recently approved a project to help Senegal adapt to coastal erosion. Among other impacts, erosion has led to salinization and abandonment of rice paddies. The project proposes to erect barriers and dykes to enable reclamation of the rice fields.

The results framework in the proposal includes indicators, a description of the baseline and targets at the end of the project, and means for verification of whether the targets have been achieved. The expected outcome is that "the lands for rice growing activities in Joal are protected against salination." The indicator is "study reports, number of curbs and dikes built." In the baseline "rice-growing activities affected by intrusion of saline waters" and the target is that "the technical studies and the dikes to prevent salt intrusion into the rice-growing areas of Joal are done."

This result will be verified by inspection of the reports and dykes. These indicators clearly assist the implementing organization in assessment of whether intended outcomes have been achieved, and provide accountability to the funding source, enabling assessment of whether the funded activities have been conducted. Whether the studies and infrastructure increase use of the protected lands and rice yields, as well as the impacts on farmers' livelihoods will be addressed in the final evaluation planned in the project design.

For further reading see: http://adaptation-fund.org/system/files/SENEGAL_Adapation%20project_full_28%20oct%202010_0.pdf

6.3.2 Reporting and Verification

According to the Consultative Group of Experts (CGE) on national communications, most developing countries find national communications sections on vulnerability and adaptation difficult to complete.[177] The CGE recommends that capacity is built in permanent teams consisting of relevant experts involved in the preparation process. Improving coordination among national stakeholders and improving the management of information could enhance the quality and reliability of the information. Specific problems highlighted include: the rapid

[177] UNFCCC. 2010. Progress report on the work of the Consultative Group of Experts on National Communications from Parties not included in Annex I to the Convention. Addendum. Technical problems and constraints affecting non-Annex I Parties in the process of and preparation of their national communications and the assessment of their capacity-building needs. In *Subsidiary Body for Implementation*.(FCCC/SBI/2010/21.Add1)

turnover of experts; institutional instability or, at times, the total lack of institutions dedicated to the preparation of national communications; reliance on international consultants instead of building local expertise; the lack of data archiving; and the lack of institutional arrangements for data collection, quality assurance and quality control, and data sharing.

For most countries, funding for adaptation in the agricultural sector is likely to derive from several sources, including national, bilateral, or multilateral, as well as dedicated climate-adaptation funding. Each source of finance will have its own requirements of performance and benefits monitoring and its own channels for reporting. Better coordination among the different sources of funding and the national agencies and a single-impact monitoring framework would tremendously increase efficiency of the limited financial, human, and institutional resources available. Coordination can be facilitated if adaptation actions are integrated into national and sectoral development plans and inter-ministerial climate–change-coordination agencies play a role in collating performance data. Linking national systems with international measurement would benefit from guidance from international institutions (e.g., from IPCC) to help Parties develop internationally comparable, standardized reporting systems, thus avoiding each country having to develop its own system independently, and enabling comparison so that Parties can learn and improve the effectiveness of adaptation activities over time. In addition, adaptation measurement and reporting systems could increase accountability through greater participation of local stakeholders in defining how measurement and reporting systems can meet diverse stakeholders' information and learning needs.[178] An internationally comparable system could also potentially increase the efficiency of adaptation funding.

6.4 MRV for Mitigation

6.4.1 Mitigation Performance and Benefits Measurement

Approaches to measure mitigation impacts in agriculture already exist at international, national, programmatic, and project levels. The COP has approved the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas and the Good Practice Guidance for Land Use, Land-Use Change and Forestry that provide internationally agreed methods and guidance for estimating and measuring carbon stock changes and GHG emissions from land use, land-use

[178] Haddad, L., J. Lindstrom, and Y. Pinto. 2010. The sorry state of M&E in agriculture: Can people-centered approaches help? *IDS Bulletin* 41(6).

change, and forestry (LULUCF) at the national level.[179] Guidance in the form of a decision tree is provided on the:

- Choice of estimation method considering Tier 1, Tier 2 and Tier 3 approaches
- Choice of activity data
- Uncertainty assessment
- Quality assurance and quality control procedures
- Data and information to be documented, archived, and reported

The basic methodological approach is to combine information on the national territorial area where agricultural activities are conducted (activity data) with coefficients (emission factors) that quantify the emissions or removals per unit of activity. Data on changes in land use and management activities derive from activity inventory data. Emission factors are applied in different ways depending on the data available for the country and for each management activity. These are divided into three tiers distinguished by level of uncertainty. Key elements of good practice include applying consistent, transparent estimates of activity data and emission factors that neither over- nor under-estimate emissions. National inventories should cover all sources and sinks and all GHGs.

With a few exceptions, developing countries and most developed countries are currently using Tier 1 emission factors, which have a wide range of uncertainty.[180] Due to a lack of data, emission factors often only consider very broad climatic regions instead of agroecological zones that better reflect production conditions. Most emission factors were based on measurements in temperate climate zones, and emission factors for other climatic regions may be based on fewer reported observations, and thus have a wider uncertainty. Sometimes the consistency of the measurement protocols influences the emission factor used. For example, the IPCC emission factor for soil tillage activities considers soil carbon changes to a 30-centimeter soil depth, but different values would be obtained if different soil depths were considered. Emission factors for crop shifting within the cropland land-use category are significantly different depending on crops, rotations, and management practices. Uncertainty regarding agricultural nitrous oxide (N_2O) emissions is particularly challenging. IPCC N_2O emission factors have been recently reviewed[181] and the IPCC expert panel concluded that the methodology reflects the current

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[179] IPCC. 2003. *Good Practice guidance for land use, land-use change and forestry*. J. Penman, M. Gytarsky, T. Hiraishi, T. Krug,, D. Kruger, R. Pipatti, L. Buendia, K. Miwa, T. Ngara, K. Tanabe, F. Wagner (eds). Hayama, Japan: IPCC/IGES, Hayama, Japan.

[180] Smith *et al*. 2007. FN3; Lokupitiya E., and K. Paustian. 2006. Agricultural soil greenhouse gas emissions: A review of national inventory methods. *Journal of Environmental Quality* 35: 1413-1427.

[181] IPCC. 2006. *Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, forestry, and other land use.* Prepared by the National Greenhouse Gas Inventories Programme, H.S., Eggleston L. Buendia, K. Miwa, T. Ngara, and K.Tanabe (eds). Japan: IGES, http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html).

status of science, but that for some activities, such as permanent grass-legume pastures, direct and indirect emissions are unknown and more research is required.[182] Furthermore, N_2O and methane emission factors still have a high level of uncertainty due to limited data availability. For example, FAO highlighted that the calculated GHG emissions from the dairy sector have margin of error of ±26 percent at the 95 percent level of confidence.[183] Even within developed countries that have elected to account for cropland and grazing land emissions in the Kyoto Protocol's first commitment period, uncertainties associated with agricultural emissions range between 13 and 100 percent.[184] Therefore, there is a strong global interest in improving IPCC emission factors, and for individual countries to move toward Tier 2 and Tier 3 approaches.

6.4.2 National, Programmatic, and Project Accounting

Mitigation performance and benefit measurement systems have been developed at national, programmatic, and project levels. Examples are provided in Boxes 6. 2, 6.3, 6.4, and 6.5.

The GHG impact of a number of the 32 agricultural nationally appropriate mitigation action proposals submitted by developing countries (see Error! Reference source not found.)[185] can be quantified using the existing IPCC guidelines (e.g., restoration of grazing land). Others (e.g., improving post-harvest grain storage) would require an efficiency-accounting approach to quantify the benefits. Existing protocols can provide guidance on practical methods for accounting using either activity-based or output-based (i.e. efficiency) accounting approaches. Climate response measures such as the promotion of irrigation-based agricultural development require reference emission trajectories with and without the proposed activity to understand the mitigation impact. Mitigation actions requiring efficiency-accounting approaches may be able to draw on life-cycle analysis to account for the carbon footprint of agricultural products (as opposed to activity-based accounting, the basis for IPCC guidelines), which is a rapidly evolving field.

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[182] IPCC. 2010. IPCC Expert Meeting on HWP, Wetlands and Soil N_2O, October 19-21, 2010, Geneva, http://www.ipcc-nggip.iges.or.jp/meeting/pdfiles/1010_MeetingReport_AdvanceCopy.pdf

[183] FAO. 2010. *GHG emissions from the livestock sector: A lifecycle assessment.* Rome, http://www.fao.org/docrep/012/k7930e/k7930e00.pdf).

[184] See various submissions at http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5270.php

[185] A complete list of NAMAs can be found at: ULR: http://unfccc.int/meetings/cop_15/copenhagen_accord/items/5265.php

Box 6.2. National, Programmatic, and Project Accounting
National GHG inventory systems: Manure emissions accounting in Ireland

Emissions from livestock and manure management contribute the majority of Ireland's agricultural emissions. Prior to Ireland's inventory submission in 2006, a Tier 1 approach was used to estimate methane emissions from enteric fermentation and CH_4 and N_2O emissions from manure management. A research program funded by the Environmental Protection Agency from 2000 to 2006 developed improved activity data and emission factors for these GHG sources.

Activity data for Ireland's cattle herd was improved by shifting from a simple system of classifying cattle as "dairy" or "other" to a categorization of 11 different types of cattle based on function and age. Tier 2 emission factors for enteric fermentation were developed by dividing the country into three regions for which cattle production systems were characterized in terms of calving dates, the dates of winter housing and spring turn-out, to grass, milk yield and composition, forage and concentrate feeding level, cow live-weight and live-weight change and lactation period.

Nitrous oxide emissions from manure management were estimated based on the same data along with information from a survey of manure management facilities and practices on more than 400 farms. Calculation of enteric fermentation and manure management emissions using the Tier 2 approach enabled a decrease in uncertainty of estimates for enteric fermentation emission factors from an average of 33 percent before 2006 to an average of 20 percent post-2006. For manure management uncertainties in activity data decreased from an average of 32 percent to less than 4 percent and for emission factors from an average of 75 percent to 40 percent. Moving to a Tier 2 methodology also led to a net reduction in the national inventory of 11,900 tonnes of CH_4 (0.25 million tonnes CO_2 equivalent) for 2003.

Source: See O'Mara F., M. Ryan, J. Connolly, P. O'Toole, O. Carton, J. Lenehan, D. Lovett, B. Hyde, E. Jordan, and M. Hawkins. 2007. *Climate change: Estimation of emissions of greenhouse gases from agriculture and strategies for their reduction* (2000-LS-5.1.1) Synthesis Report. Environment Protection Agency, Wexford.

Box 6.3 Programmatic MRV: Accounting for mitigation impacts of sown biodiverse pastures in Portugal

Portugal is one of two Annex I countries that has elected to report grassland management in its national inventory. Within Portugal, mitigation through pasture management has been supported through the Terraprima Programme. This program supports the cultivation of biodiverse pastures on smallholders' lands. The baseline is typically natural grasslands or abandoned croplands with limited soil organic matter content, low fertility, and a low carrying capacity. Cultivation of mixed species of highly productive forage grasses and legumes sequesters carbon and increases carrying capacity, giving farmers an incentive to maintain the grasslands for between 10 and 25 years. Inclusion of legumes also reduces the need for nitrogen fertilizers. To account for carbon sequestration benefits, research was conducted at eight sites nationwide over five years. Data from sown biodiverse pastures was compared with unimproved pastures and fertilized natural pastures at each site, and used to calibrate a model describing the carbon sequestration rates under different management practices. The difference between with-program and without-program sequestration rates was then used as a Tier 2 emission factor along with data on the area of adoption to describe the emission reductions due to program implementation.

It is intended to sow a total of 42,000 hectares in 2009-2010, which will generate an estimated 0.9 Mt CO_2–eq over three years. Contracts for three years were signed with participating farmers, and monitoring visits to each farm provide technical support as well as verification functions. Since the management of the improved pastures is economically profitable for farmers, they have an incentive to maintain the pastures over a much longer period.

Sources: See Domingos T. 2009. Project Terraprima – Portuguese Carbon Fund: carbon sequestration in sown biodiverse pastures. Presentation at E.U. side event to UNFCCC COP15 on December 10, 2009, Copenhagen; Teixeira R., T. Domingos, A. Costa, R. Oliveira, *et al.* 2010. Soil organic matter dynamics in Portuguese natural and sown rainfed grasslands. *Ecological Modelling* 222(4): 993-1001;

Box 6.4 Project accounting: Kenya's sustainable agricultural land-management methodology

Kenya's land-management methodology, which was proposed to the Voluntary Carbon Standard, involves estimating and monitoring greenhouse gas emissions related to the adoption of sustainable land management practices (SALM) in agricultural landscapes. In this methodology, SALM is defined as any practice that increases the carbon stocks on the land. Examples of SALM are (but are not limited to) manure management, use of cover corps, returning composted crop residuals to the field, and the introduction of trees into the landscape. The methodology is to monitor project activities and use soil-carbon models to estimate carbon sequestration rates. An Activity Baseline and Monitoring Survey (ABMS) tool was developed to monitor the adoption and maintenance of SALM practices and its impact on crop yield, which is a main driver of soil carbon sequestration. This methodology is based on the Kenya Agriculture Carbon Project, which was developed in partnership among VI Agroforestry, the Government of Kenya, and the World Bank.

Source: http://www.v-c-s.org/docs/Adoption%20of%20Sustainable%20Agricultural%20Land%20Management%20%28SALM%29%20Revised.pdf

Box 6.5 National GHG inventory systems: GHG inventory accounting for cropland management in Denmark

Denmark has used a mix of empirical research and modeling to generate GHG accounts for agriculture. GIS analysis was used to calculate areas under cropland and grassland and areas of each of these under mineral and organic soils. The national soils classification was used to distinguish between shallow and deep organic soils. A nationally parameterized model validated against long-term experiments, C-Tool was used at the county level (average 250 000 hectares) using data on annual crop yields, residues returned to soils, and amount of solid manure and slurry in the specific county based on output from the DIEMA-model. Climate data drive the model. In 1987, a national soil sampling program was initiated on approximately 600 agricultural fields scattered throughout Denmark on all soil types and 320 plots were resampled in 1998. Further resampling in 2008 and 2013 will verify the model predictions made by C-Tool. Uncertainty analysis suggests that the uncertainty in the activity data for the agricultural sector is rather low. Most uncertainty is associated with the emission factors, especially the emission/sink from mineral soils and organic soils. Denmark collects information on each land plot derived from a Land Parcel Information System, in compliance with E. U. requirements as a precondition for making agri-environment payments under its common agriculture policy.

Table 6.2: Analysis of suitable accounting approaches for NAMAs

Suitable accounting approach	Mitigation Actions
Activity-based (tonnes of CO_2/ha)	14
Efficiency based (tonnes of CO_2/unit of output)	7
Agriculture related but classified by IPCC as energy project	1
NAMA not sufficiently described to understand measurement requirements	10
Total	**32**

6.4.3 Reporting

Under the Cancun Agreements, developed countries are obliged to submit annual national communications, including National GHG Inventory Reports (NIRs) and emission reduction progress reports every six months. Developing countries are obliged to submit national communications including national GHG inventories every four years. The NIRs must be transparent, consistent, comparable, complete, and accurate.[186] The national communications of developed countries are required to estimate the impact of mitigation actions on GHG emissions, and are encouraged, but not required, to compare these to a baseline or reference scenario at the sectoral level. Developing countries have not been required to estimate the impacts of specific mitigation actions, but the Cancun Agreements[187] suggests that both domestic and internationally supported mitigation actions will be measured in accordance with guidelines to be developed under the Convention. Agreements on guidelines for baseline or reference emission scenarios will have major implications for measurement requirements.

Currently, agriculture sector components of national GHG inventories must be consistent with the IPCC Guidelines for National Greenhouse Gas Inventories.[188] Tools such as the Agriculture and Land Use National Greenhouse Gas Inventory Software assist in planning and implementation of national GHG inventories are increasingly used by developing countries to report agricultural GHG emissions.[189] Carbon stock changes from biomass, dead organic matter, and soils have to be considered in the inventory as well as non-CO_2 emissions from burning and other sources (e.g., CH_4 emissions from rice paddies), livestock emissions and animal waste (CH_4 and N_2O), as well as N_2O emissions related to fertilizer use and the soil nitrogen cycle). All developed-country Parties report agricultural emissions; however, under Article 3.4 of the Kyoto Protocol, Parties can choose whether emissions and removals from cropland and grassland management are accounted as contributing to the national GHG commitments under the Kyoto Protocol.[190] Of the current developed-country Parties under the Kyoto Protocol, only four accounted for cropland management and two reported grazing land management in the first reporting period.[191]

6.4.4 Verification

Article 7.2 of the Convention requires the COP to conduct a regular review on the basis of available information of the implementation of the Convention and the progress toward the

[186] IPCC. 2000. *Special report on land use, land-use change and forestry, Summary for policy makers*, Geneva, http://www.ipcc.ch/pdf/special-reports/spm/srl-en.pdf); Decision 2/CMP6 on Land Use, Land-Use Change and Forestry, http://unfccc.int/files/meetings/cop_16/application/pdf/cop16_lulucf.pdf).

[187] UNFCCC Decision 1/CP.16, para 61, 62.

[188] IPCC. 2006. *Guidelines for National Greenhouse Gas Inventories*.

[189] Agriculture and Land Use National Greenhouse Gas Inventory Software, http://www.nrel.colostate.edu/projects/ghgtool/).

[190] Discussions relating to the second commitment period are still ongoing, see Decision 2/CMP6, FCCC/KP/CMP/2010/12/Add.1 at http://unfccc.int/resource/docs/2010/cmp6/eng/12a01.pdf#page=3

[191] Cropland management was elected by Canada, Denmark, Portugal, and Spain, grazing land management by Portugal and Denmark. See http://unfccc.int/files/national_reports/initial_reports_under_the_kyoto_protocol/application/pdf/ec_assigned_amount_report_en.pdf.

Convention's objective. To implement this requirement, each developed country national communication is subject to an in-depth review by an international team of experts[192] coordinated by the Secretariat.[193] Under the Cancun Agreements, there will be an enhanced review of developed countries' progress in mitigation and international assessment of achieving economy-wide emission reduction targets.[194] For developing countries, there will be international consultation and analysis on biennially submitted national communications.[195]

The Cancun Agreements also outline the framework for verification of mitigation actions in developing countries. The purpose of international verification is to promote transparency. Domestic mitigation actions in developing countries will be verified domestically using general guidelines to be developed under the Convention. Considering different verification procedures and measurement quality bars, challenges remain regarding the establishment of a common scale with which to compare the mitigation impacts of activities. Excessive stringency applied to all types of action would stifle incentives to upscale mitigation and adaptation in the agricultural sector.

The establishment of an international registry for NAMAs[196] and the initiation of a work program for the development of modalities and guidelines for the registry were agreed in Cancun.[197] Registries can play key roles in helping match developing countries financial, technology, and capacity needs with international support and enabling verification of both support and effects. The detailed arrangements for facilitating support to the development of registries and MRV arrangements are to be developed through a work program.[198] Modalities for linking agricultural mitigation options identified at national level with the international registry will be relevant in this work program.

6.5 Emerging Issues Relevant to the Convention

6.5.1 Continuous Improvement in Measuring Agricultural Emissions

Estimation of agricultural emissions requires activity data as well as data on emission factors. Many countries lack accurate activity data for the agriculture sector, and many agricultural

[192] For background on the Consultative Group of Experts on National Communications from Parties not included in Annex I to the Convention (CGE), see http://unfccc.int/national_reports/non-annex_i_natcom/cge/items/2608.php).
[193] For background on National Communications of Annex I countries, see http://unfccc.int/national_reports/annex_i_natcom_/items/3076.php.
[194] UNFCCC Decision 1/CP16, paras 42 and 44.
[195] Ibid. FN194, para. 63.
[196] Ibid. FN194, para. 53.
[197] Ibid.FN194, para. 67.
[198] Ibid. FN194, para. 66.

emission factors still have a high uncertainty. Uncertainty associated with emission factors can be reduced through targeted research.[199] Improved measurement of agricultural emissions requires increased availability of data, improved capacities for research, and increased investment in basic research on agricultural GHGs. Many countries are also undertaking efforts to improve the collection of agricultural statistics, which can provide a better basis for estimating activity data.[200]

For many countries, using the Tier 1 emission factors to estimate the distribution of GHG emissions within the agriculture sector is the starting point not only for identifying and prioritizing mitigation options, but also for identifying areas for investment in research to derive country-specific Tier 2 emission factors and improve activity data. There are a number of initiatives to help developing countries establish national inventory systems, improve their national inventory estimates, and enhance research on agricultural emission factors. Developed countries are also working to continuously improve their own emission estimates and methods for agricultural emission measurement.

Some countries may already have identified key activities that meet agriculture sector and national development objectives, while also mitigating climate change. Where such activities have already been identified, the potential to access international support for implementing mitigation actions may provide incentives for targeted research to reduce uncertainties in activity data and emission factors. Where research is led by the potential for smallholders to upscale adoption of mitigation practices, it is also necessary to develop cost-effective approaches to monitoring emission reductions due to activity adoption.

This process can be illustrated by the example of soil carbon sequestration. Practices that increase soil carbon are well known and often result in a positive crop-yield response as well as enhanced climate resilience. Given the importance of soil organic carbon for agricultural production and food security, measurement of emission reductions from improved management practices affecting soil emissions is of global importance. Reliable systems for measurement and monitoring of agricultural soil carbon stock changes and N_2O flux exist.[201] The challenge is not that soil carbon stock changes cannot be measured, but how to design cost-effective and efficient spatially explicit measurement and modeling regimes.

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[199] For example, the Global Alliance for Agricultural Greenhouse Gas Emissions (see Chapter 5, Box 5.3) is working on standards, capacities and data for improved emission factors for paddy, cropland, and livestock management.
[200] The Global Strategy for Improving Agricultural and Rural Statistics is relevant to this. See http://www.fao.org/fileadmin/templates/ess/documents/meetings_and_workshops/ICAS5/Ag_Statistics_Strategy_Final.pdf; Wilkes, A; Wang, S; Tennigkeit T; Feng, J, 2011. Agricultural Monitoring and Evaluation Systems: What can we learn for the MRV of agricultural NAMAs?. ICRAF Working Paper No. 126, Beijing, China: World Agroforestry Centre.
[201] FAO. 2009. FN40.

The spatial variability of soil carbon stocks is often high and stock changes are relatively small compared with the soil carbon stocks. Because of this low "signal-to-noise" ratio, it requires time periods of 5-10 years to adequately detect the cumulative change.[202] Options to quantify soil carbon stock changes for agricultural soils include direct measurement of soil carbon stock changes, and the use of carbon estimation models together with activity monitoring. Direct measurements can improve the quality of the estimation models.[203] A priority need is to develop a limited but high-quality global network of soil benchmark monitoring sites with controlled best agricultural management practices. The results can be used to reduce the uncertainty of soil carbon models, and thus enable wider application of low-cost activity monitoring approaches.

6.5.2 Complimentary Accounting Frameworks

The IPCC guidelines use activity-based accounting metrics focused on measuring absolute GHG emissions per unit of land or per unit of activity (e.g., head of livestock). Efficiency-accounting approaches measure the emission intensity per unit of output. This can be done using life cycle analysis (LCA) approaches.[204] LCA methods are still under development for many products, and given the diversity of agricultural production systems, standard approaches may not suit all contexts, presenting an obstacle to comparability within and among countries. Generating sufficient data for efficiency accounting is challenging, particularly when production systems are diverse and when products are part of global value chains. Moreover, a full efficiency-accounting approach for the agriculture sector is not fully compatible with the current IPCC approach. Emissions of some inputs are categorized in the IPCC framework as being created outside the agriculture sector, which might lead to double counting and other consistency issues. However, considering the need to further food production to meet current and future food security goals, efficiency accounting may be more suited to reflecting emissions while allowing for growth in food production. Pursuit of emission reductions per unit of output incentivizes increased food production with minimum emissions.[205] See Table 6.3 for a comparison of the various accounting frameworks.

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[202] Ibid. FN40.

[203] There are a few hundred long-term field experimental sites globally in which soil carbon has been measured (for up to several decades) under different agricultural cropping systems. The majority of these are located in temperate regions (e.g., Europe, North America, Australia, New Zealand). A large number of long-term experiments with measurements of soil carbon also exist in China, India, and South America, but only a few such sites can be found in Africa.

[204] FAO. 2010. *Greenhouse gas emissions from the dairy sector: A life cycle assessment*; ISO. 2006. ISO 14044:2006- Environmental management - Life cycle assessment - Requirements and guidelines.

[205] Regarding the trade implications of different forms of incentives that might be linked with output-based measures, see Blandford D. and T. Josling. 2009. *Greenhouse gas reduction policies and agriculture: Implications for production incentives and international trade disciplines*, ICTSD–IPC Platform on Climate Change, Agriculture and Trade, Issue

Table 6.3: Complementary Accounting Frameworks

	Activity-Based Accounting within National Territory	Efficiency Accounting
Advantages	• Focus on absolute emissions • IPCC standards available and experiences of applying them exist • Considers indirect land-use changes • Emission and sequestration potential can be geographically referenced	• Focus on maximum output with minimum GHGs • Aligned with food-chain approach and low carbon development policies • Second best option to capture emissions between developed and developing countries as long as no full global land-based accounting system is in place
Limitations	• Without global full-land accounting, perverse incentives may exist to ignore land-use emissions in countries without an inventory	• Data demanding • IPCC standards not available • Setting system boundaries is complex (e.g., diverse production systems, globalized value chains)

6.5.3 Measurement of Co-Benefits

Agricultural mitigation and adaptation activities should be developed within the context of sustainable development (see e.g., Cancun decision 1/CP16 on NAMAs). This may require the development of safeguards to ensure that the synergies between adaptation and mitigation, and between mitigation and sustainable development are maximized in the deployment of climate action in agriculture. Screening tools should be used to guide international support agencies and national agricultural agencies' decision-making processes. Social safeguards have been addressed in the Cancun Agreements in relation to REDD+, where a system for reporting information on how social safeguards are being addressed is established.[206] The agricultural sector could review the lessons learned from REDD+ and develop agriculture-specific safeguards considering specific country contexts (see Chapter 5, Table 5.5).

6.5.4 Measurement of Support

Considering the scale of new climate finance commitments, the risk of diverting funding from other development purposes is even greater than before. In this context, developing countries

Brief No.1, Geneva: International Centre for Trade and Sustainable Development and Washington D.C.: International Food and Agricultural Trade Policy Council.

206 UNFCCC Decision 1/CP16 para. 71(d)

have demanded MRV of financial support from developed countries. The Copenhagen Accord confirms that MRV of financial support should conform to existing and future guidelines.[207]

The main objective of MRV for public financial support is to guarantee transparency, while accurately discerning the scales and shifts of financial flows and guaranteeing the comparability of each developed country's efforts.[208] A robust MRV system can increase the transparency of additional financing. Different ways to establish baselines have been proposed taking into account environmental effectives, efficiency, distributional considerations, institutional feasibility, and political acceptability.[209] The MRV systems to support the transparency of financial contributions will complement current reporting in UNFCCC national communications and through the "Rio Markers" of the OECD Development Assistance Committee.

6.6 Main Messages

Measurement of adaptation: Measurement of adaptation performance and benefits at regional, sectoral, or national scales is complex, and there is no consensus on indicators or methods. Where specific adaptation actions are well defined, results-based frameworks can be used.

A top-down route to improving emission estimates: Both developing and developed countries need to continuously improve capacities for reducing uncertainty in estimates of agricultural emissions. Application of the Tier 1 estimation method can identify emissions hotspots where there are likely to be significant mitigation options, and also help identify key sources of uncertainty in activity data and emission factors. More investment in agricultural monitoring and evaluation capacity and research activities to improve greenhouse gas data availability is required.

MRV guidelines for mitigation actions consistent with continuous improvement in data and capacities: Given the lack of Tier 2 or 3 emission factor data for many GHG sources in many countries, and considering the large variability in capacities for measurement, the quality bars imposed by MRV guidelines will be of key importance in determining whether future mechanisms are able to incentivize upscaled adoption of agricultural mitigation options with sustainable development benefits

[207] UNFCCC Decision 2/CP15 para. 4.

[208] Tamura, K., and K. Fukuda. 2010. MRV for developed countries support. In *Measurable, reportable and verifiable (MRV), trends and developments in climate change negotiations.* Japan: Institute for Global Environmental Strategies.

[209] Stadelmann, M., J.T. Roberts, and A. Michaelowa. 2010. *Keeping a big promise: Options for baselines to assess "new and additional" climate finance,* Center for Comparative and International Studies (CIS), Working Paper, No. 66.

A bottom-up approach to improving emission estimates: For countries that are already able to identify agricultural practices that deliver significant food security and mitigation benefits, a bottom-up approach to building MRV capacities would target investments at developing activity data and emission factors for these key activities.

MRV consistent with increased food production: Given the need for increased food production in the future, efficiency-accounting approaches that incentivize increased food output while reducing the intensity of GHG emissions per unit output are relevant. Current IPCC guidelines are not fully compatible with such an accounting approach, and standards for life-cycle analysis for many food products still need to be developed.

MRV of support: Reporting and verification financial support will contribute to ensuring comparability and transparency of whether developed countries' meet their finance pledges.

7. Conclusions

The impacts of climate change on agriculture have severe repercussions on economic activity, livelihoods and food production, particularly in agriculture-dependant societies in the developing world. Resilience of agriculture to such impacts is of paramount importance to affected countries. At the same time, the agricultural sector holds significant climate change mitigation potential, through reductions of GHG emissions, enhancement of sequestration, and as a main driver of forest-related emissions. The following points reflect the main conclusions of this report:

Transformation of agriculture to meet growing demand for food provides opportunities to build synergies and manage trade-offs across the multiple objectives of food security, climate change adaptation and mitigation. Due to growing global food needs, a carbon-neutral agricultural sector may be very difficult to achieve. It therefore may be more appropriate to focus policy interventions on meeting food security equitably by enhancing climate resilience of production and distribution systems without commensurate increases in emissions. Integrated approaches (e.g. landscape, ecosystem and value-chain approaches) are likely to be useful in balancing multiple goals in land-use and food systems.

Lower emissions options that do not compromise development and food security goals are possible. Agriculture offers a wealth of opportunities to deliver simultaneously on improving agricultural resilience to climate change, increasing food production and lowering emissions. Many of these opportunities use practices, technologies, and systems that are already available and affordable, but need to be tailored to specific contexts and may require incentives from climate finance to ensure adoption. Some interventions also benefit wider environmental services, farming incomes, and agriculture-based economies.

From a food accessibility and availability perspective, agricultural trade offers the potential to balance productivity losses and offset shifts in production patterns. Climate change will affect comparative advantages in agriculture, and may further drive up food prices. Trade, combined with increased investment in agricultural production, can ensure supply of food to world markets by counterbalancing climate-induced production decreases in certain regions. Ensuring a supportive role of trade policy in addressing climate change and avoiding perverse interaction between existing trade and climate change regulative frameworks needs to be explored at the most effective venues, including under the Convention and the multilateral trading system, both within and outside of established negotiation tracks.

Early action can build confidence, capacity and knowledge. Early action allows countries to take the lead in preparing for near and longer-term agricultural adaptation and mitigation action, and link these closely with national food security and broader economic development efforts, while negotiations continue in the context of the Convention. It may also provide experiences that can help to shape enabling mechanisms that are to enhance national level action.

Managing the interface between agriculture and forests. Agriculture is one of the main drivers of deforestation. Curbing expansion of agriculture into forested areas will require actively addressing the complexity surrounding competing land uses, driven by increasing demands for food, fuel, carbon storage, livelihoods, economic growth, as well as the protection of forests and biodiversity. Integrated approaches (land-use planning, landscape and ecosystem approaches) may help to consolidate multiple goals or objectives within broader efforts to plan and manage land use.

Finance, technology and capacity building are essential to motivate larger scale adaptation efforts and emission reductions from the agricultural sector. Incentive frameworks under the Convention do not currently provide adequate support. Technology deployment, institutional strengthening, increased capacity building, and dedicated financial support can promote more sustainable and climate-friendly agricultural practices. The newly established technology mechanism may ostensibly respond to needs identified by developing countries as set forth in national technology needs assessments, of which a significant portion thus far relate to agriculture and forestry.

Finally, strengthening existing agricultural monitoring and evaluation systems is essential to implementing effective climate response measures and for climate performance and benefit measurements. For measurement of adaptation actions, results-based frameworks are emerging as common practice. Regarding mitigation, there is a general need to improve methods and data availability for measurement, reporting, and verification of emission reductions. Where country specific data are unavailable, IPCC emission factors can be used to highlight hotspots for targeted mitigation efforts. Where mitigation practices have already been selected, data collection can accompany such interventions. In countries with significant potential to increase agricultural output, methods for accounting for reduced emission intensity (emissions per unit product) may be more suitable than the IPCC activity-based estimation approach.

Annex 1 Agricultural NAMAs

NAMAs represent voluntary GHG emission reduction goals by developing countries that are to be realized through technology transfer and financial support from developed countries. These initiatives will likely form the basis for future projects and programs as fast-start and adaptation financing flows to developing countries. NAMA submissions by developing counties relevant to agriculture are summarized below in Table A.1.

Table 1: Agricultural NAMA submissions to the UNFCCC (February 2011)

Country	Mode	Activity	Implementation
Brazil	GHG cuts & sinks	Cropland and livestock management	Integrated crop-livestock system (range of estimated reduction:18–22 million tCO_2–eq in 2020).
			No-till farming (range of estimated reduction: 16–20 million tCO_2–eq in 2020).
			Implementation of agroforestry practices and systems on 261,840 sq km of agricultural land for livelihood improvement and carbon sequestration.
Central African Republic	N/A	Land and livestock management	Increase of forage seed and their popularization in the following regions: Ouham, Ouham–Pende et Nana–Mambere.
	GHG sinks	Crop intensification and improvement	Intensification of the production of improved agricultural seeds with farmers.
Chad Republic	GHG sinks	Crop intensification and improvement	Multiplication of forage seeds and their popularization with farmers. Manufacturing of compost and fertilizer.
Republic of Congo	Capacity & sinks	Crop improvement and extension	Choosing and popularizing of agricultural species better adapted to climate change. Capacity building of farmers with improved techniques and crops better adjusted to global warming.
Eritrea	GHG sinks	Sustainable land management	Implement projects and programs to enhance soil carbon stocks in agricultural soils.
	N/A	Sustainable land planning	Develop and elaborate appropriate and integrated plans that support both adaptation and mitigation actions for coastal zone management, water resources, and agriculture, and for the protection and rehabilitation of areas in Eritrea affected by drought and desertification, as well as floods
Ethiopia	GHG cuts & sinks	Cropland management and	Application of compost on 8,000 sq km of agricultural land of rural local communities for increased carbon retention by the soil.

Country	Mode	Activity	Implementation
		agroforestry	Implementation of agroforestry practices and systems on 261,840 sq km of agricultural land for livelihood improvement and carbon sequestration.
Gabon	GHG sinks	Agroforestry	Mention of "agroforestry" as an action domain "with proper funding, 100,000 ha are targeted and with application of diverse international mechanisms, 1900,000 ha are targeted."
Ghana	GHG cuts & sinks	Sustainable land management	Uncontrolled burning (promote spot and zero burning practices); Improved land preparation (promote minimum tillage; incentivize use of biofuels for mechanized agriculture; Use of nitrogen-based fertilizers (promote the use of organic fertilizers; promote integrated use of plant nutrients).
	GHG cuts	Crop switching	Predominant cultivation of rice in low lands (promote the cultivation of high-yielding upland rice cultivation.
	GHG cuts & sinks	Post-harvest practices	Burning of crop residues (promote the recycling of crop residues).
	GHG cuts & sinks		High post-harvest losses (improve storage facilities and promote the use of post-harvest technologies).
Ivory Coast	N/A	N/A	"Durable development of agricultural operations."
Jordan	GHG cuts & sinks	Cropland and live stock management	Growing perennial forages in Badia region; Best management practices in irrigated farming fertilization applications.
	GHG cuts	Methane capture	Use of methane emitted from livestock, chicken farming, and slaughter houses
Macedonia	GHG cuts	Enabling conditions for GHG emission reduction	(1) Completion of institutional and legal reforms in irrigation sector, (2) increasing institutional and individual capacity for applying international funds, (3) development of systems to apply "good agricultural practices," (4) financial incentives for mitigation technologies.
		Mitigation technologies	(1) Installation of methane recovery and flaring systems at selected farms; (2) research support program for development of new mitigation technologies and transfer of existing ones; (3) introduction of practices that use the agriculture potential for renewable energy and carbon sequestration; (4) programmatic CDM projects.
	Capacity	Carbon finance capacity building	National and local training and capacity strengthening for (1) training for CDM potential in agriculture; (2) training for preparation of CDM documentation.

Country	Mode	Activity	Implementation
		Mitigation technologies and capacity building	Training of farmers/decision makers in (1) GHG mitigation issues (upgrade to current curricula and syllabuses); (2) training of farmers for adopting new technologies; (3) familiarization of public and institutions with the problems of climate mitigation.
Madagascar	N/A	Crop improvement and fertilization	(1) Increase forage seeds and ensure their popularization; (2) intensify the production of enhanced agricultural seeds; (3) manufacture compost and fertilizers in accordance with the quality levels applicable to rural environment in agricultural investment zones.
Mauretania	N/A	Efficiency	Policies with regard to agriculture: (1) promote public transportation; (2) utilize butane gas as a replacement of the use of wood products; (3) use of energy-efficient lamps.
Mongolia	GHG sinks	Livestock management	Limit the increase of the total number of livestock by increasing the productivity of each type of animal, especially cattle.
Morocco	GHG cuts & sinks	Cropland management	Increase efficiency of agricultural land; potential reduction by 2025 is $KtCO_2e$/year
Papua New Guinea	GHG cuts	N/A	High-level policy objectives for GHG reductions in agriculture sector of 15–27 $MtCO_2$–eq/year relative to BAU projections of 31–58 Mt CO_2/year by 2030 (estimates in 2010 of 25–38 $MtCO_2$–eq/year)
Peru	GHG cuts & sinks	Livestock, soil and agricultural practices	Ministry of Agriculture will coordinate NAMAs implemented for GHG mitigation: (1) livestock management; (2) agricultural residue management; (3) soil and agricultural system improvement.
Sierra Leone	GHG sinks	Sustainable land management and agroforestry	Introducing conservation farming and promoting the use of other sustainable agricultural practices e.g. agroforestry.
	GHG cuts	Bio energy	Developing agricultural waste incineration programs for energy production.
Togo	GHG cuts	Efficiency	(1) Reduction of energy consumption by use of common transportation; (2) use of gas as a replacement for fuel; (3) Replacing nonenergy-efficient lamps with energy-efficient ones.
Tunisia	GHG cuts & sinks	Sustainable land management and efficiency	(1) Expand “biological farming” to 500,000 ha by 2014; (2) upgrade farms to “international standards” and promote water-saving irrigation on ≥ 200,000 ha vs. 120,000 ha in 2009; (3) support brackish water desalinization of treated wastewater for agriculture using recycling and efficient technologies.

Annex 2 Action on Food Security

Table 1: Venues for global consensus and action on food security[210]

Venue	Call to Action	Priority Actions
United Nations Secretary-General's High-Level Task Force on the Global Food Security Crisis	"To promote a comprehensive and unified response to the challenge of achieving food security."	• A mechanism for intensifying and coordinating the work of the UN system, donors, and other stakeholders. • Develop a Comprehensive Framework for Action to outline possible short- and long-term actions for governments and organizations to take to secure a global food supply.
Committee on World Food Security	"The United Nations' forum for reviewing and following up on policies concerning world food security."	• Reformed committee includes a wider group of stakeholders to increase its ability to ensure food security and nutrition for all. • Focus on the global coordination of efforts to ensure food security. • Aims to be the foremost inclusive international and intergovernmental platform dealing with food security and nutrition. • Committee's High-Level Panel of Experts on food security and nutrition to look at interface of climate change, agricultural productivity, and food security.
United Nations Standing Committee on Nutrition	"To promote cooperation among UN agencies and partner organizations in support of community, national, regional, and international efforts to end malnutrition in all of its forms in this generation."	• High-level advocacy, plus communications and identification of science and operational gaps. • Track and report on progress toward achieving the Millennium Development Goals (MDGs) and other nutrition-related goals, including nutrition related chronic diseases (NRCDs), in both development and humanitarian aid settings. • Promotion of human rights approach to nutrition.

210 Adapted from *Farming First 2009: Farming First's guide to food security initiatives,* http://www.farmingfirst.org/downloads/FarmingFirst_Guide_FoodSecurity.pdf)
See also de Haen, H., and A. Macmillan. 2010. *Towards global governance of food security*. Rural 21 Focus Paper, http://www.rural21.com/uploads/media/R21_towards_golbal_governance_03.pdf)

Venue	Call to Action	Priority Actions
L'Aquila Food G8. Security Initiative	"We will partner with vulnerable countries and regions to help them develop and implement their own food security strategies, and together substantially increase our commitments of financial and technical assistance."	• A comprehensive approach to food security, effective coordination, support for country-owned processes and plans and use of multilateral institutions whenever appropriate. • Harmonization of donor practices in line with the Rome Principles, as established in the L'Aquila statement.
UN Millennium Development Goal 1	"Goal 1: Eradicate extreme poverty and hunger by 2015." "Halve, between 1990 and 2015, the proportion of people who suffer from hunger."	• Make the MDGs the centerpiece of national poverty-reduction strategies supported by international processes. • Provide recommendations for action at international, national, and community levels.