CLIMATEFOCUS

Carbon market and climate finance for climate-smart agriculture in developing countries

DFID Climate Change, Agriculture and Food Security Policy Research Program

Disclaimer

The views expressed are solely those of the authors and do not necessarily reflect the positions or policies of the United Kingdom and government agencies. Funding for this report was provided by the DFID Climate Change, Agriculture and Food Security Policy Research Program.

Prepared for:

Agriculture & Carbon Market Assessment

DFID Climate Change, Agriculture and Food Security Policy Research Program

12 April 2011

United Kingdom Department for International Development
Abercrombie House
Eaglesham Road
East Kilbride, Glasgow G75 8UA

Version 1.0

Prepared by:
Climate Focus Inc.
1025 Connecticut Ave NW, Suite 1102
Washington, DC 20036
USA

IIASA
Schlossplatz 1
A-2361 Laxenburg
Austria

UNIQUE Forestry Consultants
Schnewlinstr. 10
79098 Freiburg im Breisgau
Germany

Content

1. Executive Summary

The UK Department for International Development has commissioned this study to assess the value and effectiveness of carbon market and climate finance strategies to enhance agricultural investment, food security and emission reductions in developing countries, particularly for smallholders. The assessment will inform recommendations to implement these strategies through national development policies and post-2012 climate agreements and/or policy measures.

Two of the greatest challenges facing the world this century are interrelated: feeding 9 billion people by 2020, and reversing the build-up of greenhouse gases (GHG) in the atmosphere. Agriculture covers 1.5 billion hectares of the planet having expanded more than 2.7 million hectares annually between 1990 and 2005, more than any time in human history (World Bank 2010).[1] To ensure a stable climate, agricultural productivity must rise to meet demand without relying on inefficient agricultural practices and clearance of the world's remaining forests, the largest reservoir of terrestrial biodiversity and carbon apart from soils.

An emerging set of agricultural practices and policies can help deliver climate benefits and food security through sustainable agricultural intensification and improved agronomy. These measures are not yet standard practice due to transaction costs, lack of financing, inadequate knowledge, and local implementation barriers. Our findings enable policy makers to identify and act on climate finance opportunities that can help sustainably supply the world's food and biofuel, improve the lives of rural poor and stabilize GHG emissions in the agriculture sector. This research is the result of comprehensive global land use modeling and examination of the productivity and mitigation benefits of individual agricultural practices and financing options.

The opportunity

In the context of climate change, agriculture is often described as a problem and a solution. As the primary source of methane and nitrous oxide emissions, agriculture is directly responsible for 10-12% of global GHG emissions (5.1 to 6.1 $GtCO_2e$ in 2005), and the main driver of land use conversion and deforestation in the tropics. The emissions profile rises to 30% if indirect deforestation and emissions in the food chain are included. Sources of demand in the agricultural sector – population, income (GDP per capita) and bioenergy[2] consumption – are all expected to rise during the 21st century creating unprecedented land use pressures, only partially counterbalanced by improved intensification, efficiency and technology. In a business-as-usual future, agriculture will suffer declining rate of yield growth, land degradation, food insecurity and unabated deforestation in developing countries.

Yet there is opportunity for significant GHG mitigation, food security and livelihood benefits. The IPCC estimates biophysical emission reduction potential in the sector is 5.5-6 $GtCO_2$-eq/yr. Improved agricultural practices can also increase productivity and resilience in developing countries where agriculture is a main economic engine contributing 29% of GDP and employing 65% of the workforce (compared to the global average of 4% of global GDP). Poverty reduction is also inextricably tied to GDP growth in the agriculture sector, since it is at least twice as effective at reducing poverty as growth outside the sector, according to the World Bank's 2008 World Development Report.

The challenges of working in the sector, however, are formidable. Long-standing development challenges in the agricultural sector include i) low investment and productivity; ii) poor infrastructure; iii) lack of funding for agricultural research; iv) inadequate use of yield-enhancing technologies; iv) weak linkages between agriculture and other sectors; and v) unfavourable policy and regulatory environments Agriculture

[1] Declines in industrialized and transition countries (-0.9 and -2 million respectively) were eclipsed by increases of 5.5 million ha annually in developing countries.

[2] Bioenergy demand remains approximately constant at 2005 levels and constitutes tree plantations that generally do not compete with food production.

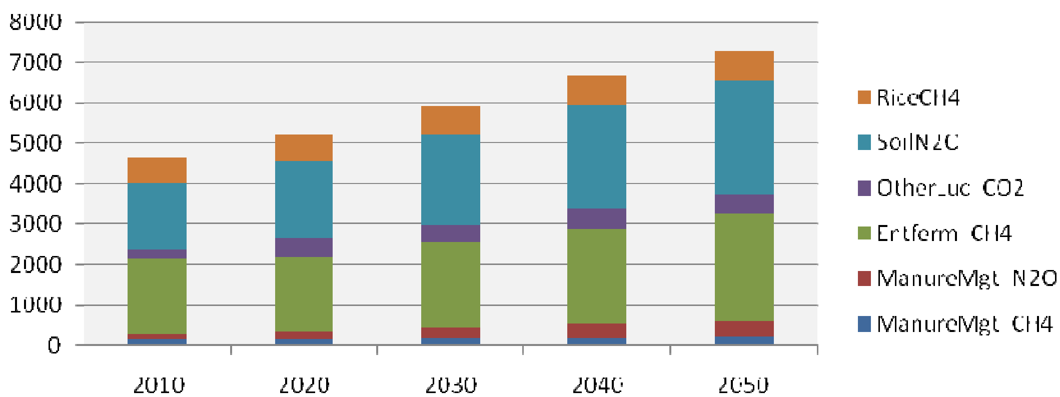
is also composed of location-specific methods at vastly different geographic scales with uneven access to markets. This reflects the rapid commercialization of food production systems in the developing world, shifting demand preferences, and the linkage of domestic and international agricultural markets. Despite these challenges, pioneering efforts can build on existing knowledge and early successes.

Modelling the future

We estimated the mitigation and economic potential of various agricultural measures, and developed economic scenarios of future global land use, using the Global Biosphere Optimisation Model (GLOBIOM) developed by IIASA.[3] Our model results suggest emissions, while significant, can be drastically reduced through a shift toward sustainable agricultural intensification and global trade, improvements in technology and conservation measures such as REDD+.

Emissions: Agricultural emissions in developing countries are projected to rise between 57% and 70% by the middle of the century in a business-as-usual scenario (Figure 1). If the pace of crop technology improvements is static, as is conservatively assumed, sectoral emissions could reach 8,600 $MtCO_2$ per year by 2050, equivalent to about 10-15% of baseline emissions across IPCC scenarios (A2, B2 and B1) or 65% in 450ppm stabilization scenarios without abatement. Livestock (feed production, methane from enteric fermentation, and manure management) as well as global expansion of fertilized cropland onto natural ecosystems account for the largest share of GHG emissions. These two categories account for more than 90% of total emissions.

Figure 1: Developing country emissions from agriculture by category *(MtCO2eq p.a.)*

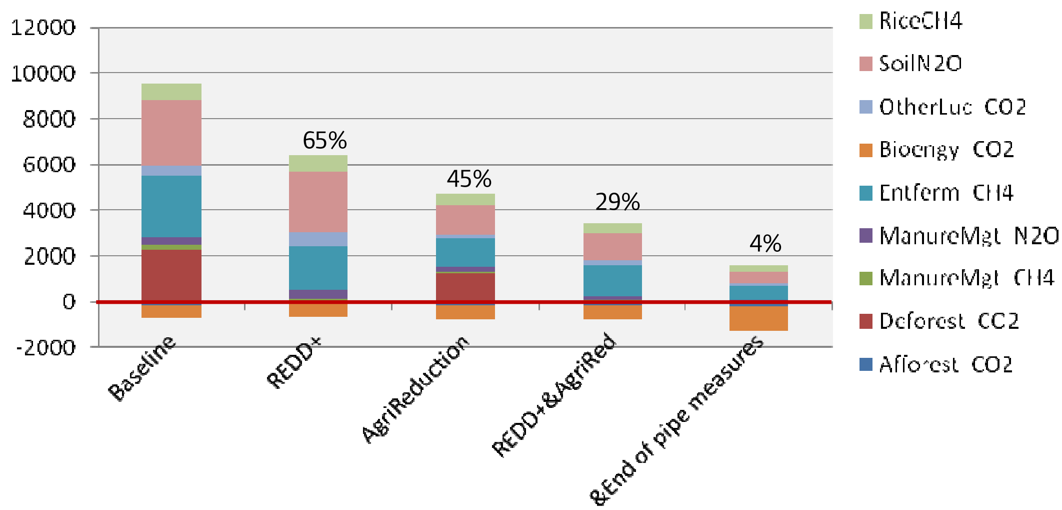


Emission reductions: According to the model, agricultural abatement measures could cut emissions by up to 55% (3,600 $MtCO_2e$/yr) from a baseline of 8,600 $MtCO_2e$/yr by 2050, increasing with REDD+ (71%) and end-of-pipe measures (96%).

The primary sources of agricultural emission reductions are livestock, cropland/grazing land management and avoiding land use changes such as deforestation (Figure 2). The impact of measures to reduce soil carbon losses are also likely to be large but excluded from the model because of greater uncertainty in the data and exclusion in the modeling assumptions.

[3] The model simulates land use decision in 27 global regions, as well as agricultural practices associated with these factors

Figure 2: Land use emission reduction potential by practice (GHG balance in developing countries by 2050)*



Forests and REDD+: Forest clearance could continue at the rate of 12 million ha/yr of forest by 2050, almost equal to the worst annual global losses of tropical forest between 1990-2010, without crop improvements or an effective REDD+ mechanism. Rising demand for agricultural products will continue to make forest encroachment cost-effective. Ending deforestation will likely be a political decision in the end. Financial incentives, perhaps through REDD+ targets or regulations, appear necessary to slow or halt deforestation. Yet improvements in agricultural technology, trade and efficiency are a necessary thought not sufficient condition to achieve this.

Outlook: Global land use (terrestrial biosphere), driven by the agricultural sector and forest conservation, could sequester almost as much GHG emissions as is emitted by 2050 if aggressive end-of-pipe mitigation measures such as bio-energy/biofuels are combined with REDD+ and on-farm measures for cropland and pastureland management.

Although our model suggests a 96% reduction from the terrestrial baseline is technically possible, this is unlikely due to the prohibitive transaction costs associated with major institutional implementation challenges (e.g. local governments lack means to enforce policies or offer alternative livelihoods for those engaged in deforestation). Emissions would also increase given that emission reductions from REDD+ are accounted only once, while emissions related to fertilizer and other inputs continue into the future. Although carbon-neutral food production is probably not achievable, even realizing a moderate share of this mitigation potential represents globally significant GHG reductions.

Food security and a stable climate: The agricultural connection

A number of effective and well-established agricultural practices are suitable for fast-start mitigation actions. The suite of measures identified as promising early investments are:

- *Cropland management (sustainable land management and nutrient applications):* The most promising cropland mitigation practices are input-based, using organic or synthetic fertilizer, soil and water conservation or irrigation, extending crop rotations including cover crops, green manure and agroforestry and increasing cropping intensity by introducing more than one crop per year and yields on existing agricultural land. These create GHG emission reductions and carbon sequestration above ground and below ground (although the benefits of soil carbon remain contentious).

- *Pasture and grazing land management:* Better pasture and grazing land management to increase grazing productivity and soil carbon sequestration may involve seeding fodder grasses and legumes and often require temporary de-stocking to match the grassland carrying capacity with the number of animals. Medium intensity grazing often maintains the highest soil carbon stocks as well as plant biodiversity.
- *Livestock management:* Improved land-management is usually implemented in a package together with advanced livestock management practices adopting better feeding practices (including food additives), animal breeding, marketing and value adding activities and veterinary services. Advances in livestock management in general will reduce the emissions per unit of output, but not necessarily overall emissions if the global trend to consume more emission intensive meat continues.
- *Land use, land-use change, REDD+:* Land-use changes (forest to grazing land or grazing land to cropland) result in substantial emissions and biodiversity loss. These can be prevented through better land-use planning and market-driven or regulatory enforcement mechanisms. Sustainable intensification of fertile land and preventing agricultural expansion on marginal land generally lowers emissions.

There are a number of widely accepted, no-regret mitigation options within these categories known to offer strong food security and adaptation benefits: preventing land-use changes, encouraging crop rotations with legumes to enhance soil nutrient status, agroforestry, carbon sequestration on smallholder farms and low-energy or water efficient irrigation systems. These could be implemented immediately using the available fast-start public climate finance, although it should be noted the practices mentioned above face implementation challenges due to capital (e.g. irrigation) or labour (e.g. composting and residue management) requirements, as well as investment or implementation barriers.

Finance

Climate financing from public sources, about USD8 billion annually across all sectors, is inadequate to meet mitigation and adaptation needs in developing countries since necessary agricultural adaptation investments alone are estimated to be USD 7 billion annually.[4,5] Existing agriculture mitigation finance mechanisms for developing countries are limited to the Clean Development Mechanism (CDM), which has proven to be inappropriate for the majority of agricultural mitigation options. With the exception of waste management solutions, the CDM is not mobilizing agricultural emissions due: a) to a lack of eligibility; b) non-scalable project approaches; c) challenges of aggregating smallholders and deploying effective practices; and d) insufficient and untested carbon measurement systems. However, new climate finance mechanism may address these challenges provided that they allow the definition of innovative financial instruments to address unique needs of agricultural sector; support the building of legal/policy frameworks; and rely on appropriate measurement, reporting and verification (MRV) systems.

We focus on the two most promising approaches for climate finance in the agricultural sector: a) market-oriented incentives for direct investments; and ii) results-based regulatory and economic reforms/incentives that contribute to GHG mitigation in the agricultural sector such as nationally appropriate mitigation actions (NAMAs) or REDD+. Climate-specific financing can add crucial financial and political resources, and act as convening force, for agricultural investments that depend primarily on conventional financial instruments. Nine options under each the two approaches are listed below.

a) Market-oriented incentives for direct investments

Risk management: Designing and supporting financial instruments that reduce or redistribute risks for investments in agriculture

---

[4] As of 2010, climate finance from the UNFCCC, multilateral and bilateral sources including the CDM, GEF Trust Fund, Adaptation Fund, World Bank Climate Investment Funders and others amounted to USD8 billion annually. HAGCCF (High-Level Advisory Group on Climate Change Financing), 2010, "Report of the Secretary-General's High-Level Advisory Group on Climate Change Financing." 5 November 2009.

[5] http://siteresources.worldbank.org/EXTCC/Resources/407863-1229101582229/D&CCDP_4-Agriculture9-15-10.pdf

Monetizing agricultural/carbon/ecosystem service revenue streams: Financial instruments (e.g. bonds) monetizing revenue stream from improved agricultural productivity and/or ecosystem services

Transition cost subsidies: Creation of funds and financial instruments that subsidize upfront costs for transition to improved agricultural practices

Direct purchase: Purchase or creation of sustained demand for carbon credits, potentially with a quota for credits derived from agricultural projects

b) Regulatory and economic reforms

Subsidies or tariffs: Removal or modification of domestic subsidies or tariffs that encourage unsustainable agricultural activities – or disincentivize more efficient production – with international trading partners

Regulatory mandates: Implementation and enforcement of regulatory mandates for adoption of specific agricultural practices, minimum standards or processes, lowering transaction costs for adoption

Sustainability criteria: Creating, recognizing or mandating market-based sustainability criteria and labeling (within the borders of current WTO agreements)

Regulatory infrastructure: investments in the regulatory infrastructure that lower the transition costs of adopting agricultural methods

Land-use planning and tenure reform: Investments in land use planning and tenure reform to support sustainable land management practices, enforcement, monitoring and improved governance

Prioritized domestic or international actions can be matched with climate finance instruments, as well as linked to bilateral and multilateral funds. Determining the most appropriate climate financing method for the agricultural sector is unlikely to yield a single answer. Our experience shows broad distinctions are possible for financing categories of agricultural mitigation/adaptation measures – grant or performance-based, bilateral or multilateral, public or private, however, the appropriate institutional arrangements for each country will depend on i) effective agricultural practices; ii) evolution of climate policy under the United Nations Framework Convention on Climate Change; iii) social and political circumstances in host countries.

Stakeholder Analysis

Strategy to encourage CSA: A clear preference was expressed for workable, practical systems to pilot and scale agricultural mitigation and adaptation projects prior to an elaborate readiness process.

> "The problem is that the project focus is a relatively short time frame and does not set up the enabling environment: human capacity, development, physical infrastructure to support human capital on the research and outreach side, but also policies…[sometimes] we don't need new agronomists but to build more roads." Gerald Nelson of International Food Policy Research Institute.

Role of agriculture in post-2012 climate agreement Several developing country representatives (government and civil society) resisted two points that complicate market-based climate mechanisms in the agricultural sector: i) opposition to agriculture as a mitigation measure as it is currently stipulated in the AWG-LCA text, instead of an adaptation-driven element of the climate regime; ii) creation of fungible market-based offsets in an international system of crediting emission reductions for agriculture. There is also a dearth of UNFCCC advocates among developing countries to push this agenda forward (e.g. Coalition of Rainforest Nations for REDD+) raising the possibility of strengthening advocates (some African nations) through resources for a coordinated campaign (e.g. Advocacy Fund)

*Relative role of markets and governmen*t: Resistance to agricultural carbon markets focused on the expense, complexity and uncertainty of establishing new market infrastructure, and the fears that this would expose countries and farmers to excessive delays, lack of liquidity, transaction costs and downside risks or disturb policies promoting more efficient CSA practices. This is not to preclude private sector engagement. A role for the private sector in designing, financing, and/or implementing CSA was not opposed – rather, it was the carbon-market means to do so that raised opposition. Other points included:

- Transaction costs involved with changing individual behaviour, and distributing financing through centralized systems would be high and likely impractical.
- Climate finance should pursue a dual strategy to strengthen government facilitated agricultural knowledge sharing networks, including complimentary private and NGO supported initiatives, while opening market-access at the national level and preserve the option to directly incentivize farmers.

Food Security: Food security must be a central aim for climate strategies in the agricultural sector to work. No mitigation measure should be permitted that dislocates or interferes with regional food supply without compensatory systems; measures that increase productivity *must also raise demand* in domestic or international markets.

Climate finance governance: Two key domestic and international issues were raised: country-appropriate administration of funds, and coordination of international financing both among funders and within countries.

- Domestic: a purely local or purely national strategy for CSA financing was seen as flawed; suggested system of internal checks and balances through decentralized selection of activities and implementation by communities/local jurisdictions with national oversight/accountability.
- International: Financing should be coordinated at the international level to complement developing country-led objectives– mitigation, food security, and poverty – through harmonized and transparent funding strategies.

Barriers: Barriers identified were diverse but can be summarized as:

- Lack of strong legal and regulatory frameworks will be a limiting factor to implement agricultural mitigation measures through climate finance.
- Knowledge remains a key barrier to implementing agricultural projects and policies. "There is no consensus on what is known or what we need to know," stated one respondent.
- UNFCCC negotiations will struggle with the issue of trade; very contentious
- International understanding of MRV concepts and practical design is relatively limited and negotiators will be hard-pressed to design workable systems given this limited knowledge base.

Options for Engagement

We outline a strategy that focuses first on lifting investment barriers and increasing incentives for sustainable agricultural intensification while also considering the possibility of a carbon-markets approach in the future. Stakeholders have noted that a carbon market mechanism for agriculture appears premature and technically impractical at this time. The categories below represent options to finance agricultural practices from public and private sector funds that have the potential to achieve the multiple aims of GHG mitigation, enhanced productivity, food security and improved livelihoods.

- ***Reducing barriers to adopt sustainability standards: Transitional fund model***

Transition funds are designed to subsidize the costs for farmer and agricultural processers to adopt sustainable practices usually connected to industry-wide environmental and social standards. The assumption is that improved productivity and efficiency gains will offset higher costs related to meeting these standards and subsidies can be phased-out over time. Supplies of global agricultural commodities, many of which involve extensive networks of smallholder out-growers, are extremely price-sensitive and difficult to influence through standards with low premiums or significant upfront costs. A transition fund removes this barrier to adoption by providing finance that lowers producers' initial investments in auditing, quality control, and improved practices enabling it to achieve certification and adopt sustainable practices.

This transition fund model could be used to foster the adoption of agricultural practices among smallholder producer associations and agribusinesses, and influence the decisions of domestic and foreign investors. Beneficiaries of this fund would receive performance payments (with upfront financing possible) using a predefined MRV system and respective climate benefit and livelihood indicators and benchmarks.

This model appears most promising for cash crops where a quality premium is paid and additional environmental and social costs can be partly covered from this premium. Agricultural producers invest in sustainable agricultural intensification and commit themselves not to engage directly or indirectly in deforestation or forest degradation. This may be appropriate for cocoa management in West Africa, tobacco production in East Africa or palm oil, soy, and sugar/ethanol agribusiness in Asia – particularly the small-scale production of these cash-crops. The beef industry in Brazil is one widely known example for domestic investment in related policies cited in the report. The Brazilian government linked preferential government loans with the condition that land-use plans are enforced and producer do not expand their production area to reduce the direct but also indirect deforestation pressure. MRV systems also monitor performance and enforce policies.

- ***Addressing Risk***

Farmers, particularly the rural poor, face market volatility and harvest risks with little or no insurance against input loss and crop failure. As a result, farmers reduce inputs as a risk reduction measure triggering a degrading cycle or reduced inputs over time followed by production declines. By helping farmers manage these risks through simple but accessible insurance options, private sector investment can flow into improved agriculture at limited public expense. Climate finance support for risk-sharing instruments should correspond to improved productivity, GHG mitigation and resilience/adaptation. These instruments include innovative forms of crop and input insurance, loan guarantees for private investors replacing collateral (often preventing smallholders from taking loans), group loans and microfinance systems. Climate finance could be used to pay for the insurance and risk premium or could also contribute to reduce the interest rate depending on climate benefit monitoring.

Successful efforts to avoid this and unlock crucial financing are the Kilimo Salama input insurance model in Kenya and crop insurance mechanisms such as Harita model in Ethiopia. Loan guarantees without a climate finance component are also successfully offered by a number of development banks (e.g. USAID Development Credit Agency).

- ***Leveraging private sector investment: Access to technology***

Agricultural research is mainly funded by the public sector in developing countries. A lack of private sector engagement at the research stage often means that innovations subsequently lack the private sector finance needed if they are to be commercialised and applied at scale. The fund could fill this void by attracting private sector capital to invest in agricultural mitigation and adaptation innovations designed to meet multiple social and environmental objectives. These include irrigation technology to increase biomass production and soil carbon sequestration; precision farming technology enabling more efficient fertilizer application; and carbon monitoring systems that are simple, cost effective and locally managed by private sector entrepreneurs. Micro-irrigation system entrepreneurs in India represent effective private sector engagement in this space. A systematic overview of agricultural innovations and diffusion pathways is provided in the World Bank's Enhancing Agricultural Innovation study.[6]

- ***Harnessing carbon markets***

Global carbon markets represent a large potential source of finance for improved agriculture in the future. At the moment, demand for carbon credits from the agricultural sector is limited (particularly those with productivity and smallholder benefits): protocols for measuring, reporting and verification (MRV) are not yet in place at the national-scale, most agricultural CDM credits are not eligible for the European emission trading scheme project sizes are small. Political support for new market mechanisms – particularly ones influencing food production or prices, is limited, according to stakeholders. Carbon market financing may

[6] http://siteresources.worldbank.org/INTARD/Resources/Enhancing_Ag_Innovation.pdf

therefore become a viable long-term strategy, but it is not a short to medium-term option at a global scale. To support the development of viable agricultural carbon projects and contribute to beneficial agricultural research with scaling potential, we recommend strategic purchases of agricultural carbon credits and/or direct finance of strategic projects in cases where efforts lay the scientific and institutional foundation for broader activities. This foundation may include MRV, Programme of Activities, integrated supply chain initiatives and testing new technologies or techniques.

- ***Strengthening public sector capacities for national climate-smart agricultural initiatives***

International climate finance can be used to support countries that have demonstrated their commitment to establish the infrastructure and capacity to monitor agricultural emissions, along with policies and measures to reduce agricultural emissions. Financial support could be provided for an agricultural readiness process, the establishment of national agricultural GHG monitoring systems including national reference emission levels and related capacity building. Financing could be linked to milestones related to the MRV system development and reporting accuracy. Performance payments for emission reductions achieved would provide incentives not only to set-up monitoring systems but also to adopt agricultural mitigation activities. The fast-start financing committed under the Cancun Agreements could provide suitable financing pathways such as NAMAs or bilateral initiatives.

This report outlines the promising carbon market and climate finance strategies in the agricultural sector. Realizing their potential to enhance agricultural investment, food security and emission reductions in developing countries, will require tailoring the delivery; management and target of agricultural climate financing to their specific countries and contexts. It will also require a long term commitment to transforming agriculture from how we grow food, to the ways that we trade and consume it.

2. Introduction

2.1. Objectives

The UK Department for International Development has commissioned this study to assess the value and effectiveness of carbon market and climate finance strategies that enhance agricultural investment, food security and emission reductions in developing countries, particularly for smallholders. Such an assessment will inform recommendations to implement these strategies through national development policies and post-2012 climate agreements and/or policy measures.

A consortium composed of Climate Focus, the International Institute for Applied Systems Analysis (IIASA) and UNIQUE Forestry Consultants (UNIQUE) has examined i) the role of agricultural mitigation practices for greenhouse gas (GHG) abatement and food production through extensive economic modeling of the land-use sector ii) existing and proposed market-based projects and policies that engage the private sector in agricultural mitigation and adaptation activities in developing countries through the short, medium and long-term (post-2020); iii) feasible climate-smart agricultural (CSA) practices with an assessment of their design, scope, effectiveness and relevant barriers. The term climate-smart agriculture expresses, in an abbreviated form, sustainable agricultural activities that can potentially benefit development, food security, adaptation and mitigation. Agriculture is climate-smart if it sustainably increases productivity and resilience (adaptation), reduces/removes greenhouse gases (mitigation), and enhances national food security and development (FAO, 2010a). There is no blueprint for climate-smart agriculture. The specific contexts of countries and communities would shape if and how it is ultimately implemented.

2.2. Methods

The study builds on four components carried out by the Consortium: i) modeling of the global agricultural and land-use sectors to assess the emission reduction potential and opportunities for abatement; ii) assessment of climate finance mechanisms (existing and proposed); iii) assessment of an array of feasible land use practices for CSA, and potential benefits for smallholders; iv) synthesis of this data based on the literature review, policy analysis, modeling and field experience to formulate conclusions about agricultural practices offering food security and climate benefits.

The IIASA team led by Michael Obersteiner developed a partial-equilibrium economic model to analyze the global agricultural and land-use sectors. The model, known as the Global Biosphere Optimization Model (GLOBIOM), simulates an economically "optimized" world where rational firms and individual actors maximize net welfare given the financial, geographic and technological constraints of the model. Our modeling results supply insights about the direction of agricultural trends (cultivated area, crops selection, and preferred practices), economic forces in the sector, drivers of demand and supply, and the critical components of a global agricultural strategy to achieve adaptation, mitigation and food security objectives.

These findings do not depict the world as it must be between 2011 and 2050. Rather, the model describes a range of possible scenarios under reasonable economic and environmental assumptions. These findings informed our recommendations to DFID of CSA practices and climate-finance mechanisms that can achieve large scale GHG mitigation and food security in the context of macroeconomic pressures shaping agriculture during the next century. The methodology we used to reach these recommendations was designed to identify and select promising CSA opportunities that meet the following criteria: i) cost-effective GHG mitigation potential; ii) enhancing or maintaining productivity gains and food security; iii) value for climate change adaptation; iv) feasible potential for implementation.

Our analytical methodology consisted of the following steps:

1.	Conduct extensive literature review and stakeholder consultations on CSA opportunities, barriers, priorities and risks.
2.	Parameterize the IIASA GLOBIOM model to simulate global economic activity and constraints in the agriculture sector (including related land use activities) from 2010-2050. We selected several underlying scenarios (baseline, with/without REDD+, with/without biofuels demand, with/without technical improvements to agricultural productivity) as well as all major agricultural practices/measures identified as potential sources of GHG emissions or abatement: rice cultivation (CH_4), soil management (N_20), bioenergy (CO_2), enteric fermentation (CH_4), manure management (N_20 and CH_4) and deforestation/afforestation (CO_2).
3.	Run the GLOBIOM model and organize datasets for analysis
4.	Assess each agriculture measure/practice in the selected scenarios (see the first step above) analyzing potential GHG abatement volume, scale, geographic distribution, and timing.
5.	Assess macroeconomic trends in the agriculture sector to understand probable future conditions and extrapolate relationships between factors such as food demand or natural resource constraints and deforestation or agricultural trade.
6.	Map market and performance-based climate finance opportunities (existing and proposed) in the agricultural sector based on literature review, stakeholder interviews and global surveys. Research focused on identifying a) international climate finance sources, esp. performance or market-linked, b) suitable mechanisms or arrangements associated with these to delivering financing in the agricultural sector. Existing and proposed agriculture and climate financing mechanisms were assessed and case studies were profiled when possible.
7.	Review of agricultural mitigation practices for smallholder farmers with adaptation and food security benefits. The analysis considered the IPCC classification from Smith et al (2007), but reduced the number of options reflecting the most promising mitigation categories with a focus on feasible practices contributing to sustainable agricultural intensification and smallholder participation.
8.	Identify feasible agricultural practices and financing opportunities based on the modeling and scoping process described above. Final options are based on comprehensive literature review, policy research and the field experiences of the author assessed according to ability to deliver sustainable productivity and food security gains, economic viability and climate mitigation potential.

2.3. Definitions and Assumptions

The agricultural sector in this report is considered to include all land use activities related to cultivating, producing and processing food, fiber and fuel. While broadly defined, we have limited our detailed analysis to agricultural activities that show potential for emission reductions and climate-resilience benefits in developing countries, particularly those that accrue to smallholders. The following assumptions identified in the TORs have guided our work, although at times we have qualified these in our analysis:

- Investment in agriculture needs to i) build resilience and protect the poor and ii) reduce GHG emissions relative to BAU
- New or reformed financial mechanisms that comprehensively cover land-use emissions including agriculture should be used to help scale finance to low-income countries and reduce overall mitigation costs
- Potential climate finance flows for Least Industrialized Countries could be substantial
- Agriculture will be relevant for post-2012 climate agreement/regime and research for this study should inform DFID's policy position as well as assisting in guiding climate finance flows

It should be noted that the results and recommendations in this report are based on the best available information but subject to significant uncertainties regarding the direction and magnitude of climate change, estimates of food production and the impact on food security around the world (Vermeulen *et al*. 2010). Actions taken on the basis of this information should be revaluated over time as new data becomes available and experience adds to our understanding of policies and financing mechanisms.

3. Background

Agriculture contributes 4% of global GDP and provides employment for 1.3 billion people, about one-fifth of the global population (Smith *et al.* 2007; World Bank 2007). This proportion is even higher in developing countries where about 29% of GDP and 65% of the workforce depends on agriculture for their livelihoods on average, particularly among the rural poor (World Bank 2007). In short, agriculture is the central economic engine and labor demand for many developing countries. The sector's importance -- and vulnerability -- will only grow in the coming decades as the areas devoted to agriculture expand, cultivation intensifies and extreme climatic conditions become more common.

There is not much room for error. Stocks of agricultural commodities are at all-time lows. Food price shocks are increasingly common as spare production capacity dries up. The global food system appears increasingly fragile as individual nations have temporarily cut off exports in times of crisis. The rate of technological improvement in the sector is also continuing a decade-long decline, while the future is expected to bring more of the same. During the next half-century, the demands placed on the agricultural sector will be unprecedented: i) the global population growth is set to rise from 7 billion in 2030 to more than 9 billion by 2050; ii) growing affluence is driving demand for resource-extensive diets as well as an interconnected global food system subject to price shocks; iii) competition for land, water and energy is intensifying in constrained regions; iv) GHG emissions and adaptation must be delivered by the agricultural sector to achieve IPCCC targets for avoiding dangerous interference with the climate system (Vuren *et al.* 2009; Foresight 2011).

There is an opportunity to link these objectives through Climate Smart Agriculture (CSA). Agriculture is rapidly ascending on the world's agenda for development and climate mitigation. There is emerging discussion -- voiced by agricultural researchers, development agencies, governments and economists -- that the world will need to feed itself more efficiently and sustainably if we are to satisfy future demand without serious environmental and social damage. Poverty reduction, food security, and cost-effective GHG abatement and climate adaptation are often complementary goals in developing countries (Nelson *et al.* 2010a). While tradeoffs exist, particularly between agricultural expansion and GHG mitigation, many untapped CSA opportunities can enhance food security and GHG mitigation, and mobilize new sources of financing. Pilot projects in Kenya (see box below) and elsewhere have shown this to be true on a small scale. Sustained investment in improved agriculture, much of which qualifies as CSA, may demonstrate this on a global scale as countries and development agencies strive to meet development targets such as the Millennium Development Goals that call for halving the proportion of people with income less than USD1/day between 1990-2015, most of whom live in rural areas.

Box 1: Kenya agricultural carbon project case studies: Kisumu and Kitale

The Government of Kenya, supported by the World Bank BioCarbon Fund, explored soil carbon sequestration options in Kenya developing a carbon project and accounting methodology suitable for smallholder farmers. Project sites in Kisumu and Kitale were selected based on a competitive tender. Using a farm enterprise focused extension approach, the project proponent NGO VI Agroforestry in Western Kenya supports 60,000 small-scale farms to adopt Sustainable Agricultural Land Management (SALM) practices that increase the productivity of mixed-maize farming systems, enhance climate resilience and pay farmers for increasing soil carbon stocks. The carbon accounting methodology (based on consultations with leading soil carbon experts) uses an activity monitoring approach with modeling based on default-values validated by long-term agricultural research trials in Kenya. The methodology passed the first validation against the Verified Carbon Standard (VCS) in February 2011. When the second validation is successfully complete, it can be approved by VCS and subsequently the project can be validated, verified and emission reductions can be registered and transacted.

The carbon project area covers a region of 116,000 ha with SALM practices to be adopted on 45,000 ha expected to abate 1.2 million tCO_2 over a 20-year period. Project roll-out started in January 2010 with SALM practiced on 14,500 ha. A carbon purchasing contract was signed in November 2010.

Barriers

Long-standing development challenges in the agricultural sector include i) low investment and productivity; ii) poor infrastructure; iii) lack of funding for agricultural research; iv) inadequate use of yield-enhancing technologies; iv) weak linkages between agriculture and other sectors; and v) unfavourable policy and regulatory environments (ECA 2009). These also apply to climate financing for the sector, where climate impacts (shifting weather patterns and extreme conditions) have also emerged as a new challenge.

Solutions to these will not be universal. Agriculture, particularly in the developing world, is radically different region by region. It operates on different geographic scales with location-specific methods, local knowledge, and uneven access to markets. Land-conversion in Sub-Saharan Africa is driven by small-scale agriculture compared to Latin America where large-scale agriculture for export markets plays a much larger role (although subsistence farming also occurs) (FAO 2002). In Southeast Asia, sectoral drivers are both domestic food demand and exports (e.g palm oil) reflecting the rapid commercialization of food production systems in the developing world, shifting demand preferences, and the integration of domestic and international agricultural markets that is happening globally. This is leading in many places to larger land holdings, increased farming specialization and less reliance on non-traded inputs (e.g. family labor), (Pingali 2007).

Over time, the decisions about how to farm (and by extension adapt to climate change or mitigate GHG) are increasingly dependent on large-agribusiness or the regional and global political economy rather than farmers or local factors (Burton and Lim 2005). As a result, efforts to confront these challenges will need to be designed for each country, drawing on the country-specific and broader development experience available, while accounting for global market and political conditions.

For climate finance, a central challenge will be the lack of strong domestic legal and regulatory frameworks related to CSA, or a robust international mechanism to support them (although finance channels under the UNFCCC may prove useful). This will limit implementation and climate finance for agricultural mitigation measures. Creating a new mechanism for the agricultural sector seems unlikely, as developing countries do not have an organized coalition to advocate for agriculture in the climate negotiations (on par with the Coalition of Rainforest Nations and G77 support that propelled REDD+ onto the international agenda), and many are divided about whether climate mitigation, rather than adaptation, should be the primary focus. This is further complicated by issues of international trade, MRV, land tenure and carbon-rights (Perez et al. 2007).

Independent of how CSA is financed, and these challenges are met, low-carbon development paths that target the agricultural sector offer an extremely promising model for economic progress. Clear opportunities exist to achieve the multiple benefits of food security, economic growth and GHG mitigation. Even as the changing climate reshapes the agro-ecology of farming around the world, CSA measures can restore soil carbon and improve production efficiency while buffering against fresh water scarcity, soil degradation, climate variability and flooding (World Bank 2007). Agriculture is also one of the best ways to drive down poverty rates: The 2008 World Development Report by the World Bank notes that GDP growth originating in agriculture is at least twice as effective in reducing poverty as GDP growth originating outside the sector.

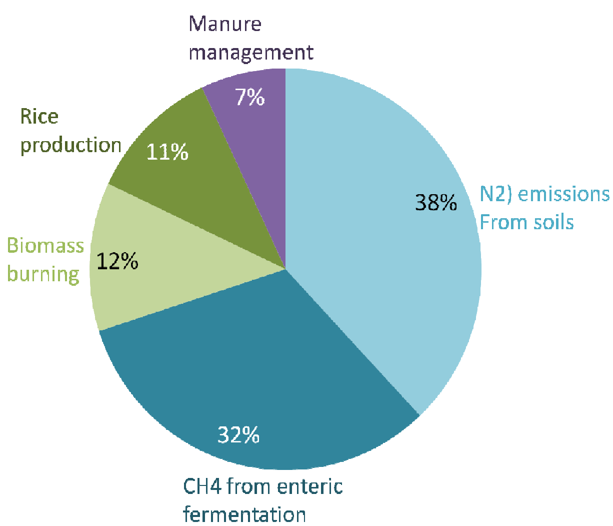
For now, governments and organizations can take immediate action by experimenting with CSA practices and financing strategies that lay the foundation for future increases in productivity to promote economic and environmental sustainability. Strategic investments in agriculture, as well as the policy and incentive framework for the sector, have the potential to address the interrelated issues of energy, water, infrastructure land management, climate and conservation on a global scale (Foresight 2011).

3.1. Mitigation

CSA promises to pull once separate strands of climate and development policy together in a systematic and cost-effective approach to improve social, economic, and environmental aspects of sustainability and environmental conservation (Smith *et al*. 2007). Yet the knowledge and capacity to do this, despite new research initiatives such as the CGIAR Research Program on "Climate Change, Agriculture and Food Security" and emerging market-based incentives for agricultural investments, are limited. This section examines the scientific, economic and political context to take equitable and effective actions in the agricultural sector for GHG mitigation and food security.

Agriculture holds cost-effective mitigation and adaptation potential as one of the world's largest GHG emitting sectors (Smith *et al*. 2007) responsible for an estimated 10-12% of total GHG emissions (5.1 to 6.1 $GtCO_2e$). This proportion rises to as much as 30% when accounting for tropical deforestation driven by agricultural expansion for food, fiber and fuel. The sector is responsible for 47% of the world's methane (CH_4) and 58% of its nitrous oxide (N_20) emissions, primarily from production and application of nitrogen fertilizers, livestock production, and rice cultivation (Smith *et al.* 2007). The remaining GHG emissions are from biomass burning (12%), rice production (11%), and manure management (7%) as shown in Figure 3 below.

Figure 3: Direct GHG emissions in the agriculture sector (Smith et al. 2007)[7]



This occurred almost exclusively in developing countries where emissions increased by 32%, compared to an average decline of 12% in developed countries.[8] The primary drivers of this divergence were adoption of sustainable land use policy and productivity gains in developed countries where the terrestrial carbon sink has grown through reforestation and other land use shifts. In developing countries, this GHG trend is expected to continue in both absolute and relative terms for the foreseeable future driven by population, increasing affluence, diet, and new technologies (Martino 2009).

Theoretically, agriculture's global biophysical mitigation potential (5.5-6 $GtCO_2$-eq/yr) is roughly equal to its total emissions of 6.1 GtCO2-eq/yr (2005; Smith *et al.* 2007), rivaling the mitigation potential of the

[7] Excluding land use change; IPCC.

[8]

energy and industrial sectors, as shown below (Figure 4). Geographic distribution of this mitigation potential (Figure 5) is primarily in developing countries, particularly Asia, Latin America and eastern Africa.

Figure 4: Relative GHG mitigation potential by sector (reproduced from Smith et al. 2007)

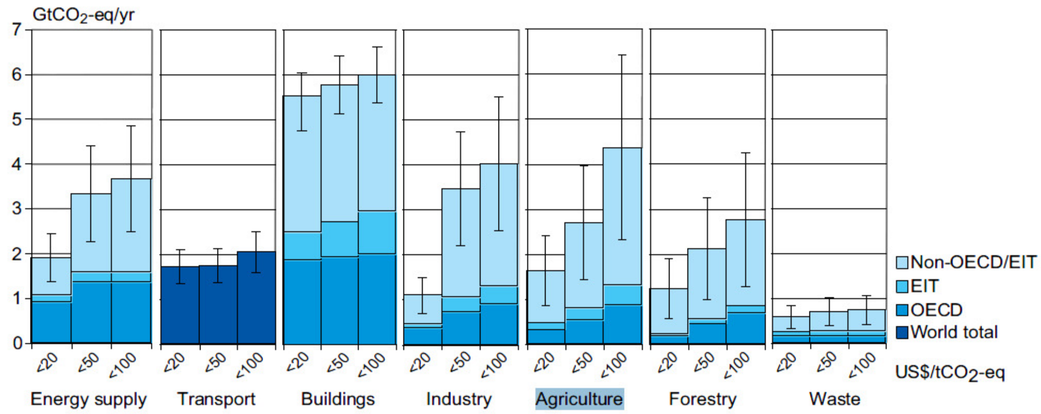
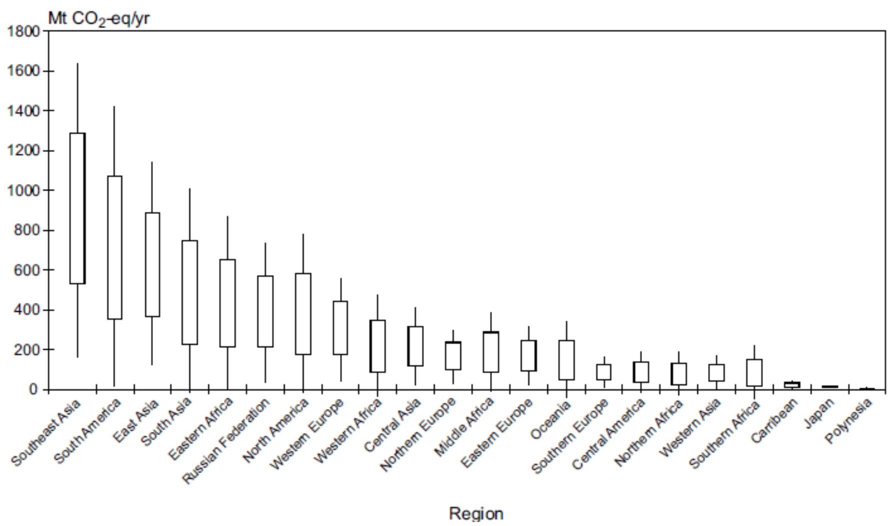


Figure 5: Total technical mitigation potentials (all practices, all GHGs) for each region by 2030 (reproduced from Smith et al. 2007)

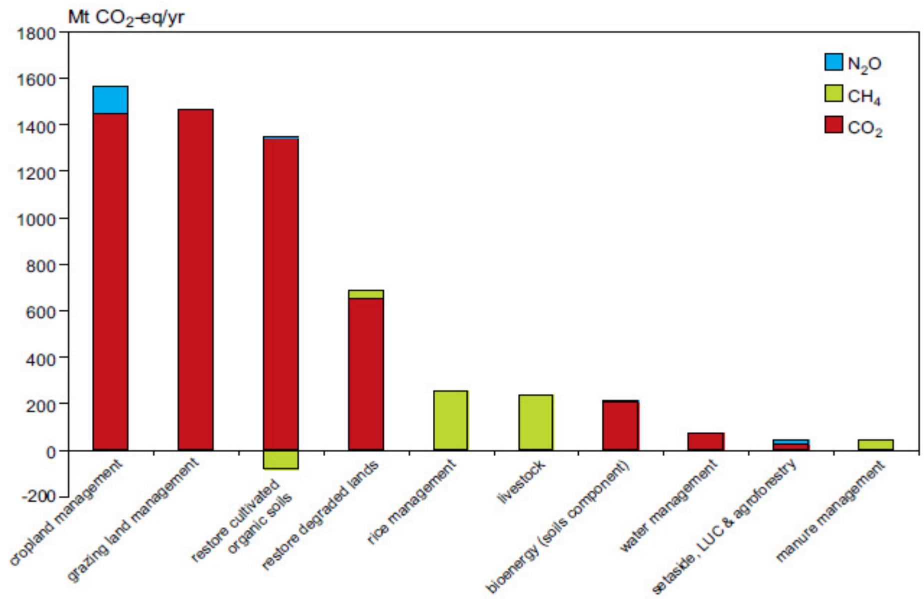


Most of the mitigation potential (about 90%) relies on soil carbon sequestration, with 9% from methane and 2% soil N_2O abatement, reports IPCC (Smith et al. 2007). Over time, however, soil carbon stocks will reach equilibrium (or saturation) and net emissions from the agricultural sector must increase since food production-related emissions can be reduced but not eliminated. The EU Commission estimates that agriculture will contribute about one-third of total GHG emissions by 2050 (European Commission 2011), even when considering agricultural mitigation eases abatement pressure on other sectors.

Agricultural mitigation potential is also limited by what fraction will be feasible or economical compared to non-agricultural options. Economic global mitigation potentials based on opportunity costs (Figure 2) 1500-1600 (USD20) 2500-2700 (USD50) and 4000-4300 MtCO2-eq/yr (USD100) at the respective carbon prices (USD/per tCO2e) through 2030, according to the IPCC (Smith et al. 2007). As a result, meaningful global abatement from agricultural practices must increase or maintain net agricultural production and scale, and clear numerous political, implementation and financial barriers, besides meeting opportunity costs.

As shown in
Figure 6 below, the most promising agricultural GHG mitigation options include i) improved crop and grazing land management (e.g. nutrient use, tillage, and residue management), ii) restoration of drained organic land and iii) restoration of degraded lands. Most of this potential resides in soil carbon sequestration (89%) followed by reducing CH_4 emissions (9%) and N_2O emissions (2%) (Smith *et al*. 2007; Marino 2009).[9] The greatest economic potential appears to be in improved crop and grazing land management offering combined mitigation potential of about 1.5 $GtCO_2e$ per year, mostly in developing countries.

Figure 6: Global GHG mitigation potential of agricultural management practices in 2030 (Smith *et al.* 2007)



Quantifying the effective costs and benefits of these practices – rather than merely the theoretical opportunity cost of alternative land uses -- is critical. Yet comprehensive country-by-country marginal abatement costs are not well understood. The primary reasons are the complex interdependent economic and agronomic systems that exist in each country, region or locality. With the exception of larger, industrial agricultural systems, it is difficult to predict the value and economic beneficiaries of specific practices in isolation or accurately estimate or measure the real costs and implementation barriers. The few examples show extensive variability, and true investment and transaction costs are not studied on a large scale (FAO 2009). Uncertainty with regards to the economic mitigation potential will continue considering the state of scientific knowledge, vast scope of activities, diversity of agricultural landscapes, and inherent uncertainties associated with climate change impacts.

3.2. Adaptation

Adaptation is essential as GHG emissions now exceed the most pessimistic emission projections developed by the Intergovernmental Panel on Climate Change (IPCC), (Raupach *et al*. 2007). Observed CO_2 concentrations in the atmosphere are 391 parts per million (up from about 325 ppm in 1965) implying global temperatures and sea level rise will "all be near or above the high end of the CO_2 emission

[9] For non-CO_2 crop and livestock abatement options, cost-effective mitigation includes 270–1520 MtCO2-eq/yr globally (USD20/tCO2e) and 640–1870 MtCO2-eq/yr (USD50/tCOe) by 2030.

projections of the United Nations-IPCC" (Raupach *et al*. 2007). Temperature increases between 3.2 to 7.2°F (1.8-4.0°C) during the 21st century, if not inevitable, appear plausible.[10]

The most pronounced changes are expected in tropical and subtropical regions of developing countries where impacts will be "predominately negative" (Padgham 2009). Long-term shifts in temperature and precipitation are likely to alter production seasons, pest and disease patterns, increase the frequency of extreme weather events and modify the available set of crops and management practices (FAO 2010c). These changes are already being felt. The UN Office for the Coordination of Humanitarian Affairs reports that about 70 percent of disasters are now climate-related, up from 50 percent two decades ago, and affect 2.4 billion people compared to 1.7 billion previously (Sheeran 2010). Traditional farming societies report unprecedented seasonal patterns, failed rains, difficulties in growing historical crops and other phenomena.

Politically, adaptation in developing countries will primarily focus on producing enough food to feed a population of 5.5 billion people vulnerable to price shocks and climate change. As noted by government officials and community representatives, food security is the "non-negotiable" priority for developing countries facing an increasingly volatile global market for food, and uncertain climate conditions in the future. Yet climate change is expected to make securing reliable and affordable supply of food increasingly difficult. Climate models differ on the specifics but the overall trend is strongly negative for crop yields in developing countries. By 2030, cereal yields could decline in most developing countries with harvest reductions for maize (30%) and wheat (15%) in Southern Africa by 2030 (Lobell *et al*. 2008), grain harvests in Latin America might fall 30% by 2080 (Parry *et al*. 2004). Overall, the UN Food and Agricultural Organization (FAO) predicts that 49 million more people will be at risk of hunger due to climate change by 2020 (FAO 2005).

As a result, adaptation in agriculture faces four primary challenges: i) maintaining productivity, ii) strengthening food security, iii) increasing resilience to future climate shocks, and iv) expanding sustainable climate-smart intensification while providing a route out of poverty for the rural poor. Many effective adaptation measures already exist to cope with climate variability but considering the expected temperature increase and the anticipated rise in extreme events substantial research and experimentation are required to achieve food security in particular beyond 2050. Proactive adaptation will demand, at a minimum, improvements in "crop varieties and species, livestock breeds, cropping patterns, water resource management, changes in rural livelihood strategies and related policy interventions" (Thornton 2011). Sustainable economic growth itself, particularly in agriculture, offers a powerful form of climate change adaptation that can reduce poverty, increase GHG mitigation and strengthen adaptation. Trade, as well, may prove crucial in ensuring the food is grown most efficiently for the most number of people.

Climate change adaptation in the agricultural sector appears "manageable" through 2050 assuming adequate investments in productivity enhancements and agricultural resilience (Nelson *et al*. 2010a). If GHG abatement measures are unsuccessful and temperatures increases up to 4°C by 2080, the severity of challenges climbs dramatically. Model scenarios from the FAO predict global crop yields decline between 1.3-9% by 2030, 4.2- 12% by 2050 and 14.3-29% by 2080. In Africa, as much as a quarter of countries could see climatic conditions over cultivated areas with "no current analogues" meaning few if any resources are readily available to adapt to these new conditions (Thornton 2011). More profound steps may be necessary as local climatic conditions diverge from historical norms and the resilience of existing ecological and human systems in diminishes over time.

---

[10] "O2 emissions from fossil-fuel burning and industrial processes have been accelerating at a global scale, with their growth rate increasing from 1.1% y 1 for 1990–1999 to >3% y 1 for 2000–2004. The emissions growth rate since 2000 was greater than for the most fossil-fuel intensive of the Intergovernmental Panel on Climate Change emissions scenarios developed in the late 1990s. Global emissions growth since 2000 was driven by a cessation or reversal of earlier declining trends in the energy intensity of gross domestic product (GDP) (energy/GDP) and the carbon intensity of energy (emissions/energy), coupled with continuing increases in population and per-capita GDP." (Raupach *et al.* 2007)

A comprehensive review of impacts in the agricultural sector is outside the scope of this study, we have summarized regional impacts below and review the adaptation potential, benefits and tradeoffs associated with the agricultural options recommended in Section 7.

Table 1: Specific climate impacts on agriculture by region (summarized from Padgham 2009)

Region	Impacts
Sub-Saharan Africa	One of most vulnerable regions for food security due to repeated exposure to extreme climate events, very high reliance on rainfed agriculture, agrarian driven economic growth, entrenched poverty. Warming temperatures and aridity amplify vulnerabilities.
Middle East and North Africa	Increasingly vulnerable to combined effects of population growth, climate change, and natural resource base degradation. High temperatures, low and erratic precipitation, prolonged drought, and land degradation constrain agriculture currently -- intensification will make food production increasingly untenable.
South Asia	Higher incidence of flooding in flood-prone areas, persistence of drought in semiarid areas, temperature increases. Reductions in both yield and area of suitability of region's two main cereal crops (wheat and rice). Long-term changes to the region's water resources caused by loss of glacier melt water. Sea-level rise is a threat to rice production in low-lying coastal zones and river deltas.
East Asia and the Pacific	Temperature rise, flooding in Southeast Asia, sea-level rise in the Mekong and other major river deltas, and an increased intensity of El Niño–induced drought in Indonesia. Impacts on rice production and (in China) wheat and maize yields. Agricultural productivity in northern Asia could increase as a result of temperature rise, with potential benefits greatest where water is not limited.
Central Asia	Increased flood and drought risks from glacier retreat and melt water. Northern Europe and northern Central Asia may benefit from a longer growing season. Southeastern Europe could be negatively affected by temperature rise and increased moisture deficits.
Central and South America	Intensification of moisture deficits in northeastern Brazil and parts of the Amazon and Central America. Increase flood risk in southern Central America and southeastern South America. Positive benefits to agriculture in southern cone region of South America from an increase in the number of frost-free days. Profound effects on water budgets in the Andes as glaciers retreat over the next several decades and temperatures rise in high elevation mountain ranges.

3.3. Political context

Agriculture has historically been on the sidelines of international climate negotiations. While mentioned explicitly in the 1992 United Nations Framework Convention on Climate Change (UNFCCC), the sector has only recently attracted attention as deserving special consideration for mitigation. The emphasis has previously been placed generally on adaptation and food production (Article 2; Article 4.1e), despite the recognition of the sector's mitigation potential in the UNFCCC (Article 4.1c):

> Article 2: "The ultimate objective of this Convention ...is to achieve...stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic

> interference with the climate system. Such a level 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." [Emphasis added]
>
> Article 4.1 (c): "Promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases not controlled by the Montreal Protocol in all relevant sectors, including the energy, transport, industry, *agriculture, forestry and waste management sectors;"* [Emphasis added]
>
> Article 4.1 (e): "Cooperate in preparing for adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone management, *water resources and agriculture, and for the protection and rehabilitation of areas, particularly in Africa, affected by drought and desertification, as well as floods;"* [Emphasis added]

Under the Kyoto Protocol (KP)[1] 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.[2] By contrast, the Clean Development Mechanism (CDM), a mitigation crediting mechanism for developing countries, limits eligibility of land use or agricultural activities by accepting only manure and waste water management, afforestation and reforestation projects. The primary mitigation opportunities (especially for smallholders) to enhance soil carbon stocks through cropland or rangeland management are excluded.

Countries have started discussing agriculture in the context of cooperative sectoral approaches in the context of the Ad-Hoc Working Group on Long-term Cooperative Action (AWG-LCA) established after the 13th session of the conference of the parties (COP) to the UNFCCC. The draft decision text of COP15 and COP16 (not adopted) called for countries to promote research and cooperate on measures to reduce emissions through shared agricultural technology and practices (FCCC/AWGLCA/2009/L.7/Add.9). It emphasized activities that "improve the efficiency and productivity of agricultural systems in a sustainable manner" while contributing to adaptation. The text recognized the interests of "small and marginal farmers" as well as the rights of indigenous peoples, in the course of implementing these actions, and stressed - in brackets - that these should not impose "arbitrary or unjustifiable discrimination….or restriction on trade." Finally, any sectoral or sector-specific actions in the agriculture sector were to take into account the interrelated aspects of agriculture and food security, adaptation and mitigation. The AWG-LCA also requested the Subsidiary Body for Scientific and Technological Advice (SBSTA) to establish a work programme on agriculture to enhance the implementation of the decision.

COP15 failed to reach agreement on agriculture. However, the COP took "note" of the Copenhagen Accord opening the door for the submissions of more than 43 proposals for nationally appropriate mitigation actions (NAMAs), submitted as of January 2011, of which 20 include agricultural activities such as 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 (See Section 6 for a discussion and Annex 8.4 for a full list). Morocco and Papua New Guinea, notably, submitted quantitative voluntary agricultural mitigation targets, while Brazil quantified emission reduction commitments in relation to particular activities such as restoration and conservation, improved life stock management, conservation tillage, N-fixing activities.

[1] Negotiated in 1997 and entered into force in 2005.

[2] These countries are obligated to report certain agricultural emissions (mainly CH4 and NO2 emissions from human-induced biological processes) while CO2 removal or emission from cropland management is optional (Article 3.4).[2] Only a few countries have elected to do so (FAO 2010b). Those 'net changes' must be "measured as verifiable changes in carbon stocks in each commitment period" (Kyoto Protocol). Forest carbon stocks by developed countries are treated separately (Article 3.3 KP; Article 3.4 KP).

It was hoped that COP16 (29 Nov – 10 Dec 2010) would reach an agreement on agriculture based on a text negotiated by the AWG-LCA.[3] Although the Cancun Agreements set the stage for a new climate agreement after 2012, legitimized emission targets in the Copenhagen Accord and restored trust among diplomatic negotiators prior to COP17 in 2011, no deal on agriculture was included in the final text. A decision on agriculture failed because of the unfortunate coupling of action on agriculture with bunker fuels under the joint header of cooperative sectoral approaches and dispute of over language concerning trade, a highly controversial topic in international negotiations, despite consensus on the role of agriculture as a major factor in GHG emissions, its mitigation potential and the importance of food security. [4]

[3] The AWG-LCA was set-up by the Bali Action Plan as a subsidiary body under the Convention. Its initial mandate (in effect until 2009) has been extended by the COP and the outcome of the LCA's work is to be presented at COP 16.
[4] In a section in the AWG-LCA text on "*cooperative sectoral approaches and sector-specific actions*" including agriculture was ultimately deleted in the final version adopted by the UNFCCC. The first complication was the conflation of agriculture and bunker fuels under one heading (FCCC/AWGLCA/2010/CRP.1) without differentiation or separation. However, prolonged disagreement on a formulation for trade-related language, namely the reference that cooperative sectoral approaches and sector-specific actions in the agriculture sector should not cause "*arbitrary or unjustifiable discrimination of a disguised restriction on international trade*"[4] led to the sections removal from the final Cancun Agreements. The elimination of that chapter means that SBSTA has no mandate to establish a work programme on agriculture.

4. Modeling GHG in the agriculture sector

We assessed the projected volumes, cost, geography, GHG emissions, and abatement potential in the agricultural sector in 27 global regions, as well as agricultural practices associated with these factors using the GLOBIOM model.[11] The categories of variables in the model were:

- *Agricultural mitigation measures:* The measures include intensification, productivity increases, redistribution of cultivation for higher yields, agricultural trade increases, crop switching and others. They primarily reduce non-CO_2 GHG emissions and increase carbon sequestration in biomass.
- *Livestock measures:* These measures include adoption of better breeds, improved animal health, feed changes, and system changes. For example, GHGs emissions are reduced as producers move from extensive to intensive systems as defined by the FAO livestock categorization.
- *Geographic shifts:* Such measures promote a shift of cultivated land from more arid regions to grasslands and other productive biomes.
- *Demand shifts*: These are behavioral changes leading to lower human consumption of meat and decreased demand on livestock production.
- *REDD+ and land use changes:* These simulate economic incentives for conservation of forest carbon through payments under a global REDD+ scheme.
- *Biofuels:* Such measures anticipate future government-mandated demand for biofuels compliant with biofuels standards.

Scenarios were run under three different annual crop growth assumptions -- 0.0%; 0.5%; and 0.5% combined with enhanced livestock productivity -- to compare how these assumptions affected the final output. The "crop growth" factor is important, particularly for future deforestation rates. It describes the annual input-neutral[12] improvement of seeds, genetic stock, pest and disease management, and waste. Historically, this has improved at a rate which is consistent with the 0.5% input-neutral crop growth assumption per year, leading to large productivity increases without proportionally expanding agricultural land area. This pace is slowing markedly and the impacts of climate change will make this still harder to maintain in the future.

Table 2: Growth rates of agricultural production, percent p.a. (Expert Meeting on How to Feed the World in 2050, 24-26 June 2009)

Regions	1961-2007	1981-2007	1991-2007	2005/07 - 2030	2030-50	2005/07 - 2050
Developing countries	3.5	3.6	3.5	1.8	1.1	1.5
(idem, excl. China and India)	3.0	3.0	3.1	2.1	1.4	1.8
Sub-Saharan Africa	2.6	3.3	3.1	2.7	1.9	2.3
Near East/North Africa	3.0	2.7	2.5	2.1	1.3	1.7
Latin America and Caribbean	3.0	3.0	3.4	2.1	1.2	1.7
South Asia	2.8	2.8	2.4	2.0	1.3	1.6
East Asia	4.3	4.5	4.3	1.3	0.6	1.0

[11] Global Biomass Optimisation Model (GLOBIOM)

[12] Input neutral means more production is achieved independent of intensification due to additional fertilizer and irrigation water inputs and agrochemicals.

We therefore conservatively assess multiple crop growth assumptions with 0% input-neutral crop growth being the conservative assumption and the 0.5% rate being the historically consistent assumption. We have not analyzed a high-tech input-neutral crop growth scenario as we do not know the underlying physiological processes to incorporate in the biophysical crop growth model.

It is important to note that the GLOBIOM model does not simulate carbon sequestration potential from soils because the initial carbon values of soils are too poorly quantified preventing robust estimates of agricultural management impacts on soil carbon. Yet given its global importance, particularly for smallholders, we have included this as a central agricultural opportunity in our final analysis based on IPCC data estimating 89% of total agricultural GHG abatement potential resides in soils (extrapolated from an extensive body of scientific literature, economic potential and field trials). There is still contention over how much of this is ultimately feasible (Baker et al. 2007), the lack of scientific certainty around soil carbon benefits from conservation tillage/no-till (B. Govaerts et al. 2009; Baker et al. 2007; Luo 2010), clarity about sequestration mechanisms (Govaerts et al. 2009; Luo 2010)). Despite these concerns, most soil carbon measures remain "an important technology that improve soil processes, controls soil erosion and reduces production cost" independent of soil carbon sequestration rates (B. Govaerts et al. 2009).

The results of the modeling are summarized below.

4.1. Modeling results

Agricultural emissions in developing countries are projected to rise through the middle of the century by 57% to 70% in a business-as-usual scenario.[13] By 2050, total annual emissions are expected to reach 8,500 $MtCO_2$ per year if yield growth assumptions remain flat. The fundamental drivers of demand in the agricultural sector – population, income (GDP per capita) and bioenergy[14] consumption – all rise steadily during the 21st century, with meat/food consumption growing fastest to 50% above 2000 levels. These conditions exert mounting intensification and conversion pressure on croplands and forests for agriculture only partially counterbalanced by the expected levels of intensification and crop improvements. Table 3 describes the different categories of agricultural emissions.

Table 3: Agricultural emission category definitions

Category	GHG Source	Associated mitigation measures/practices excluding end-of pipe type measures
Rice	Methane (CH_4) from the anaerobic decay of biomass, usually submerged	Substitution with other cereals, geographic relocation, optimized agronomics
Soil	Nitrous oxide from the application and waste of chemical fertilizers	Relocation of agricultural production, optimized agronomics
Other LUC	CO_2 from biomass decay/oxidation in conversion of non-forest biomes	Minimize carbon emissions when expanding cropland and grassland
Enteric fermentation	CH_4 from incomplete food digestion in ruminant stomach	Relocate production, shifts out of ruminant production, livestock system shifts, improved animal nutrition

[13] Modeled as 0.5% and 0% input-neutral crop growth, optimistic and conservative scenarios respectively
[14] Bioenergy demand remains approximately constant at 2005 levels and constitutes tree plantations that generally do not compete with food production.

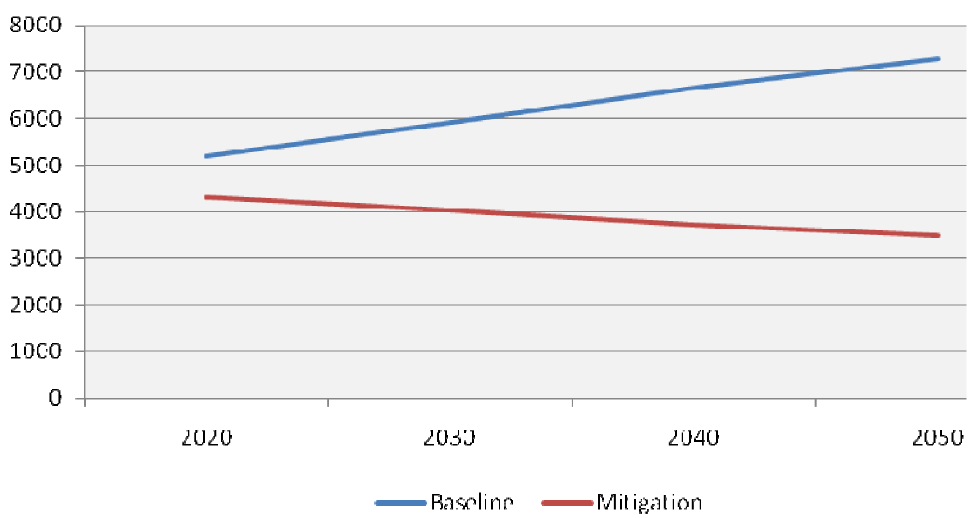
Manure management	N_2O, CH_4 from manure decomposition	Relocation of production, livestock system shifts, improved animal nutrition
End-of –pipe measures	Fertilizer, tillage, and emissions from other processing activities	Technological-oriented solutions including nitrogen suppressants on fields, and other treatments

The GHG emission trends are modeled below (Figure 7 and Figure 8). The largest share of GHG emissions is attributable to livestock (primarily methane from enteric fermentation, but also manure management) as well as the global expansion of (often inefficiently) fertilized cropland onto natural ecosystems. Together, these categories account for more than 90% of total emissions (See Figure 8). However, a range of mitigation actions achieve both GHG emission reductions/removals and increases in food production offering significant CSA potential in developing countries. The abatement measures shown in Table 4 can cut emissions 3,600 $MtCO_2e$/yr from baseline 8,600 $MtCO_2e$/yr by 2050.

The primary sources of modeled agricultural emission reductions sector are livestock, cropland/grazing land management and land use changes such as deforestation. As noted, this model excludes soil carbon sequestration because spatial information on current soil carbon stocks, which is required to assess the soil carbon gap, is not globally available with reliable quality. However, soil carbon is an integrated indicator for soil fertility and, thus, strongly connected to long-run sustainability of food production and adaptation to climate change. We integrate this into our review of CSA practices in Section 5.

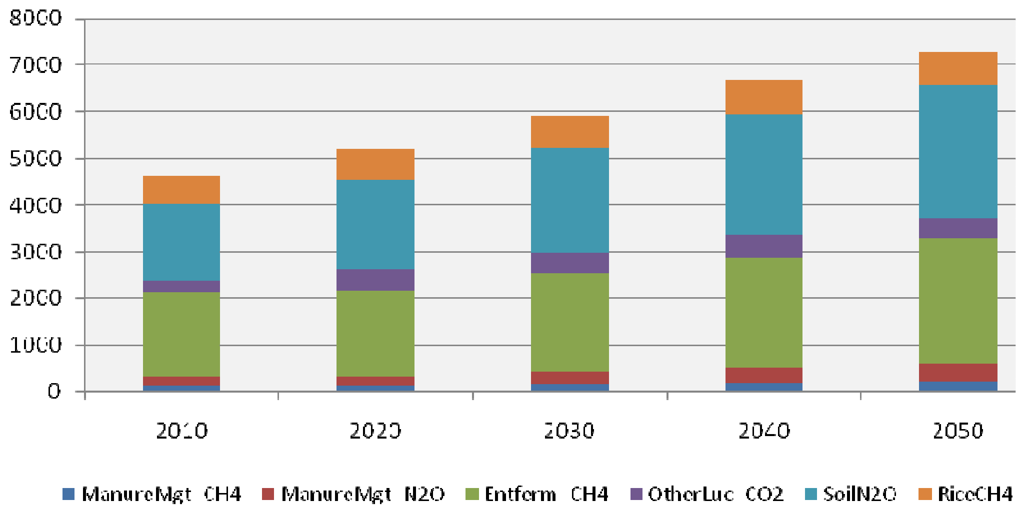
The relative climate impact of agriculture will grow if aggressive energy sector mitigation and REDD+ measures consistent with the IPCC-goal of limiting atmospheric GHG concentrations to 450 ppm are implemented. By 2050, half of the total GHG emissions could come from the agricultural sector even if abatement measures are adopted given drastic reductions in other sector. Agriculture would also account for most global non-CO_2 emissions (primarily N_2O and CH_4) representing about 5,000 $MtCO_2$/year by 2050 of which some 3,500 MtCO2eq/year coming from developing countries. This suggests an increasingly important role for agriculture in the global GHG budget assuming effective constraints are imposed on industrial and energy-related GHG emissions.

Figure 7: Developing country emissions (MtCO2eq p.a.) (blue) relative to mitigation scenario (red) consistent with IPCC 450ppmV stabilization scenario**



** Agriculture in 0.5% input-neutral crop yield growth BAU scenario

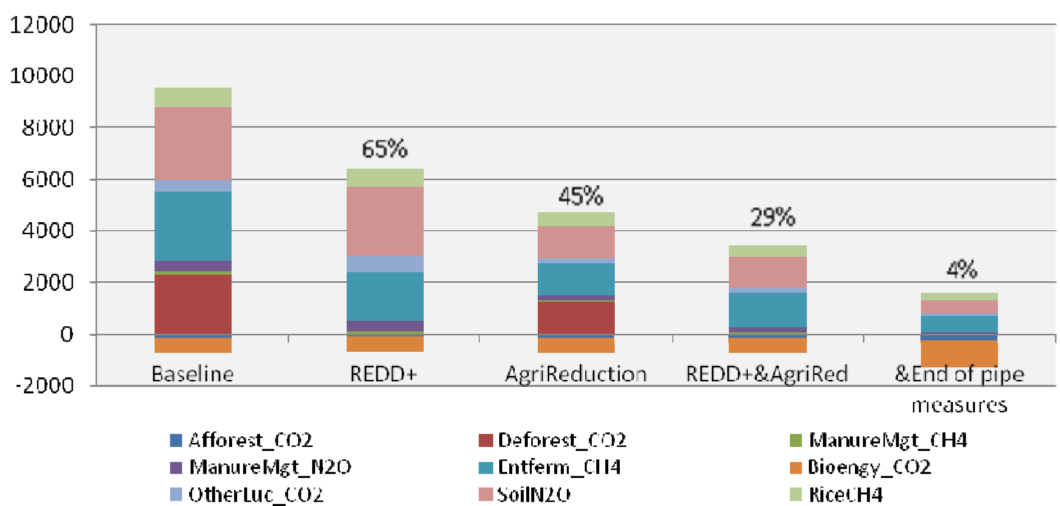
Figure 8: Developing country emissions from agriculture by category* *(MtCO2eq p.a.)*



*0.5% crop yield growth in baseline

The progressive scenarios displayed in Figure 9 show GHG emissions from the entire land use sector (broken down by source) for developing countries in the baseline scenario followed by four mitigation scenarios (REDD+, agricultural reductions, combined, and + end-of-pipe) for developing countries.

Figure 9: Total terrestrial GHG balance for developing countries in 2050 under different policy scenarios including end of pipe measures (% represent fraction of baseline emissions)



The largest abatement potential, as categorized in modeled mitigation areas, are improved livestock management and reducing nitrogen emissions from croplands by using fertilizer more efficiently. The livestock sector is also a crucial element of mitigation as it affects multiple emission drivers including methane from enteric fermentation, pasture management and indirect land use changes. Global CSA measures do two things to curb GHG emissions:

- increase production efficiency (milk or meat per livestock head, yields per hectare)

- reduce the absolute total number of animals and cultivated area relative to the baseline by optimising the geographic location of production

Table 4: Agricultural emissions from abatement measures relative to the baseline ($MtCO_2e$).

Activity	Baseline	REDD+	Agri Reduction	REDD+ & AgriRed	&End of pipe measures
Afforestation (CO_2)	-140.0	-85.1	-159.8	-171.5	-257.2
Deforestation (CO_2)	2,257.6	1.5	1,222.6	1.5	1.5
Manure Management (CH_4)	192.3	140.0	86.6	92.1	27.6
Manure Management (N_20)	396.3	369.0	177.3	153.9	46.2
Enteric fermentation (CH_4)	2,681.2	1,868.7	1,261.0	1,353.2	608.9
Bioenergy (CO_2)	-577.6	-579.3	-577.4	-576.6	-1,037.9
Other land use change (CO_2)	470.3	657.9	188.2	226.0	158.2
Soil and fertilizer emissions (N_2O)	2,813.2	2,648.8	1,261.3	1,164.1	465.7
Rice cultivation (CH_4)	733.5	719.5	513.0	477.0	310.1

Deforestation

Deforestation continues in each of the baseline scenarios. Without external incentives for forest carbon conservation, the economic pressures to clear forest land will drive continuous net deforestation through 2050, mostly in the tropics. We project a minimum deforestation rate of 4.5 million ha per year under optimistic scenarios for crop improvements (0.5% and 0.5% plus livestock improvements), while 12 million ha could be cleared to meet demand for agricultural land without such improvements or REDD+ incentives as shown in Figure 10. Our model also finds cropland under cultivation will not decrease through 2050, despite intensification and crop improvements. Even under the most stringent abatement scenarios, the model predicts slight increases in irrigated, high-input and subsistence cropland with only slight declines in high-input agricultural areas.

Figure 10: Deforestation scenarios under different baseline assumptions for crop and livestock improvement (millions ha)

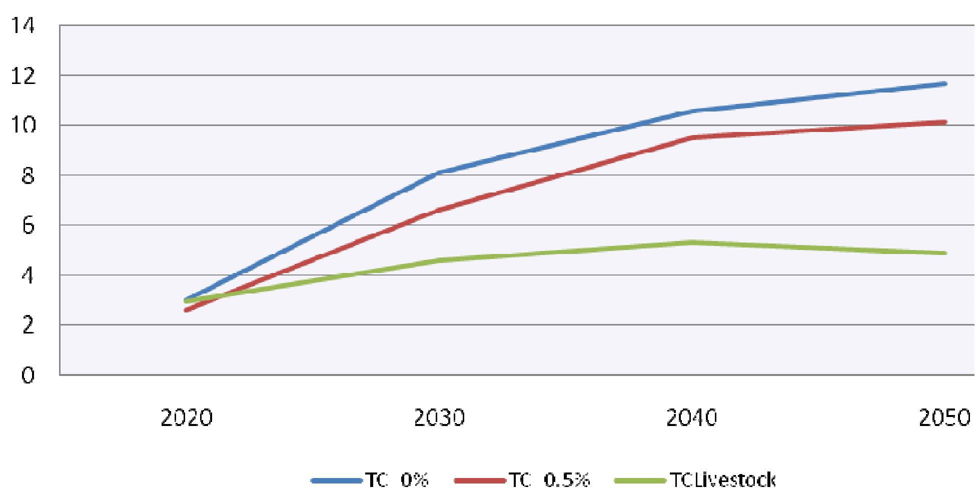
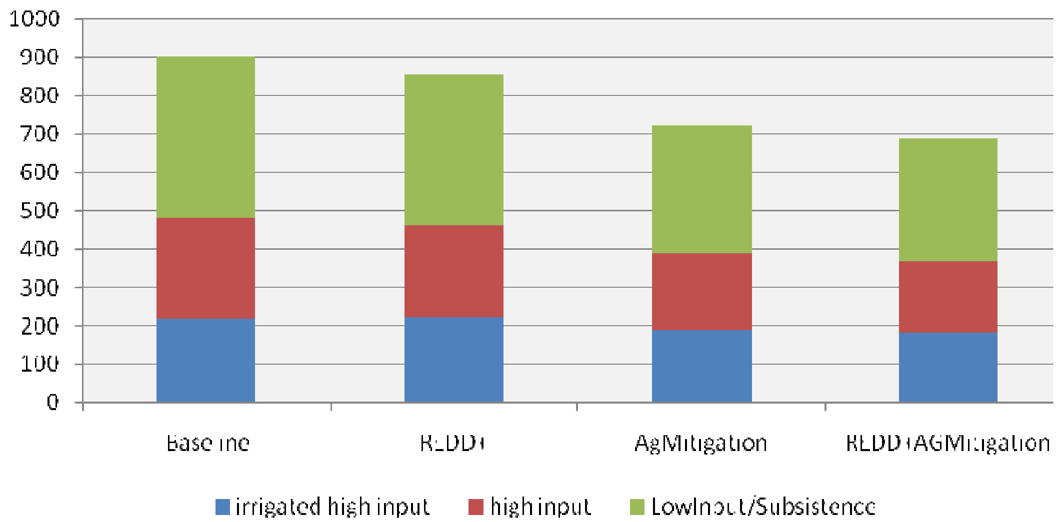


Figure 11: Cropland area under different management practices given expansions of GHG measures (Million hectares)



4.2. Analysis

Agriculture covers 1.5 billion hectares globally having expanded more than 2.7 million ha annually between 1990-2005, more than any time in human history (World Bank 2010).[15] Our model results suggest agricultural expansion will continue, along with a rapid shift toward agricultural intensification and global trade. This may drive deforestation, and perhaps even accelerate it, if REDD+ or other forest conservation measures are not in place.

The ability to achieve significant GHG abatement in the agricultural sector, stabilize emissions and boost productivity, will depend primarily on improvements in crop production and livestock management (see Figure 9) followed by reduced nitrogen emissions from croplands. As mentioned above, global CSA measures can both increase production efficiency (milk or meat per livestock head, yields per hectare) and curb land expansion (land-sparing measures) by optimising the geographic location of production and thus reducing the absolute total number of animals or cultivated area relative to the baseline.

These findings have several implications distilled into four points below:

- Agricultural abatement measures in agriculture can cut emissions 55% (3,600 $MtCO_2e/yr$) from the baseline of 8,600 $MtCO_2e/yr$ by 2050 from a theoretical perspective (feasible volumes are likely much lower)
  - Combining this with REDD+ results in emission reductions of 71% from the baseline
  - Adding end-of-pipe measures results in a 96% reduction in agricultural GHG
- Livestock, cropland/grazing land management and REDD+ are the primary sources of emission reductions.
- Expansion of agriculture into forests and other biomes, particularly grasslands, will continue or even accelerate without countervailing polices and/or economic incentives (such as REDD+).
- Abatement measures and REDD+ will not be enough to prevent all forest clearance or encroachment on natural ecosystems. Projected agricultural demand and resources constraints (productivity per hectare) implies that minimum deforestation (perhaps several million hectares)

[15] Declines in industrialized and transition countries (-0.9 and -2 million respectively) were eclipsed by increases of 5.5 million ha annually in developing countries.

would occur create enough land for future agricultural expansion given technological (crop growth improvement) assumptions.

This is obviously sensitive to actual demand, productivity gains, trade and other factors, but illustrates the magnitude of future pressures.

To better understand these different futures, two extreme scenarios in the agriculture sector outline the possible agricultural development pathways for this century: "no productivity increases" and "no expansion of cultivated land" (Grieg-Gran 2010). A middle path of intensification and expansion is probable, but these scenarios reveal the scale of the agricultural improvements required and consequences of not achieving them. The FAO predicts food production (in value terms) will need to increase 70% by 2050 to meet demand, translating into a 49% rise in the volume of cereals (extra billion tons) and 85% rise in meat production (200 million extra tons) (Bruinsma 2009). This will unfold against a backdrop of increasing demands on the sector, limited resources and climate impacts.

In a "no expansion" scenario, cereal yield growth will need to rise 1.07% annually in developing countries to prevent large-scale expansion onto new lands, particularly forests. Even though historic growth rate between 1961 and 2007 have been 2.2%/yr (Grieg-Gran 2010), this is slowing and rates of 0.5% or even 0% considering land degradation and climate impacts appear probable. In a scenario of "no productivity improvements," the FAO data suggests cereal production will convert 600 million additional hectares by 2050, equivalent to a historical deforestation rate of 13 million hectare annually (Grieg-Gran 2010).

Our model shows it remains cost-effective to clear forest to meet food demand through 2050, and perhaps beyond. Assuming neither crop improvements nor a REDD+ mechanism, agricultural demand for land leads to the clearance of 12 million ha/yr of forest by 2050 – almost equal to the worst annual global losses of tropical forest between 1990-2010 – in a pessimistic scenario. The two corollaries to this given the modeling assumptions are:

- Ending deforestation must ultimately be a political decision to extend incentives for forest conservation. Economic demand from the agricultural sector will rise and forest encroachment remains cost effective in the absence of compensation for conserving forest carbon stocks.
- Improvements to the effectiveness and productivity of crop species and livestock management regimes, as well as their adaptive capacity, can profoundly affect future demand for additional agricultural land.

Opportunities for abatement in the agricultural sector – and terrestrial carbon more broadly -- are still promising (See Table 4 above). Globally, the total terrestrial GHG balance, driven by the agricultural sector, could become almost net-zero by 2050 with aggressive end-of-pipe mitigation measures such as bio-energy/biofuels combined with REDD+ and on-farm measures for cropland and pastureland management resulting in 96% reduction from the terrestrial GHG baseline. The emissions path for aggressive agricultural mitigation, while providing sufficient food and commodities, is explained in more detail below. Figure 12 to Figure 15 below show the potential for emission reductions from specific agricultural measures, and their geographical distribution.

Figure 12: GHG emissions by region in the GLOBIUM model (baseline; 2020 (left) and 2050 (right)

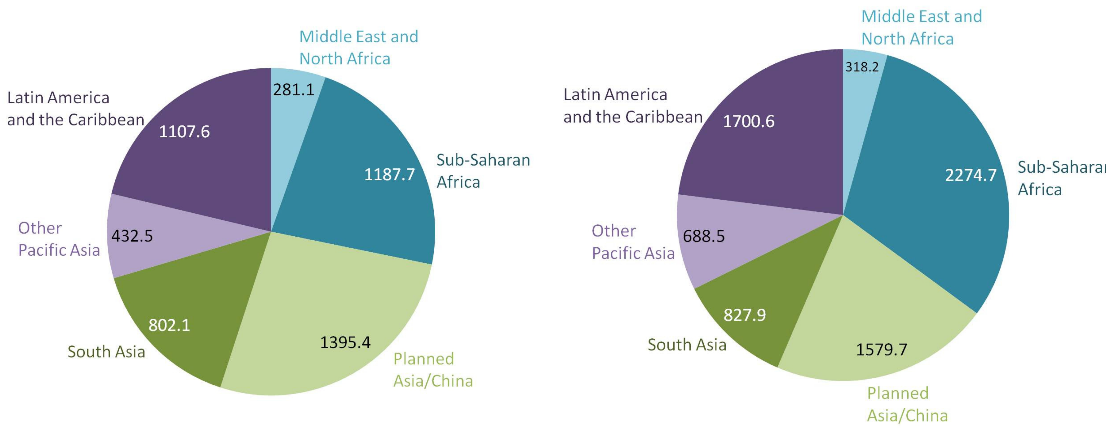


Figure 13: Emission reduction potential by GHG category and region (2020; baseline scenario; $MtCO_2e$)

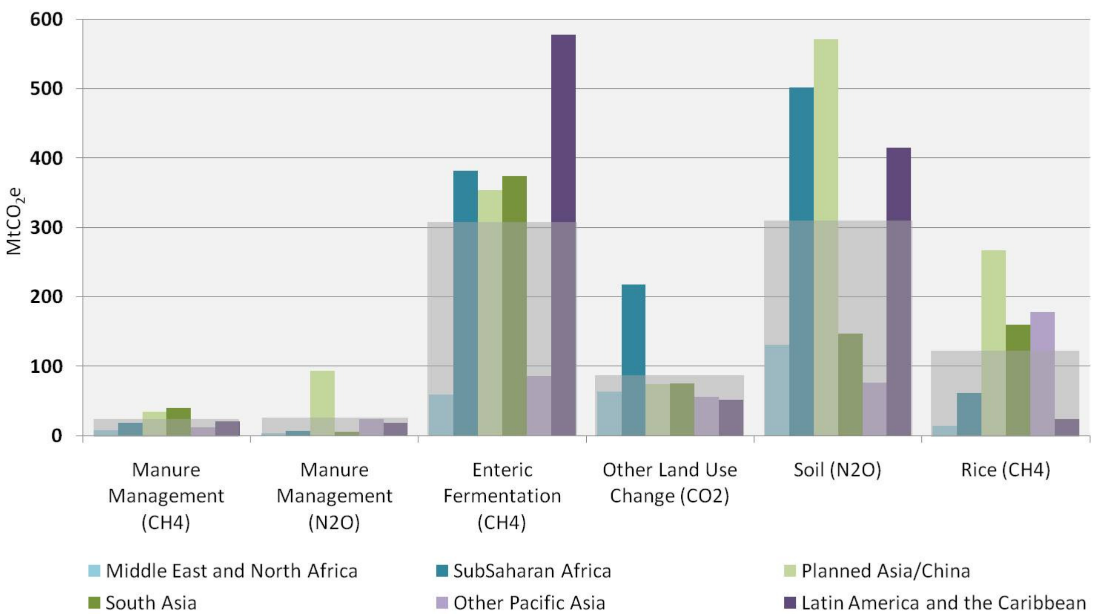


Table 5: Top three GHG abatement potential by GHG category and region (2020 baseline; $MtCO_2e$)

Type of emission	Highest emitter	Second highest emitter	Third highest emitter
Manure management (CH_4)	South Asia	Planned Asia/China	Latin America (L.A.) and the Caribbean
Manure management (N_2O)	Planned Asia/China	Other Pacific Asia	L.A. & Caribbean
Enteric Fermentation (CH_4)	Latin America and the Caribbean	South Asia	Planned Asia/China
Other land use change (CO_2)	Sub-Saharan Africa	South Asia	Planned Asia/China
Soil (N_2O)	Planned Asia/China	Sub-Saharan Africa	L.A. and the Caribbean
Rice (CH_4)	Planned Asia/China	Other Pacific Asia	South Asia

Figure 14: GHG emissions by region in GLOBIUM model (REDD+ scenario, 2020 (left) and 2050 (right)

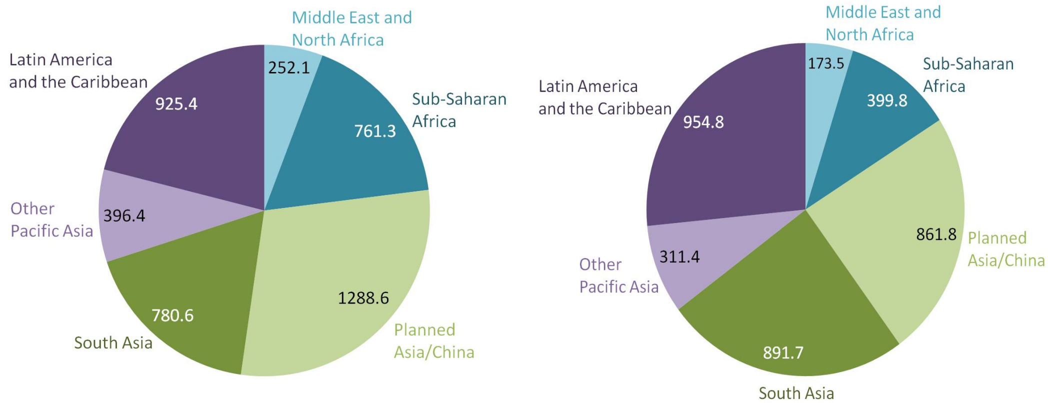


Figure 15: Emission reduction potential by GHG category and region (2020; REDD+ scenario; MtCO2e)

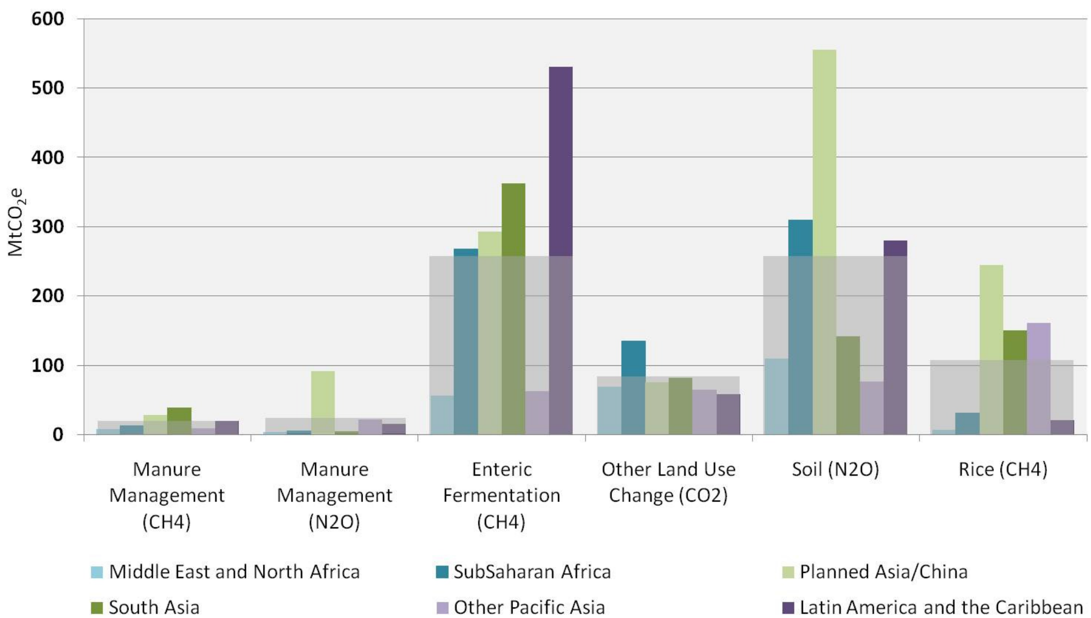


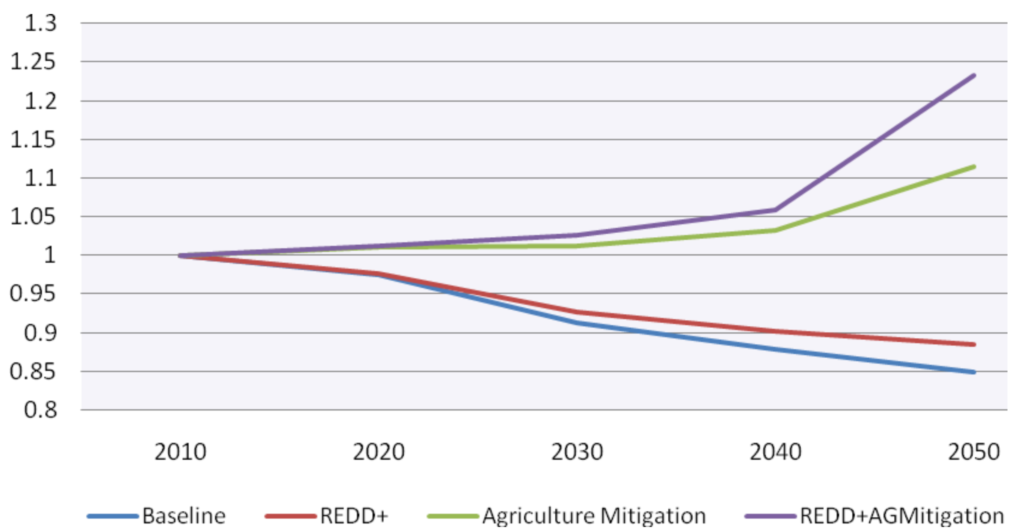
Table 6: GHG abatement country potential (Top three) by practice/region in 2020; REDD+ scenario (MtCO2e)

Type of emission	Highest emitter	Second highest emitter	Third highest emitter
Manure management (CH_4)	South Asia	Planned Asia/China	L. America & Caribbean
Manure management (N_2O)	Planned Asia/China	Other Pacific Asia	L. America & Caribbean
Enteric Fermentation (CH_4)	L. America & Caribbean	Sub-Saharan Africa	South Asia
Other land use change (CO_2)	Sub-Saharan Africa	South Asia	Planned Asia/China
Soil (N_2O)	Planned Asia/China	Sub-Saharan Africa	L. America and the Caribbean
Rice (CH_4)	Planned Asia/China	Other Pacific Asia	South Asia

Emission abatement comes at a cost. Assuming the cost of agricultural mitigation – or, that is, a price on carbon – is passed on to consumers, real crop prices are predicted to rise as much as 25% above 2010 levels in the modeling scenario. This is most pronounced in future years as resource constraints arise. If GHG abatement is compensated by an external carbon market (or other financial incentives), as is REDD+ in this model, the cost would be externalized leaving agricultural commodity prices relatively stable in respect to mitigation measures. This implies payments for agricultural emission reductions, market-based or otherwise, could alleviate price increases.[16] Angelsen (2010) suggested that there may be an unpleasant choice between REDD+ and feeding the hungry, but data shows that during the last two decades agricultural productivity increased by 3.3-3.4% annually, while annual gross deforestation increased agricultural land area by just 0.3%, confirming our modeling result that REDD+ and food security can be achieved simultaneously *if* substantial improvements in "crop growth" – or the technological increase of production – can be sustained.

It is also worth noting that these price estimates likely underestimate actual increases given the optimistic baseline (0.5% crop improvement and livestock measures) and assumption of full efficiency. A 0% crop growth scenario implies price increases of 10% independent of any mitigation measures, and investments costs of irrigation, fertilizer, and intensification could add to the price even more.

Figure 16: Crop Price Index under the 0.5% crop improvement and livestock improvement scenario[17]



Finally, trade is critical to increasing the efficiency of the global agricultural sector, managing prices increase and ensuring food security leads to GHG abatement. Agriculture is using less land by shifting and concentrating production in more favourable areas. The logical consequence is an increase in trade. However, land-use policies can only concentrate production if economic development is triggering urban migration and reducing land-use pressure from the most marginal agricultural production places. Under an aggressive mitigation scenario, wheat trade volumes rise 60% above the no-mitigation baseline of 13% of global wheat harvest. Today, the FAO (2010) estimates 20% of wheat production is traded/exported, and most other agricultural commodities are less heavily traded. The obvious limitations to achieving these levels of trade volumes suggest major constraints on achieving efficient global CSA.

[16] It is worth noting that price gains in baseline crop growth scenarios relative to 0.5% in crop productivity result in real prices 15-17% below 2000 levels compared to of 15% for no improvement.

[17] The drop in crop prices under a REDD+ scenario are to a large degree the results of "leakage" or agricultural expansion into grasslands and other natural land with low carbon stocks.

Agricultural model comparison

The GLOBIOM model used for this analysis is the only total land use model with a detailed geospatial representation of agricultural production options and detailed agronomic measures to boost production and abate GHGs ("bottom-up" approach). It is multi-scale (sub-national, national, global) model that simulates aggregate world demand, supply, and prices for commodities and land with biophysical and economic constraints. The model parameters include engineering costing of measures; total land use representation (agriculture, forestry, bioenergy, natural conservation); international trade and commercial barriers; and other environmental services (biodiversity, water, nutrient cycling, etc).

We have briefly reviewed the differences with existing agricultural modeling efforts. We found most models focus on deforestation but consider agriculture only as a driver of deforestation rather than as direct source of GHG emissions. A list of major regional and global models that incorporate agriculture is summarized from the Terrestrial Carbon Group (2009) below.[18]

- *Global Timber Model (GTM):* simulates global competition between forestry and agricultural land; non-spatially explicit. Considers avoided deforestation, afforestation and biofuels. Difficult to scale results to national or sub-national levels.
- *Land Use Carbon Sequestration model (LUCS model)* : Rural land-use change as function of population demographics and land use/land management data, non-spatially explicit model. national scale.
- *SimAmazonia 1:* Regional deforestation rates determined by opportunity costs versus agriculture and timber rents, existing and proposed protected areas, and current and future roads; Incorporates two models at sub-national scale. Future deforestation based on transportation and utility infrastructure, protected areas, and biophysical features.
- *Terrestrial Carbon Group "Three Filters":* Predictive deforestation model of 76 developing countries with REDD incentives. Spatially-explicit carbon stock model excludes areas with legal protection biophysical unsuitability, and / or economic infeasibility; national and partially global scale (Terrestrial Carbon Group, 2008);
- *GTAP model and derivatives (LEITAP, MIRAGE):* Land use simulation (general equilibrium approach) does not deal directly with emissions. Provided iLUC assessments for California.[19]

There are a limited number of explicitly linked climate and agriculture models. The most prominent scenarios have been conducted by Stanford University's Multi-Gas Mitigation and Climate Change project (EMF 21) with agricultural mitigation estimates derived from marginal abatement cost curves.[20] The IMAGE group has produced agricultural GHG emissions estimates with LEITAP scenarios predicting baselines and model diet changes (Stehfest and Kabat 2009). Finally, the Potsdam Institute for Climate Impact Research is working on sectoral emissions is the MagPIE model (Popp *et al.* 2010).

---

[18] The full list of forest cover/ REDD+ models are available from TCG (2009):
http://www.theredddesk.org/sites/default/files/resources/pdf/2010/TCG_Policy_Brief_2_Tools_for_Setting_Reference_Emission_Levels_Jun_09.pdf

[19] https://www.gtap.agecon.purdue.edu/models/landuse.asp

[20] http://emf.stanford.edu/research/emf21/

5. CSA systems and measures

A number of effective and well-established climate-smart agricultural practices are suitable for fast start mitigation actions (FAO 2010) from intensified smallholder production of cash crops such as cocoa or coffee to sustainable grazing practices on pasturelands. These apply key techniques including minimal tillage, increased or reduced but more efficient application of nitrogen fertilizers, erosion prevention, woody perennial intercropping, rotational grazing, and manure management, improved quality of feed and livestock conversion efficiencies, and conservation of natural ecosystems. Research and expertise from a number of pilot initiatives including the 40 projects covering 12.75 million ha reviewed in the framework of the Foresight Global Food and Farming project (Pretty *et al*. 2011) provide useful if preliminary guidance to establish scaleable initiatives.

In this section, we briefly review promising agricultural systems amenable to of CSA practices with strong synergies for smallholders, as well as the barriers to implementing them. We review four primary agricultural opportunities -- promising candidates for short to medium-term actions – that frame our recommendations for CSA initiatives in Section 7. These are:

- Cropland management (sustainable land management and nutrient applications)
- Pasture and grazing land management
- Livestock management
- Land-use, land use change, REDD+

We selected these systems or opportunities (integrated agro-eco regions, farming practices and/or technologies) by reviewing: i) abatement potential from GLOBIUM model; ii) published analyses and the scientific literature iii) stakeholder reviews and iv) consulting our field expertise with feasible systems for CSA interventions with smallholder benefits in the developing world (where there are 500 million small farms with less than 2 ha; Wiggins *et al*. 2010). When prioritizing the opportunities, we excluded four agricultural measures (from the GLOBIOM model) because they are standalone activities and/or require a much broader policy discussion: 1) geographic shifts 2) behavioral change/demand shifts; 3) bioenergy; and 4) some categories of processing, post-harvesting and emission reduction activities

5.1. Cropland management

Cropland management describes the location-appropriate farming techniques to maintain/increase yields over the long term and sustain soil fertility, water, biodiversity and other resources. The key dynamic in this system is the return of residue biomass and nutrients to the soil that increases soil fertility leading to larger more reliable yields and increased soil carbon. The GLOBIOM model shows increasing soil fertility enables sustainable intensification to achieve food security without the need for proportional cropland expansion. Combined with effective land-use planning policies, this significantly reduces emissions and deforestation and forest degradation from a business-as-usual scenario.

Practices and measures

Technologies to increase soil carbon sequestration are readily available and among the most promising fast-start mitigation actions in the agricultural sector. Soil carbon sequestration measures in general require a two-pronged approach: i) increasing biomass production and decomposition in the soils and ii) prevent soil carbon losses (e.g. composting systems and erosion control). The costs (marginal abatement curve) are expected to be low or negative as yields increase, but capacity building and front loaded investment costs are financial implementation barriers. The most promising practices to reduce GHG emissions through intensification or input-based cropland management[21] are:

[21] as efficient organic or synthetic fertilizer use, soil and water conservation or irrigation, and extending crop rotations including cover and mulch crops and agroforestry

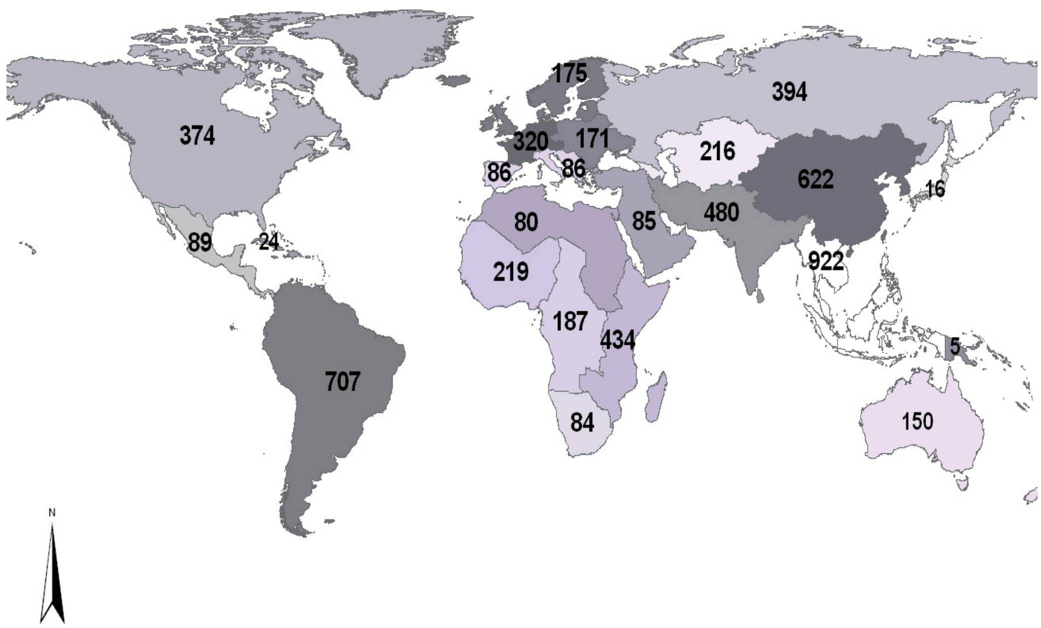
- Reduced or zero tillage
- Improved fertilizer management to intensify food production and increase soil carbon sequestration.
- Residue management
- Mid-season wet rice drainage and crop breeding efforts to maximize risk adjusted yields and resistance to pests and diseases.
- Pest treatment[22] (prevent crop losses and related reductions in soil carbon sequestration rates).
- Effective extension and access to finance to invest in inputs and labour to adopt CSA activities.
- Biochar: potential for long-term carbon soil carbon storage and soil improvement benefits (nutrients, water retention, etc.), although research ongoing.

More generally, maintaining crop productivity increase also depends on investments in research, in particular in plant breeding and in the sustainable intensification of agriculture. Investment in irrigation and geographic shift of production intensity, without triggering land-use changes will also contribute to reach the productivity enhancement target as outlined in the GLOBIOM model.

Potential

Demand pressures and declining soil fertility means improved cropland management will need become a critical feature of agriculture in the future. Technical mitigation potential for agriculture (see Figure 17 below) is concentrated in developing regions of Asia, Latin America and Eastern Africa, primarily related to soil carbon sequestration. Economic mitigation for croplands is estimated to be about 563 million tCO_2e/yr (non-Annex I countries at a carbon price of USD20 using the B1 SRES climate scenario; Smith *et al.* 2007).

Figure 17: Technical mitigation potential in $MtCO_2e$/yr by 2030, by region (Smith et al, 2007)



Investments in soil carbon sequestration and other agricultural intensification activities could have a strong impact on poverty reduction, and help ignite a more sustainable "green revolution" and broader economic transformation eluding regions such as Sub-Saharan Africa where agricultural productivity has been stagnating for decades (Diao *et al.* 2010). It is almost certain that such investments will be necessary if we

[22] Production and use of fertilizer and pesticide are also sources of GHG emissions although these can be more than compensated by deploying them under the right circumstances.

are to maintain or even approach the gains of the past. Since 1961, global cropland area grew 27% while yields rocketed by 135% (Burney *et al.* 2010). Growth will be significantly slower than during the previous four decades (1961-2010). Estimates by Bruinsma (2009) show production area increases of 9% through 2050 while crop intensity and yield growth drops to 16% and 75% respectively.

Case studies

China: A typical Chinese farmer uses nearly twice as much fertilizer per area compared to his or her counterpart in Britain, and 130 times more fertilizer than a farmer in Uganda. Each year, China emits 0.4-0.84 $GtCO_2e$ through the use of 27 Mt of nitrogen fertilizer, equivalent to 8-16% of China's energy-related emissions. Cutting fertilizer use 20% through improved application and production efficiency could reduce emissions by 0.29 GtCO2e/year (Kahrl *et al.* 2010). This results in negative abatement costs of EUR41/tCO_2e, according to McKinsey (2009). This was confirmed by Kahrl *et al.* (2010) who also estimated the costs of a nationwide fertilizer efficiency programme in the range of USD10/tCO_2e.

Tanzania: Green manure and agroforestry can achieve the dual objective of meeting local caloric requirements and modest reforestation of multipurpose trees in areas with low population-density (Palm *et al.* 2010). In high population density areas, only mineral fertilizer enables sufficient yield increase to meet the same objectives. While mineral fertilizer can be crucial to kick-start biomass production, organic amendments are important to maintain soil health and high crop production in the long-term (Giller *et al.* 2010). The labour demand related to green manure and agroforestry practices are often underestimated.

5.2. Pasture and grazing land management

Pasture and grazing lands store 30% of the world's soil carbon (Tennigkeit & Wilkes 2008). Their improved management includes practices that increase carbon uptake, climate resilience and productivity while reducing emissions related to soil degradation and livestock. Rangeland degradation has been the result of the breakdown of traditional resource management regimes and cessation of beneficial rangeland management practices driven by inappropriate rangeland management and development policies (IPCC 2000). In grassland ecosystems, with limited above ground biomass, as much as 98% of carbon is stored below-ground (Hungate *et al.* 1997). Restoring grasslands to healthy state can lead to long-term livelihood benefits for small pastoralists and higher incomes from increased and sustained livestock production over longer periods assuming the appropriate market infrastructure is in place.

Practices/measures

The primary mitigation mechanism on grasslands restores soil carbon stocks to their maximum equilibrium level. Better grazing management and seeding fodder grasses and legumes are usually implemented together with improved livestock feeding, marketing and value adding activities and veterinary services. Medium-intensity grazing, generally, can maintain the highest soil carbon stocks as well as plant biodiversity. Restoration of degraded grasslands may also require temporary de-stocking (which presents a major implementation barrier). However markets must reward herders for fewer but more productive livestock or higher quality livestock products. We summarize the management practices to sequester more soil carbon below.

Table 7: Pasture management practices with potential to sequester carbon or decrease emissions (Tennigkeit & Wilkes 2009)

Increasing C inputs	Decreasing C losses
1. Increasing biomass carbon inputs to soil by improved grazing management, e.g. – Improving (reducing or increasing) stocking rates – Rotational, planned or adaptive grazing – Enclosing grassland from livestock grazing.	*3. Improved management of land use conversion*, e.g. – Converting agricultural land use to permanent grassland – Avoiding conversion of grassland to cultivation – Avoiding conversion of forest to pasture

2. Increasing biomass, by – Seeding fodder grasses or legumes – Improving vegetation community structure Fertilization.	*4. Fire management and control*
	5. Alternative energy technologies to replace use of shrubs / dung as fuel.

Potential
The economic mitigation potential for soil carbon on pasturelands is estimated to be 619 million tCO_2e/yr considering comparable model assumption for cropland (Smith *et al*. 2007). This mitigation potential does not include the potential to restore degraded land which is estimated at 110 million tCO_2e/yr.

The benefits for smallholders are also large. Globally, more than 120 million pastoralists manage 3.5 billion hectares of land, according to FAOSTAT data. This is equivalent to 26% of the global land area or 69% of the global agricultural land. Significant areas of land are also devoted for livestock feed production - about 470 million hectares or 33% of cropland. This will need to increase, along with intensification, as meat and milk consumption rises. Ideally, degraded and underutilized land would be used to produce the additional feed (cereals such as maize, barley and wheat or soybeans), since land use changes from grassland to cropland will result in soil carbon losses (Guo and Gifford 2002).

Case studies
Qinghai province, China: The 3 Rivers Project, situated in the Qinghai province of north China is using carbon financing to facilitate grassland restoration and increase livestock productivity. Carbon finance is used to compensate costs and foregone income during the transition period and to increase productivity. Under the proposed pilot, herders will be offered a menu of options designed to fit their specific land use, which includes a combination of grassland restoration zoning and stocking rate management, in an incentive-based system. Given the current overstocking rates (about 45%), 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 possible other small business support measures), compensation will decrease progressively until year ten. Overall, after the first ten years of the project, households will have fewer but more productive livestock. The pilot project is supported by FAO and a number of research and implementation agencies in Qinghai province.

5.3. Livestock management

Improved feeding practices, reducing livestock disease burden and mortality, specific agents and dietary additives and animal breeding can increase production efficiency and reduce emissions. Efficiency accounting using emission per standardized product unit is considered the most suitable approach, first to identify the emission reduction potential based on live-cycle analysis, and secondly to account for emission reductions. This approach also ensures that emission reductions do not undermine food security. However, this only increases production efficiency without necessarily contributing to overall emission reductions (Murray and Baker 2011).

Practices & measures
Intensification of livestock management is the major mitigation pathway for this sub-sector.[23] Improving the quality of feed, animal health and more efficient breeds are the three primary intensification options. Regional emissions per kg of fat and protein corrected milk unit vary from 1.3-7.5 $kgCO_2e$ (FAO 2010). The former are representative for advanced milk production systems in New Zealand, while the latter represent conditions in Sub-Saharan Africa. As such, livestock intensification options vary depending on the baseline

[23] At the same time, sustained shifts away from diets on meat and milk, and protein sources with a high carbon footprint (e.g. beef compared to chicken) will also be necessary although this is beyond the scope of this analysis.

scenario and farm size (FAO 2010e). Small-scale farmers can significantly reduce emissions if they have the know-how, incentives and the option to produce or feed nutritious feed as most emissions occur on the farm rather than in subsequent processing stages.[24] The obvious advantage from high intensity livestock production should not ignore the value of extensive systems related to biodiversity conservation and related ecosystem functions (Snapp *et al.* 2010).

Potential

The livestock sector contributes 7.1 $GtCO_2$ per year or 18% of global emissions (this includes land use and direct GHG emissions), according to FAO (2010).[25] As meat and milk demand is expected to rise up to 68% between 2000 and 2030, livestock is among the most urgent agricultural sub-sectors to target for reducing emissions (FAO 2010). Our GLOBIUM modeling results also confirm this potential as discussed in Section 4. The potential for livestock-specific measures under different baselines are below:

Table 8: GHG emissions from agricultural measures under different scenarios (2020; MtCO2e)

Activity	Baseline	REDD+	Agri Reduction	REDD+ & AgriRed	&End of pipe measures
Manure Management (CH4)	192.3	140.0	86.6	92.1	27.6
Manure Management (N20)	396.3	369.0	177.3	153.9	46.2
Enteric fermentation (CH4)	2,681.2	1,868.7	1,261.0	1,353.2	608.9

Case study

Danone Group: The Danone Group, one of the world's large dairy product companies, identified GHG emissions associated with its products and designed a program to improve the health, sustainability, and milk quality of these products while reducing the climate impacts. The first step was a life-cycle analysis of supply chain followed by identification of GHG emission sources and the development of a cheap and effective MRV system. A technology measuring the composition of milk proved to be a cost-effective proxy for measuring GHG emissions from enteric fermentation in the field (a primary GHG source). The firm launched a pilot program in 2005 involving 20 French farmers and is now scaling up the program to more than 500 farms. The results showed improved milk quality, reduced GHG (methane) and yield increases of 8-10%, as well as better cow health with comparable feed costs. Although undertaken in developed countries, this efficiency-oriented approach holds promise for similar initiatives in the developing world.

5.4. Land-use change and REDD+

Land use planning and improved agronomy can directly address the causes of agricultural inefficiencies, land degradation and deforestation – a major source of direct and indirect GHG emissions from the agricultural sector. As tropical forests are the primary source of new agricultural land, agriculture is the main driver of land-use changes related to deforestation and forest degradation. According to Gibbs *et al.* (2010) more than 80% of the new agricultural land came from intact and disturbed tropical forests between 1980 and 2000. Angelsen (2010) suggested that there may be an unpleasant choice between REDD+ and feeding the hungry, but data shows that during the last two decades agricultural productivity increased by 3.3-3.4% annually, while annual gross deforestation increased agricultural land area by just 0.3%, confirming our modeling result that REDD+ and food security can be achieved simultaneously *if* substantial improvements in "crop growth" – or the technological increase of production – can be sustained.

---

[24] e.g. 93% of all dairy-related emissions including land use

[25] This figure is not comparable with the IPCC classification, i.e. methane and nitrous oxide emissions of 2.7 GtCO2 and 2.2 GtCO2e respectively are included.

Practices & measures

The measures to address agricultural-related emissions from land use change and deforestation are:

- *Sustainable intensification:* Angelsen (2010) suggests spatially delinking agricultural intensification policies to allow expansion of agricultural in areas with the greatest productivity and lowest climate impacts. Intensification should be supported in the low forested lowlands while in the uplands and frontier forests policies should be adopted that do not increase deforestation pressure such as payments for environmental services including REDD. In practice this will delink also food production and food security priorities, the latter depending on food access, income and market distribution.
- *Investments in agricultural research and development:* We have suggested that the rate of crop improvement – 3.3-3.4% annually -- may not continue given worsening outlook for climatic conditions and available biological options. However, investments in agronomic research designed specifically for developing countries and changing climatic conditions will increase the chance this rate of improvement can be preserved.
- *Agricultural trade:* International food trade is still quite low, e.g. only about 12% of cereals produced are exported (FAO, 2010). Increasing food trade may increase market liquidity and reduce food price volatility. Food price volatility is a serious risk for the rural and urban poor relying on food markets.

Potential

The potential of direct and indirect emission reductions through the improved agricultural practices above and REDD+ measures is significant, but a function of several interdependent factors making precise estimates difficult to calculate. The GLOBIUM modeling results suggests robust REDD+ and agricultural measures could theoretically halve the emissions from indirect land use change (226 $MtCO_2e$), and soil and fertilizer emissions (1,164 $MtCO_2e$), while virtually eliminating deforestation (1.5 MtCO2e from 2,258 MtCO2e).

Table 9: GHG emissions from agricultural measures under different scenarios (2020; MtCO2e)

Activity	Baseline	REDD+	Agri Reduction	REDD+ & AgriRed	&End of pipe measures
Deforestation (CO2)	2,257.6	1.5	1,222.6	1.5	1.5
Other land use change (CO2)	470.3	657.9	188.2	226.0	158.2
Soil and fertilizer emissions (N2O)	2,813.2	2,648.8	1,261.3	1,164.1	465.7

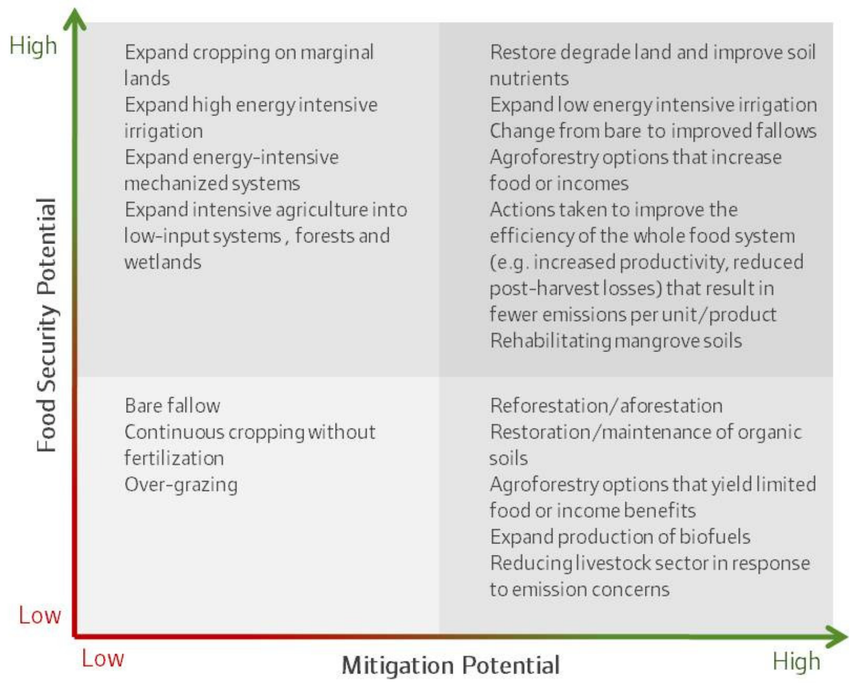
Case studies

Brasil: Cattle ranching in Brazil is associated with four-fifth of Amazonian deforestation, an area that has which suffered the largest global forest loss between 1996 and 2005 (Nepstad *et al.* 2009). In line with the National Policy for Climate Change" (NPCC) Brazil unilaterally announced in 2009 that it would reduce GHG emissions between 36-39% below "business-as-usual" (BAU) levels by 2020. Subsequently, the environmental agency (IBAMA) and the land institute (INCRA) at the federal and state level enforced land-use zoning plans together with the meat and soya industry leader and the financial sector excluded deforesters from market access and finance mechanisms. Improved fodder grass varieties, zero tillage and green manure technologies were also introduced to sustainably intensify production. Based on the combination of regulatory and market actions deforestation rates slowed down rapidly within the last 5 years. However, this process was aided by the economic downturn in the soya and cattle industry, and is only applicable in areas that have this level of extension and governance capacity (or where it could be created).

5.5. Risks and challenges

Most of the mitigation practices listed above are already field tested and applied in the framework of sustainable land management. The biggest risk of the proposed mitigation practices are that they have trade-offs related to food security. The figure below highlights which practices have strong synergies with food security and those that depending on the local context may have trade-offs with food security. No regret options in the upper right corner of the figure are related to land restoration, expanding low energy intensive irrigation adopting improved fallows, agroforestry systems increasing food production and all actions improving the production efficiency.

Figure 18: (Expanded from the Table: Examples of Potential Synergies and Trade-offs (FAO, 2009, Food Security and Agricultural Mitigation in Developing Countries: Options for Capturing Synergies)



Important is also to consider the time scale. For example improved fallows using green manure will increase yields and soil carbon but may reduce cropping intensity in the short term. Similarly restoration of degraded grasslands will increase the grassland carrying capacity in the long term but destocking might be necessary to rehabilitate grasslands. A number of mitigation practices require upfront investments or temporarily compensation payments to bridge the time gap until a higher productivity level is reached.

Measurement, Reporting and Verification

Approaches to measure mitigation impacts in agriculture already exist at international, national, programmatic and project levels. These approaches have been developed under the Convention, and as part of sub-national compliance or voluntary market-based mechanisms. However, agricultural monitoring and evaluation systems are generally weak according to a global survey (Lindstrom 2009), which means the capacity and data availability for MRV is limited and substantial investments are required.

In particular soil carbon sequestration suffers from a lack of long term data in most developing countries to calibrate models and derive default values that can predict sequestration rates depending on the agro-ecological zone and management activities. Direct soil carbon and N_2O measurements provide reliable information on soil carbon stock changes and N_2O fluxes but are not practical and cost effective for large scale mitigation projects because the spatial variability of soil carbon stocks and N_2O emissions is often high, and stock changes are relatively small compared to the soil carbon stocks. This low 'signal-to-noise' ratio requires time periods of 5-10 years to adequately detect the cumulative changes.

In general, the sustainable development benefits of adaptation and mitigation actions in agriculture far outweigh the uncertainties in measurement. Another MRV challenge is that IPCC guidelines use area-based accounting metrics focusing on measuring absolute GHG emissions per unit of land only. However, efficiency accounting approaches measuring the emission intensity per unit of output may be more suited to reflect emissions while allowing for growth in food production.

Under the convention there is no platform to agree on MRV issues related to agriculture. Therefore, it remains vague what kind of MRV systems are required (e.g. for the agricultural NAMAs submitted under the Copenhagen Accord). Implications of LULUCF accounting rules for NAMAs, considering the general aim of consistent accounting standards consistent with diverse capabilities among developing countries and the level of support received, remain unclear.

5.6. Stakeholder Analysis

The stakeholder consultations solicited views from civil society, government agencies, research institutions, and farming association representatives regarding appropriate financing mechanisms and agricultural practices to secure climate and smallholder benefits. A diverse range of views was expressed; however the central points are summarized below and reflected in appropriate sections of the report. Interviews with key stakeholders were held at the Global Conference on Agriculture, Food Security and Climate Change in The Hague, Netherlands (10/31-11/5); the United Nations climate change conference (CP16 / CMP 6) in Cancun (11/29-12/10), and through direct communication with relevant organizations and individuals throughout the year. Please see Annex 8.1 for a list of interviewees.

Strategy to encourage CSA
There was a clear preference for workable, practical systems to pilot and scale agricultural mitigation and adaptation projects. The support mechanisms for CSA, several interviewees stated, should emphasize action over readiness, and act as a pathway to scaling up activities rather than waiting for an elaborate readiness process. They noted many agricultural reforms and/or intensification trends were imminent or underway, and waiting much longer would preclude CSA-finance from having a larger impact when it was badly needed.

Some representatives stressed the need for systematic change in the sector by leveraging policies and economic incentives, if not a formal readiness process. Gerald Nelson of International Food Policy Research Institute stated: "The problem is that the project focus is a relatively short time frame and does not set up the enabling environment: human capacity, development, physical infrastructure to support human capital on the research and outreach side, but also policies…[sometimes] we don't need new agronomists but to build more roads." The transactions costs involved with changing individual behaviour, and distributing financing through centralized systems would be high and likely impractical.

Role of agriculture in post-2012 climate agreement
Several developing country representatives (government and civil society) displayed resistance to two main points that will complicate integrating market-based climate mechanisms in the agricultural sector: i) opposition to agriculture as a mitigation measure as it is currently stipulated in the AWG-LCA text, instead of an adaptation-driven element of the climate regime; ii) creation of fungible market-based offsets in an international system of crediting emission reductions for agriculture. This opposition was not universal – some African countries are considering ways to support agricultural mitigation through markets– but there appears to be a general aversion to international carbon-market based approaches to agricultural mitigation, apart from the US and to some degree Australia, and a dearth of UNFCCC advocates among developing countries that could push this agenda forward as the Coalition of Rainforest Nations did for

international forestry and reduced emissions from deforestation and forest degradation (REDD+). This raises the possibility

Resistance to agricultural carbon markets focused on the expense, complexity and uncertainty of establishing new market infrastructure, and the fears that this would expose countries and farmers to excessive delays, lack of liquidity, transaction costs and downside risks. A second fear was that offsets would disturb policy goals designed to push the agricultural sector toward more efficient CSA practices. Country representatives thought policies could and should play this role, but an offset market risked optimizing for short-term carbon credits rather than systematic, long-term sustainability strategies.

This does not preclude private sector engagement. A role for the private sector in designing, financing, and/or implementing CSA was not opposed – rather, it was the carbon-market means to do so that raised opposition. Exceptions were noted in situations where incentive payments (either market or non-market based) are made for domestic agricultural offsets in relatively straightforward agricultural applications such as fertilizer reduction or efficiency. These cases generally represented domestic policy for developed or major emerging market economies.

Role of government in carbon and agricultural markets
Assuming a carbon-market structure was in place, opinions diverged about whether CSA incentives should be mediated by government or open to direct demand from international markets. The most common recommendation was that climate finance should pursue a dual strategy to strengthen government agricultural extension programs, including complimentary private and NGO-supported extension, while opening market-access at the national level and preserve the option to directly incentivize farmers for improved practices.

Respondents suggested favouring one option or the other would fail if markets, infrastructure and training were underdeveloped – as they are in many countries. Stronger roles for governments – national, regional and/or local, or even a collaboration of these -- were emphasized in places where the quality of infrastructure, commercial sophistication, agricultural productivity and enabling conditions was low. The specific points raised by interviewees regarding this issue were:

- The feasibility of carbon market project mechanisms such as the Clean Development Mechanism (CDM), voluntary markets and others depend on the legal and regulatory context at the national level and thus a universal recommendation was not possible.
- Direct links between carbon-markets and farmers already exist in some countries but in agriculture should be managed by governments to ensure that activities do not threaten food security or unfairly exploit smallholders.

Food Security
The overriding priority of food security was a common refrain: "Mitigation cannot threaten food production," "Focus on productivity, not emission reductions [in negotiations with developing countries]," "Any climate mitigation measures that do not ensure food security will be a non-starter." However, food security is not merely a function of agricultural productivity. It is also a matter of access to food, food utilization, political stability and other important food security components. Respondents were clear that hunger – like other social problems – could not be simplified into single cause or solution. There was agreement food security must be a central aim for climate strategies in the agricultural sector to work. No single means to achieve this were offered, however the range of issues raised were:

- Measures to increase productivity must ensure that demand – either through domestic markets or links to wider international buyers – increases proportionally
- Negotiations with developing countries under the UNFCCC or through bilateral discussions need to recognize this; activities should prioritize smallholders and increasing rural income
- No mitigation measure should be permitted that dislocates or interferes with regional food supply without compensatory systems

Climate finance governance

The question of administering financial mechanisms (and initiatives) for CSA revealed strong views on two key domestic and international issues: country-appropriate administration of funds, and coordination of international financing both among funders and within countries. These were seen as important to ensure countries disbursed CSA-financing effectively, and reduce administrative and reporting burdens on developing countries. The essential points are summarized below:

Domestic CSA financial governance:

- Either a purely local or purely national strategy for CSA financing was seen as flawed. Interviewees suggested a system of internal checks and balances through decentralized selection of activities and implementation by communities/local jurisdictions with oversight and accountability by national governments.
- In some cases, where local governance was inadequate, there was some potential seen for federal government expansion of agricultural extension services and other mechanisms that directly support farmers however the perceived risk was higher.

International financing arrangements:

- Financing should be coordinated at the international level to complement developing country-led objectives– mitigation, food security, and poverty – through harmonized and transparent funding strategies.
- Financing mechanisms processes to apply, receive, and report on climate funds should be integrated into the larger climate financing frameworks for developing countries under the UNFCC or bilateral initiatives.

Barriers

- Strong legal and regulatory frameworks will be a limiting factor to implement agricultural mitigation measures through climate finance.
- Developing countries lack – and could benefit from – a coherent, organized and forceful advocacy coalition to include agriculture in a future climate finance mechanisms or agreement similar to the Coalition of Rainforest Nations and other G77 support that propelled REDD+ onto the international agenda.
- Developing and developed country views on the inclusion of agriculture in a future climate agreement diverge. The US is increasingly in favour of both mitigation and adaptation, whereas many developing countries insist on adaptation but are wary of mitigation.
- UNFCCC negotiations will struggle with the issue of trade and it may emerge that trade is not discussed in the context of sectoral approaches. Language in draft agricultural text from the AWG-LCA stated that measures should not constitute "arbitrary or unjustifiable discrimination of a disguised restriction on international trade" proved too contentious.
- International understanding of measurement, reporting and verification (MRV) concepts and practical design is relatively limited and negotiators will be hard-pressed to design workable systems given this limited knowledge base. It is likely that only high-level principles can be established politically, but it is important that the technical limitations and applications are communicated effectively.
- Knowledge remains a key barrier to implementing agricultural projects and policies. "There is no consensus on what is known or what we need to know," stated one respondent.

6. Climate finance & agriculture

Private and public investments in the agricultural sector are crucial to meet GHG emission targets identified by the IPCC, execute REDD+ strategies,[26] and secure adaptation for tropical and arid regions in developing countries. Current financing for climate change mitigation and adaptation in the agricultural sector is still modest. In private markets, between 6% of GHG offsets in the USD136 billion carbon market are sourced from the agricultural sector (2008-2009)[27], with only a small proportion accounting for soil carbon and benefitting smallholders. From public sources, financial flows are at least an order of magnitude less than expected future needs for mitigation and adaptation in developing countries. As of 2010, climate finance from the UNFCCC, multilateral and bilateral sources including the CDM, GEF Trust Fund, Adaptation Fund, World Bank Climate Investment Funders and others amounted to USD8 billion annually across all sectors. This is currently inadequate to meet mitigation and adaptation needs in developing countries, considering the necessary agricultural adaptation investments are already estimated to require USD 7 billion annually (Nelson *et al.* 2010b).[28,] There will also be strong competition for funds from other sector given that the expected annual costs for mitigation (USD80-140 billion) and adaptation (USD9– 68 billion) far exceed public sector funds, according to estimates in

Table **10** below.

Table 10: Annual mitigation and adaptation costs in developing nations (USD billion; *Parker et al 2009*)

Mitigation		Adaptation		*Sources*
2010-'20	2030	2010-'20	2030	
--	92 – 97	--	27- 66	*UNFCCC*
80 -120	--	30-68	--	*McKinsey and Co.*
140		9-41	--	*EU*

Agriculture finance, in general, however is expected to mobilize extremely large sums of private and public capital. The FAO estimates developing countries' annual investment needs for agriculture are about US$83 billion between 2005/6 through 2050.[29] Cumulatively, this represents USD9.2 trillion by mid-century to meet long-term outlook for global agricultural demand (Schmidhuber 2009). The investments can be broken down as follows (Schmidhuber 2009):

- USD3.6 trillion (40%) would be used to increase (nearly double) output and raise productivity.
- USD5.5 trillion (60%) to replace existing capital stock or added and depreciated , while

Primary agriculture accounts for US$5.2 trillion of the total, while the remaining US$4.0 trillion is used in downstream activities (processing, transportation, storage, etc.). Mechanization is the single largest investment within primary agriculture (25%) followed by expansion and improvement of irrigation (~20%).

For climate finance, funding needs could be met in large part through developed country commitments under the Cancun Agreements to "mobilize jointly USD100 billion per year by 2020 to address the needs of

---

[26] 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

[27] This may range as high as ~20% if including off-farm or bioenergy as well

[28] As of 2010, climate finance from the UNFCCC, multilateral and bilateral sources including the CDM, GEF Trust Fund, Adaptation Fund, World Bank Climate Investment Funders and others amounted to USD8 billion annually. HAGCCF (High-Level Advisory Group on Climate Change Financing), 2010, "Report of the Secretary-General's High-Level Advisory Group on Climate Change Financing." 5 November 2009.

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

developing countries" (UNFCCC 2010a). The UN High-Level Advisory Group on Climate Change Financing (HAGCCF 2010) calls such number *"challenging but feasible" and* recommends a systematic approach to mobilize public and private resources, bilateral and multilateral funds (in accord with the Bali Action Plan)[30] and new funding mechanisms. The Advisory Group identifies these sources as:[31]

- new public instruments such as emission allowance auctions and carbon taxes that could generate USD30 billion annually with another USD20 billion from carbon pricing in the international transport sector, redirected fossil fuel subsidies and other measures (given USD20-25 tCO_2e);
- multilateral banks that have the potential to multiply investments emission reductions with USD11 billion in net flows;
- private investment flows that may generate another USD200 billion in gross capital flows with USD10 billion in net transfers. Project Catalyst (2009) has estimated carbon markets could finance USD 15-45 billion in developing country abatement annually.

The scale of agricultural investments envisioned in this report exceeds what either public or private finance alone is likely to deliver in agriculture. Therefore, financial mechanisms, donor funding and public policies need to be strategically deployed through instruments that leverage much larger percentages of private capital over the short to medium term. These should aim to exploit opportunities that create suitable enabling conditions for investments into adaptation and mitigation, as well as leverage finance by using public climate finance to cover risk premiums, provide risk guarantees or capitalize and scale crop and input insurance schemes, with aggressive financing approaches. See the case studies in Box 2 for examples.

Box 2: Case studies: Risk sharing and insurance mechanisms

"Safe Farming:" Kilimo Salama input insurance

Kilimo Salama, meaning "safe farming" in the Kiswahili language, is a crop insurance policy set up by UAP Insurance of Kenya, Safaricom and the Syngenta Foundation. Farmers pay an extra 5% to insure a bag of seed, fertiliser or herbicide against crop failure. MEA Fertilisers and Syngenta East Africa, two agribusinesses hoping to benefit from higher sales of their products, match the farmers' investment to meet the full 10% cost of the insurance premium. Local agents register an insurance policy with UAP by using a camera-phone to scan a bar code on each bag sold. A text message confirming the policy is then sent to the farmer's handset. Farmers are registered at their nearest weather station, which transmits data over the mobile network. If weather conditions deteriorate, a panel of experts uses an index system to determine if crops will no longer be viable. At that point payouts are made directly to the handsets of farmers in the affected areas using Safaricom's M-PESA mobile-money service. With no field surveys, no paperwork and no middlemen, transaction costs are minimal. The scheme is designed to be self-financing. Clear terms should help Kilimo Salama overcome farmers' distrust of previous insurance schemes, says James Wambugu of UAP. So should word of mouth. The trial scheme was hit by one of the worst droughts in decades, triggering compensation payments of 80% of farmers' investments. The average amount of insured seed in the area has now risen from 2kg per farmer to 4kg

Source: Security for shillings (Insuring crops with a mobile phone)Economist 2010, 11 Mar 2010

HARITA model in Ethiopia

The Horn of Africa Risk Transfer for Adaptation (HARITA) is an innovative climate change resilience project launched by Oxfam America (OA), Swiss Re, the Relief Society of Togray (REST), International Resource Institute for Climate and Society (IRI), Nyala Insurance, among others. Between November 2007 and December 2009, a pilot climate risk management package was designed for poor farmers in the village of Adi Ha consisting of a mix of risk reduction, drought insurance, and credit. The approach consists of three main components:

a) *Risk Reduction/minimizing vulnerability*: farmers participating in the HARITA are learning how to use

[30] HAGCCF 2010; paragraph 1.e of the final report.

[31] These figures are acknowledged as highly sensitive to assumptions about carbon price and financial definitions

compost, which is critical for rebuilding soil nutrient and improving soil moisture retention. They are also building small-scale water harvesting structures and planting trees and grasses to promote soil and water conservation.

b) *Risk transfer/weather Index insurance*: HARITA proposes to introduce micro-insurance to strengthen Ethiopia's Productive Safety Net Program (PSNP) by addressing the non-chronic, "unpredictable" needs not covered under the program

c) *Prudent risk taking/credit*: Supporting poor producers in making optimal production decisions even in the face of uncertainty, for the purposes of livelihood diversification, technology adoption and entrance into more profitable lines of business.

HARITA is also innovative in the sense that it allows very vulnerable farmers to pay their premiums in the form of risk reducing labor as a result of which farmers benefit through these risk reduction measures even when there is no payout.

Sources: Oxfam America, Horn of Africa Risk Transfer for Adaptation (HARITA), Project Brief, Oxfam America, HARITA Project Report, November 2007 – December 2009

We have outlined the major climate finance instruments and arrangements for the agricultural sector in three steps below. The first defines traditional financial categories and contractual arrangements by which financing (climate or otherwise) moves in the agricultural sector. The second reviews financial tools available for market or performance-based climate financing, as well as complementary funding to enable such payments, in the agricultural sector. The third reviews existing climate financing sources and channels. In Section 7, we incorporate these in our recommendations.

6.1. National finance and policy instruments

Financial flows for agricultural investments depend, as in other sectors, on conventional financial instruments such as debt, equity and public expenditures. Most capital agricultural investments come from private sources (domestic and foreign), with public investments playing a role funding some investments directly or helping link, pool and promote private flows (Schmidhuber 2009). For the last three decades, the rate of agricultural investment has declined amid low and stable world food prices. The growth of agricultural capital stock fell from 1.1 percent in 1975–1990 to 0.50 percent in 1991–2007, along with developing countries' budgets and Official Development Assistance (ODA) for agriculture (Ghanem, 2009). Investment in agriculture is now rising rapidly after a series of price shocks and supply constraints.

Yet, as noted, FAO projections suggest developing countries' will need gross investments of about USD5.2 trillion in primary agriculture to meet long-term demand for agricultural products (Schmidhuber 2009).[32] It is not clear how these investments will be made, and an annual gap of USD22 billion relative to the annual average invested from 1997–2007 to meet the USD55 billion need each year is expected (Ghanem 2009). The possible investment channels for this financing are shown in Table 11, along with their relative advantages/disadvantages. This frames the discussion of specific delivery mechanisms in the next section.

[32] USD4.0 trillion is absorbed by downstream needs such as processing, transportation, storage, etc.

Table 11: Potential financial instruments to support climate smart agriculture in developing countries

Instruments	Modalities	Advantages	Disadvantages	Application	Available	Case Study
Debt	Senior and subordinate (mezzanine) loans	Offers low-cost financing source for projects; large/small/micro	Requires revenue stream; repayment risk; difficult to find local lenders	Projects	Limited availability for agriculture	1) Global Climate Partnership Fund http://gcpf.lu/; 2) Los Andes Private Nature Reserve, USD170,000 coffee harvest credit (Conservation International)
	Micro-finance loans to households	Offers affordable financing to low income clients; often collateral-free	Requires local presence; high monitoring costs	Projects Programmes	Not employing climate finance yet	Grameen Bank Bangladesh Spandana, India Worldwide 5.4 million agricultural insurance policy holder[33]
Equity	Direct financial investment in firm or project entity	Upfront payments; assumes project and performance risk	Difficult to find matching funding; dilutes incentives	Projects	Not employing climate finance yet	African Agricultural Capital (AAC) is a venture fund set up with Rockefeller Foundation
Cash payments (direct market)	Market transactions for emission credits; monetization of (future) emission reductions	Increases financial attractiveness of project; allows to leverage other sources of funding; hard currency	Requires costly monitoring and verification; dependent on carbon price fluctuations	Projects Programmes	Limited demand; available	1) Danone Livelihood Fund (target volume 30 Mio Euro); 2) The Juma Sustainable Development Reserve, Brazil (Seeberg-Elverfeld 2010);
Loan guarantees	Financing mitigating political or credit risks in public or private sector loans	Effectively mobilizes co financing from external sources; huge leverage potential for long-term debt finance for development.	Risk of principal loss for issuer of guarantee	Projects Programmes Policies	Very limited scope and geography; No climate finance but interested	1) USAID Development Loan Agency, IFC, KfW; 2) Agricultural input supply channels in Kenya, Malawi Uganda by Rockefeller Fnd.(WB 2007 p153); 2) Root Capital lending
Other risk sharing instrument	Weather, political and crop insurance; other risks.	Shifts investment and adoption risk away from smallholders (vulnerable)	Inappropriate use distorts markets, excessive risk taking	Projects Programmes Policies	Yes; limited geography	Index-based livestock insurance in Mongolia (World Bank 2007; p 149) and Kenya (Lybbert & Sumner 2010); Harita, Ethiopia drought insurance , Kilimo Salama input insurance Kenya, ICICI Lombard weather insurance in Andhra Pradesh, India

[33] http://www.microinsurancecentre.org/UploadDocuments/Landscape%20study%20paper.pdf

Public-private initiatives	Financing and guarantee support for targeted subsidies/incentive, joint ventures, or build-operate-transfer (BOT).	Flexible model accommodates multiple instruments; proven in large-scale project investments and potential for innovative small-scale project (see MFI*);	Historically favoured large infrastructure projects; climate finance must represent sufficient revenue stream	Projects Programmes Policies	Yes; but many still grant-financed; Not employing climate finance yet	Water efficient maize for Africa (WEMA) (Lybbert & Sumner 2010); Africa Enterprise Challenge Fund
Tariffs, taxes	Attractive feed-in tariffs or tax-incentives to support policy objectives	Enables projects that would otherwise be economically unrewarding;	Tariffs and taxes may change with a new government; continuity is uncertain	Projects Programmes Policies	Not employing climate finance yet	Renewable energy feed-in tariffs in Uganda for Bagasse and biogas projects
Grants and subsidies	Financial support to projects that serve the public interest, often provided by governments	Increases the financial attractiveness of projects that might otherwise not be economically feasible; comes at no cost	Availability is limited and continuity is uncertain; unlikely to cover entire investment cost	Projects Programmes Policies	Limited use of climate finance	1) Small Grants Programme: Climate Change to NGOs; 2) China Grassland Ecology Conservation Reward and Subsidy System

* MFI: Micro-finance institute

The instruments listed above are financial tools. To be wielded effectively, they must be used as part of an effective program, policy or other framework with clear objectives and appropriate means to obtain results in the agricultural sector. The next section lays out options to mobilize private capital within the two most promising categories of interventions allowing governments and the private sector to support climate-smart agricultural practices:

1) Improvement of the investment climate and/or incentives (risk-return ratio, risk apportionment, liability rules, etc.) for direct investments in agricultural operations and practices.

2) Regulatory and economic reforms of agriculture in developing countries

Country-specific applications in the developing world are examined in Chapter 7.

6.2. Climate financing strategies for agricultural sector

We focus on the two most promising financing approaches for the agricultural sector: a) market-oriented incentives for direct investments; and ii) results-based regulatory and economic reforms/incentives that contribute to GHG mitigation in the agricultural sector such as nationally appropriate mitigation actions (NAMAs) or REDD+. Financial flows for agricultural investments depend in part on conventional financial instruments, although climate-specific financing can add crucial financial and political resources, and act as convening force. We have listed nine options for each of these approaches below.

Table 12: Climate financing approaches for supporting CSA

Improvements to investment climate/incentives for direct investments	Regulatory and economic reforms
Risk management: Designing and supporting financial instruments that reduce or redistribute risks for investments in agriculture	*Subsidies or tariffs:* Removal of domestic subsidies or tariffs that encourage unsustainable agricultural activities – or disincentivize more efficient production – with international trading partners
Bonds based on revenue streams: Financial instruments monetizing revenue stream from improved agricultural productivity and/or ecosystem services	*Regulatory mandates:* Implementation and enforcement of regulatory mandates for adoption of specific agricultural practices, minimum standards or processes, lowering transaction costs for adoption
Transition cost subsidies: Creation of funds and financial instruments that subsidize upfront costs to transition to improved agricultural practices	*Sustainability criteria:* Creating, recognizing or mandating market-based sustainability criteria and labeling (within the borders of current WTO agreements)
Direct purchase: Purchase or creation of sustained regulatory demand for carbon credits, potentially with a quota for credits derived from agricultural projects	*Regulatory infrastructure:* investments in the regulatory infrastructure that lower the transition costs of adopting agricultural methods
	Land-use planning and tenure reform: Investments in land use planning and tenure reform to support sustainable land management practices, enforcement, monitoring and improved governance

These are detailed in the sections below.

(a) Direct investments in agricultural operations and practices

Financial instruments to reduce or redistribute risks for investments in agriculture

High or unmanageable risk deters or makes it impossible for certain categories of investors to finance climate-smart agricultural practices. In the long term, international development partners can reduce the political and technical uncertainties at the source by creating a harmonized system of global GHG accounting protocols backed by legally-binding treaties. In the short to medium term, defining market standards and political-determined benchmarks for emission reductions will reduce two of the largest political risks and broaden the pool of capital and financing sources for the sector. For development agencies and individual governments, however, this is often beyond their remit and unrealistic on a short time-horizon.

Risk sharing mechanisms, on the other hand, can be deployed by banks and multilateral institutions in coordination with governments or development agencies to unlock investment in agriculture. Few mechanisms exist to efficiently allocate financial risk in carbon market or performance-based transactions with liability for performance and political risk exist generally resting with the buyer or seller of the credits. A growing number of financial instruments have emerged to divide this risk among parties equipped to manage it and deploy funds to invest in climate assets. These instruments can take several forms and are either proposed or offered through various pilot projects:

- loan guarantees
- creating and/or underwriting insurance products
- price floors for carbon credits or other ecosystem credits
- providing price guarantees to lenders or equity investors in projects related to carbon assets or other monetized ecosystem services

These instruments share the advantage of offering leverage potential for public finance. A brief survey of cases studies and risks associated with each of these instruments is below.

Table 13: Cases studies and risks associated with each of these instruments

	Example	Description	Results	Risks
Loan guarantees	CLUSA Mozambique	Between 1995-2005, US$11.5 million in USAID funding helped farmers better organize, market products to local traders (Dorsey and Assefa 2005).	US$5.1 million leveraged from other sources (partially in form of matching grants); Farmers gained greater market access, and program copied by other donors.	- Primary risk loss of creditor capital -Requires strong domestic financial institutions - Potentially high transaction costs - May not serve most destitute farmers
	AGRA's Innovative Financing Initiative	US$17 million in loan guarantees to reduce risks of lending to smallholders	Leveraged US$160 million in loans from commercial banks in Kenya, Uganda, Tanzania, Ghana, and Mozambique (AGRA 2011)	
Insurance Products	"Kilimo Salama" (Safe Farming) microinsurance scheme in Kenya	Farmers pay extra 5% to insure seed, fertilizer, herbicide, etc. against crop failure; agribusiness match investment to meet insurance premium; Index used to determine if crops will be unviable if weather conditions deteriorate.	Average amount of seed insured in area has risen from 2kg per farmer to 4kg; Trial of 200 farmers hit by drought, triggering compensation payments of 80% of farmers' investments. (The Economist 2010).	- Incentive to neglect crops to gain higher payouts (traditional risk) but only in non-index systems - Weather data may not be available (need 30+ years); - Farmers may be unable or afford insurance (Oxfam America 2009).
	Horn of Africa Risk Transfer for Adaptation (HARITA)	Participating farmers work extra days beyond those required for normal payments to earn an insurance certificate protecting them from deficit rainfall.	Approach "multiplies the value of [donor] money by two" since it pays for insurance premium while hiring labor to carry out risk reduction measures instead of either/or (Oxfam America	

			2009).	
Providing seller price guarantees	World Bank Prototype Carbon Fund (PCF)	PCF has generally agreed to buy specified minimum amount of Emission Reductions (ERs) from a given project at a specified cost.	Project developers can either sell additional ERs on same terms and contract price as all other ERs purchased by the World Bank; or could sell additional ERs at market price	- Risk price floor too low (due to financial or political constraints): households unable to meet subsistence needs; - Per hectare subsidy: small growers will receive less financial assistance; per household subsidy: large growers might receive insufficient funds.
	Mexico's Coffee Stabilization Fund (*Fondo de Estabilizción del Café*, FEC)	Voluntary program, guarantees participating coffee growers set price for crop through USD80 million permanent fund.	Study by Ávalos-Sartorio and Blackman (2009) found in study region that the program did not significantly improve the ability of small growers to meet their subsistence needs	
Lenders/investors price guarantees	European compliance Buyer for land-fill /natural gas mitigation project	Minimum absolute or market index price with variable options to buy or sell post 2012	Ongoing carbon market practice; track-record of successfully completed sales	- Negotiation leverage may put sellers at disadvantage - inappropriate distribution of risks

In most transactions, while public finance is placed at risk, it is rarely been expended due to the relatively low rate of default in such initiatives to date. As such, these instruments leverage private capital investments worth many times the value of the ultimate public expenditure preserving public funds for additional use. The key requirements are: understanding performance risks, targeting specific agricultural measures, and managing transaction costs to ensure that public funds are preserved and deployed efficiently.

A second financing model now emerging in the context of social programs are government guarantees for private or civil society organizations to implement sanctioned programs. This model repays the implementing entities for the budgeted program costs plus an agreed-upon rate of return if it meets performance benchmarks. Success means the full value of the money plus a rate of return is disbursed. Failure means that the costs of the program are not reimbursed. This puts both capital and interest payments at risk. It has the advantage of imposing accountability, MRV and market rigor on programs traditionally executed by government agencies which sometimes lack the capacity to carry them out. For agricultural climate measures, an international donor could back a bond for a developing country's development agency or an NGO program to meet overall, mutually agreed upon performance metrics (not necessarily on a per ton of carbon basis) in a project. Entities can potentially attract private-finance based on this government guarantee. However, this approach is more risky then the models above and may only work where the risks are manageable, the rate of return is high and/or there is philanthropic funds given the risk profile and social or environmental mission of the investment.

Financial instruments monetizing revenue stream from agriculture

Fixed income instruments linked to climate-related assets are a promising option for agricultural mitigation and discussed in the recommendations (Section 7). Traditionally, climate investment has focused on higher risk private and public equity or debt. Fixed-income instruments monetize revenue or credits from climate-related projects allowing institutional investors to finance ecosystem services – as well as programs meeting specific performance standards – at a lower risk level than either equity or debt investors in projects. Several so-called green bonds or fixed income products have been issued since 2007 by the World Bank, European Investment Bank, and the International Bank for Reconstruction and Development. Investors include the State of California, Swedish national pension funds, UN pension funds, and others – institutions who have not traditionally invested in bonds from these organizations.

Two basic bond structures relevant to agriculture are described below:

1) *Bond where fraction of the interest/coupon is project off-take:* In this model, bonds are issued at competitive rates but discounted slightly and combined with a percentage of amortized revenue from climate-related projects. For example, the World Bank may issue a USD100 million bond and pay back bond holders with 3% interest plus carbon credits (or other revenue stream enabled by the climate finance) from some project (a difference of 2% from market rate). The carbon credit risk is assumed by bond holder but only for the difference in the interest. This is an attractive investment for many institutional investors, and has been successfully issued other projects in the past.

2) *Bond based on the income stream from a project:* In the case of agriculture, this amortized revenue stream could be i) share of higher productivity above some benchmark baseline; or ii) a share of cost savings after the implementation of climate-smart activities; or iii) a share of some credit for carbon/ecosystems service. The bonds are based on existing financial instruments and, while MRV and implement challenges exist, appear promising. It is also possible for other types of financing to be leveraged through these revenue streams that do strictly qualify as bonds but provide upfront financing.

These models represent a key opportunity to expand the base of climate investors to fixed-income investors. As of 2008, pension funds alone had USD25 trillion under managements, reports International Financial Services London (Reichelt 2010). To appeal to institutional investors, bonds should have i) standardized criteria and/or project eligibility (as far as possible); ii) minimum financial characteristics (size, rating, structure); iii) rigorous governance and due diligence process for project finance (Reichelt 2010). This standardization and flexibility will attract a much broader range of investors (pension funds, endowments, asset managers and sovereign wealth funds) with different risk profiles from high-yield to high-grade products (Reichelt 2010). Ultimately, government credit can support financial instruments that turn the cash or credit flow from mitigation and adaptation activities into investments for not just the relatively small pool of high-risk equity investors, but the much large portfolios allocated to fixed-income. World Bank Green Bonds[34] and energy efficiency bonds[35] issued by US states illustrate structures and terms for such programs although a unique set of arrangements will likely be needed for the agricultural sector.

Transition cost subsidies

An industry or government-financed fund to reimburse transactions costs for adopting climate-smart activities could address a major barrier preventing large scale implementation of agricultural mitigation and adaptation. Models are being developed that draw on industry taxes or public finance to create a way for individual business to cover the upfront capital costs of certification, improving agricultural methods or other program costs. This could remove a major obstacle for adoption of improved practices in the agricultural sector while creating MRV structures. NGOs such as WWF[36] and others are exploring possible initiatives.

Creation of sustained regulatory demand for carbon credits

For a market-driven offset strategy, the most important factor is robust demand for carbon credits either directly through purchase programs and tenders, or indirectly by inclusion of agricultural credits in an emission trading scheme permitting private firms to purchase offsets from agricultural sources. Further supportive measures include the development of knowledge, institutions, methodologies and methods that facilitate the accounting for GHG reductions from agricultural projects. The demand side measures include:

- issuing of a limited purchase order and creating floor price for carbon credits generated by a specific party or government
- procuring agricultural credits through public tenders (following the ERUPT/CERUPT example of

[34] http://treasury.worldbank.org/cmd/htm/WorldBankGreenBonds.html
[35] http://www.commerce.wa.gov/site/862/default.aspx
[36] http://wwf.panda.org/what_we_do/footprint/agriculture/

the Dutch government in the late 1990/2000s
- creating a direct purchasing facility to buy, sell and guarantee credits generated by appropriate standards

Interviews with stakeholders suggest creating ways for allocating risks to those best able to assume it, along with an appropriate level of government or public guarantees or risk-sharing, could unlock more large-scale investment in REDD+ from institutional investors deterred by today's political and technical uncertainties. Examples for facilities creating agricultural credit demand are the private sector proposed "Advanced Market Commitments" to purchase emission reductions generated by transformational agricultural demonstration activities occurring in partner host countries. This is grounded in the proposition that if a minimum level of future price certainty is given, significant private finance can be made available for the upfront costs of such transformational change.

b) Regulatory and economic environment

The massive scale of agricultural subsidies, market interventions and trade barriers in the agricultural sector will limit the effectiveness of any market-based agricultural climate finance schemes that do not consider how these issues shape incentives for famers and agri-businesses. We have outlined the primary challenges and opportunities – which are often one and the same –relevant to deploying effective market-based agricultural climate financing. While incentive-based payments for agriculture are unlikely to flow to address such obstacles directly, it is possible that financing from developed countries could address specific reforms and/or work in tandem to implement market-based approaches that also support structural reforms in the agricultural sector. Solutions to create this enabling environment for large-scale performance-based payments will be highly country-specific and, in some cases, a systematic process of policy reforms.

Subsidies or tariffs
Subsidies and tariffs still profoundly shape global prices and trade in agricultural commodities. Any interventions in the agricultural sector – including investments in climate mitigation and adaptation in agriculture – should consider whether support will disrupt competitive and functioning marketplace. Developed world subsidies – such as the USD3.9 billion spent on cotton in the US and EUR16 billion spent on the dairy industry by the EU – depress global prices and destroy export markets for developing world producers unable to compete with exports sold at prices the cost of production. Similarly, agricultural tariffs, averaging 60% in OECD countries and among the highest of all types of tariffs, raise trade barriers undermining other efforts to spur agricultural improvements through ODA or other means. Opportunities to pair investments in agricultural mitigation and adaptation that also address barriers to increase the strength and price of agricultural demand should be pursued.

However, this is likely to be an expensive and politically divisive strategy, despite the enormous benefits it could deliver to the developing world, particularly if implemented in conjunction with mandates or support for climate-smart agriculture The USD3.9 billion spent on US cotton subsidies, for example, have lowered global prices as much as 26% and diverted USD300 million from West and Central Africa, a prime growing region (OECD 2007). Reforming the international trade in agricultural products have been the subject of failed talks in the Doha round of the World Trade Organization talks, as well as the agricultural text for the Cancun Agreements under the UNFCCC. Political opportunities to alter or adjust the current tariff/subsidy system may appear if climate considerations can be introduced into the domestic policy discussion or in negotiations with international partners.

Regulatory mandates or market-based sustainability criteria/labelling for agricultural practices
Demand-side measures – either regulatory or market-oriented standards -- can reduce the demand for unsustainably grown, harvested or produced products, or increase the premium commanded in the market for sustainable products. Regulated standards have the attraction of being relatively straight forward for legislatures to define and pass. However, implementation is challenging and sometimes impossible in developing countries if practices are not economically viable or enforcement capacity weak. Governments

also run the risk of selecting inappropriate standards or criteria. Political pragmatism also means that developing countries, especially those with impoverished smallholders, are unlikely to adopt burdensome criteria.

Labelling or sustainability criteria – usually market-led or government sanctioned – have the advantage of remaining more flexible and attractive to producers, particularly if it increases prices. The record for such interventions – either at raising prices or achieving rapid adoption – is mixed and it remains to be seen if such measure would work in the context of mitigation and/or adaptation measures. Agricultural certification organizations such as Rainforest Alliance, UTZ certified, Fairtrade and others are well established and growing to meet demand for certified agricultural commodity supply. Few, however, have explicitly integrated climate standards and it remains to be seen whether such criteria can be effectively or economically integrated into these organizations processes.

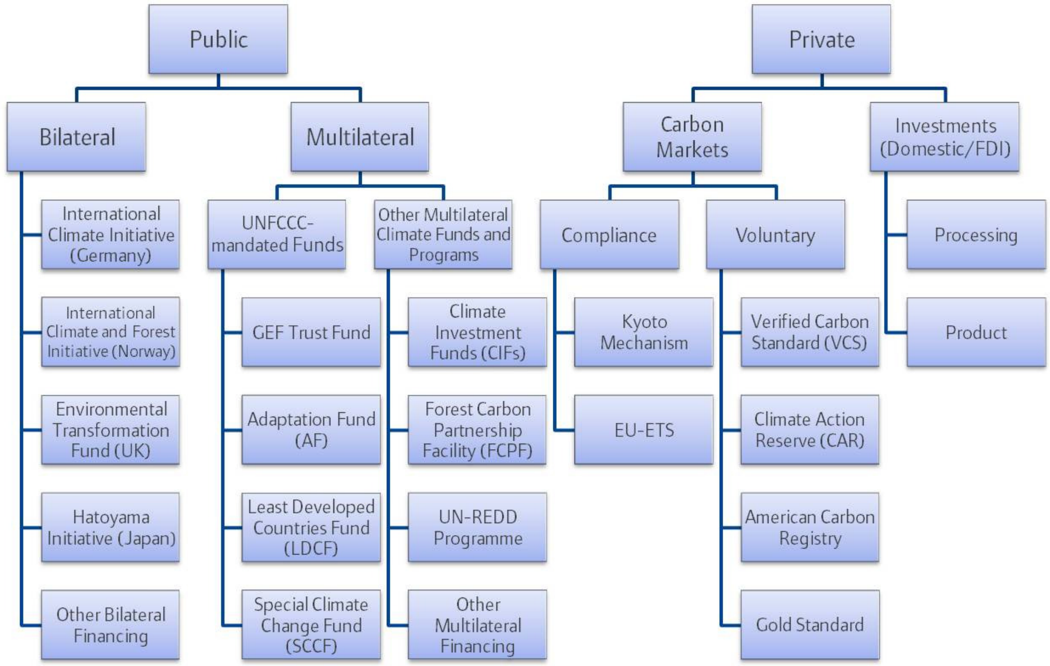
Regulatory infrastructure lowering transition costs of adopting agricultural methods
Climate change addressing practices may face regulatory or bureaucratic barriers that prevent the adoption of activities, or lower rewards for doing so. Public reforms that effectively reduce the cost of achieving this transition – possibly in conjunction with a market 'pull' factor from higher commodity prices or recoverable funds for the transition expenditures (see category above) -- could accelerate or multiply the effectiveness of climate programs in the agricultural sector.

Investments in sustainable land use planning and land tenure reform
Governments can probably achieve the most comprehensive mitigation and adaptation benefits by adopting long-delayed land use planning and land tenure reforms in the context of climate policies for the agricultural sector. While not a direct market-based approach *per se,* these measure are often a pre-requisite for large scale agricultural programs in many countries and are an underlying element of sustained and permanent emission reductions from agriculture in some regions.

6.3. International financial and policy instruments

The policies and financial instruments described above can be backed or co-financed by international climate finance. The various nationally prioritized actions will have to be matched with international finance instruments, as well as linked to bilateral and multilateral funds. Determining the most appropriate climate financing approach for agriculture is unlikely to yield a single answer. Our experience shows only broad financing distinctions and guidelines are possible for specific categories of agricultural mitigation/adaptation measures – grant or performance-based, bilateral or multilateral, public or private. The appropriate institutional arrangements depend on i) the country, ii) evolution of climate policy under the UNFCCC, and iii) social and political circumstances in host countries. We have mapped private and public financing entities whose scope of activities included agriculture in some form (Figure 19). Most of the funds listed in Figure 19 finance both mitigation and adaptation activities.

Figure 19: Overview of existing public and private financing sources for agricultural mitigation and adaptation



The chart above, while not all inclusive, identifies primary sources of climate finance that support climate-smart agriculture at this time. Financing mechanisms could change, combine or create new funding options over time, as the history of climate finance suggests a variety of modalities will emerge to meet mitigation needs. This section describes the climate finance mechanisms, practices, value and barriers in more detail. A list of fund characteristics is available in Annex 8.2.

Instruments

Performance-based approaches defined by the UNFCCC – most proximately REDD+ and NAMAs -- may or may not integrate international carbon markets, but can apply rigorous GHG accounting integral to market crediting. Agriculture is considered a critical part of REDD+ strategies as the primary driver of deforestation in many countries, and will inevitable be among the sectors incorporated into many REDD+ strategies. NAMAs are voluntary GHG mitigation commitments undertaken by developing countries, and more than half of the 44 NAMAs submitted by developing countries involve the agricultural sector (FAO 2010d). We review these two approaches in Table 14 below.

Table 14: Mitigation sectoral/policy/aggregated activities approach (market-based)

	REDD+	NAMAs
Mechanism	REDD+ is an incentive mechanisms to encourage developing countries to reduce emissions from deforestation and forest degradation; as well as conservation, sustainable management of forests and enhancement of forest carbon stocks.	NAMAs are voluntary commitments made by developing countries to reduce GHG emissions. These are submitted to the UNFCCC and available for international climate financing per terms in the Cancun Agreements.
Agricultural Practices	Terrestrial carbon activities; e.g. tree-based farming practices, agroforestry, improved agricultural practices, etc.	Unrestricted: e.g. sustainable land management and efficiency, livestock, soil and agricultural practices, cropland and livestock management, agroforestry, crop

		intensification and improvement.
Barriers	Not explicitly crediting non-tree agriculture	Still undefined financing and implementation modalities

REDD+

The Cancun Agreements established a REDD+ mechanism that encourage developing countries to contribute to mitigation actions in the forest sector through REDD+ activities. Agriculture, although not explicitly included in this decision expect through agroforestry, is expected to play a major role in countries' REDD+ strategy to address major drivers of deforestation. REDD+ readiness activities include i) a national REDD+ strategy, ii) national and, if appropriate sub national, reference (emission) levels, iii) a MRV system that is national and if appropriate sub national, and iv) a system for providing information on how the safeguards referred to are being addressed and respected throughout the implementation of REDD+ activities

NAMAs

Developing countries have agreed to take voluntary nationally appropriate mitigation actions to reduce business-as-usual emissions by 2020 under the Copenhagen Accord and Cancun Agreements. In the context of Cancun Agreements, the Conference of the Parties to the UNFCCC (COP) "[took] note" of all NAMAs to be implemented by developing country Parties. A registry will record the transfer of funds and resources to carry out these actions, as well as match available funding with countries wishing to implement actions. The COP also decided developed country parties "shall" provide enhanced support for the preparation and implementation of NAMAs. A more detailed discussion of agricultural NAMAs is included in Annex 8.4.

Delivery mechanisms

Funds

Performance-based payments for REDD+ and NAMAs can be delivered through markets or public funds. Funds are likely to support market-based mechanisms by reducing transaction costs, creating enabling conditions and supporting pilot projects. The Green Climate Fund established in accordance with the Cancun Agreements is likely to contain a window for REDD+ and may see additional dedicated finance for the agricultural sector.

It is important to note that the proliferation of climate funds and mechanisms has led to multiple, overlapping planning demands on developing countries. The success of future mechanisms depends on financing mechanisms implemented in a coherent and coordinated way. This will depend on harmonizing planning processes for climate mechanisms, as well those of other non-climate related programs for food security, land management and economic development. Such cross-sectoral processes need to manageable for developing countries now facing multiple financing and planning requirements.

A selection of the most important funds in relation to agriculture are reviewed in Annex 8.3

Market-based approaches

The role of markets – emission-related or otherwise – in incentive mechanisms is still a matter of debate under the UNFCCC (see Section 3.3). Increased private sector finance for climate mitigation is considered a vital element of mobilizing USD100 billion annually for climate actions in developing countries by 2020 committed to under the Cancun Agreements. The High-level Advisory Group on Climate Change Financing considers international private investment flows "essential for the transition to a low-carbon and climate-resilient future" and could generate around USD100 billion to USD200 billion of gross private capital flows at a carbon price of USD20-USD25 (HAGCCF 2010).

To understand the possible private sector financing approaches, it is helpful to categorize them by their relationship to "markets" representing pools of capital, investment and trade:[37]

- Carbon market: national or sub-national cap and trade systems to meet compliance GHG emission targets, as well as voluntary credit transactions to generate and sell offsets used for mitigation.
- Carbon market-linked: mechanisms that raise money indirectly through carbon markets such as auctioning allowances that are redirected into mitigation or adaptation
- Market-linked: taxes, levies or other tariffs on economic sectors or financial transactions outside a GHG emissions market
- Non-market instruments: other financing sources including ODA, philanthropy and public sector transfers that do not fall under the categories above.
- Private sector investment flows: Foreign direct investment, representing 170 billion or 10% of investment in developing countries, as well as other funds from the private sector.

Important market-based GHG mitigation options in the agricultural sector are i) compliance markets; ii) voluntary market transactions between project developers, buyers and/or brokers; domestic cap-and-trade systems.
Table **15** summarizes the main features of market-based approaches for carbon markets under the Kyoto Protocol and Voluntary Standards. An inventory of agricultural mitigation projects is available in Annex 8.3.

Table 15: Mitigation project approach (market-based) (UNFCCC, Ecosystem Marketplace, 2010)

		Clean Development Mechanism (CDM)	Voluntary carbon market	CDM PoAs
Mechanism		The CDM was authorized under the Kyoto Protocol to generate saleable certified emission reductions (CERs) in developing countries, to meet GHG targets in Annex I countries.	The voluntary carbon market represents the transaction of emission reduction credits by entities purchasing offsets outside of a compliance GHG target. Independent standards typically certify credits traded in over-the-counter or exchange transactions.	CDM Programme of activities (PoAs) are a modality under the CDM to register an unlimited number of projects and local, regional or national policies/standards as associated project activities provided that approved baseline and monitoring methodologies are used.
Agricultural Practices		Manure management, urea offset, afforestation/reforestation and bioenergy.	Voluntary market mechanisms credit, *inter alia*, agroforestry, nitrogen-, farm energy-, crop-, land use-, livestock-, and soil management.	Limited to CDM methodologies; e.g. reducing nitrous oxide emissions, reducing methane
Value (*million*)	'08	Primary: 6,511 Secondary: 26,277	728	*N/A*
	'09	Primary: 2,678 Secondary: 17,543	387	*N/A*
Barriers		Procedural/eligibility limitations A/R offset cap for Annex I targets EU-ETS exclusion of A/R credits; Expiration of ICERs or tCERS such as soil carbon sequestration	Low prices and variable credit quality Small size of market (<1% compliance) Uncertain current and future demand Lack of standardization	CDM restrictions on soil carbon Additionality and crediting constraints challenging economics

[37] Categories modified from Parker (2009)

Clean Development Mechanism

The Kyoto Protocol treats agriculture differently in Annex I (or developed) countries and developing countries. 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.[38] By contrast, in the Clean Development Mechanism (CDM), the mitigation crediting mechanism for developing countries, limits the eligibility of land use or agricultural activities covering only manure and waste water management, afforestation and reforestation while excluding the primary mitigation opportunities (especially for smallholders) to enhance soil carbon stocks through cropland or rangeland management.

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 saleable certified emission reduction (CER) credits, which can be counted towards meeting Kyoto targets. The mechanism stimulates sustainable development and emission reductions, while giving industrialized countries some flexibility in how they meet their emission reduction or limitation targets. The Cancun Agreements mandate operational reforms to expand and streamline CDM activities.

Currently there are only two explicitly agricultural projects under the CDM (reducing pump-well emissions by installing more efficiency drip irrigation systems), although many related projects fall under different categories. The broader FAO definition of agricultural projects – those that reduce GHG emissions through agricultural systems or processes including land-use, afforestation/reforestation, biomass energy and methane avoidance -- the number is considerably larger (see inventory figures in 8.3). The methodologies used by agriculture and forestry projects include: GHG removal by sinks, energy efficiency, renewable energy, fuel switch, energy efficiency in agriculture, GHG emission avoidance, GHG destruction, displacement of non-renewable biomass by renewable sources, displacement of more GHG-intensive service, renewable energy, displacement of more GHG-intensive thermal energy or heat and displacement of electricity produced by more GHG-intensive means (Larson *et al.* 2011).

Compliance markets have also imposed restrictive rules on crediting land use activities, deterring investments in agricultural projects. The EU-Emission Trading Scheme has banned trading of forest and non-CDM agricultural credits through 2020 (future inclusions depends on stringency of global GHG targets subject to European Commission approval).[39] Similarly, CDM rules and methodologies only permit temporary credits for removals from forestry activities (temporary or long-term CERs) and onerous accounting rules for forestry and the exclusion of soil carbon projects. Implicitly, this means that countries with low emissions and high sequestration potential – that is, most poor agrarian nations – are poorly positioned to participate in these markets.

To enable projects with a high replication potential that are implemented over a longer period of time, typically several years to over a decade, Parties to the Kyoto Protocol created the concept of Programme of Activities (PoA) in the CDM. In contrast to regular CDM, where the pooling of individual abatement activities is restricted to a one-off 'bundling' of a number of small similar projects, a PoA creates an umbrella structure that supports the inclusion of multiple and unlimited bundles of subprojects over time. Adding projects requires only a 'quick check' by a validator, as opposed to the more detailed and lengthy validation and registration procedure of the regular CDM project-approval cycle. Agricultural activities approved the CDM can be included under this structure to achieve large scale implementation. As of 2010,

[38] These countries are obligated to report certain agricultural emissions (mainly CH4 and NO2 emissions from human-induced biological processes) while CO2 removal or emission from cropland management is optional (Article 3.4).38 Only a few countries have elected to do so (FAO 2010b). Those 'net changes' must be "measured as verifiable changes in carbon stocks in each commitment period" (Kyoto Protocol). Forest carbon stocks by developed countries are treated separately (Article 3.3 KP; Article 3.4 KP).

[39] Depends on the progress towards and results of the international agreement on climate change (Articles 8 and 9 of Decision 406/29/EC and Article 28 of Directive 2009/29/EC). As part of the report the Commission is required to assess different modalities for including land use, land use change and forestry in the EU's reduction commitment. URL: http://ec.europa.eu/clima/policies/effort/framework_en.htm

the PoA project pipeline included 98 projects of which 2 were in agriculture, 2 in biomass energy, 22 in methane avoidance (the single biggest category along with household energy efficiency), and 2 in reforestation.

Voluntary markets

Voluntary markets account for less than 0.3% of the value of regulated markets (USD 387 million compared to approximately USD 144 billion, respectively, in 2009) yet constitute a large share of total agricultural offset demand (Ecosystem Marketplace, 2009). Offset standards explicitly encourage agricultural mitigation, and may permit ex-ante crediting (issuing credits prior to validated sequestration), flexible eligibility and accounting rules and lower up-front costs important for land use activities relying on accumulation of carbon stocks) attractive for agricultural mitigation projects. The voluntary market is predominately unregulated encompassing all transactions of emission reduction credits among entities outside of compliance GHG cap-and-trade systems. Sales are predominately "over-the-counter" between buyers and sellers (or brokers) or brokered on exchanges.

Agricultural activities accepted under voluntary standards include methane capture (4%), agricultural soil management (3%), agroforestry (1%), and afforestation/reforestation (10%) or forest management (3%) accounting for 21.3% of OTC trades in 2009 (about 9.4 million VERs).[40] Despite this, they have had a limited impact in leveraging private capital given the future of the voluntary market is clouded by financial volatility and political uncertainty. Transaction values have dropped 47% in 2009 (USD387.4 million), and traded volumes declined 26% (93.7 $MtCO_2e$). The eligibility of agricultural activities under different standards is reviewed below.

Table 16: Voluntary Carbon Market – Traded volumes and values, 2009, via the voluntary offset market (Bloomberg New Energy Finance, Ecosystem Marketplace, World Bank, 2010)

	Volume ($MtCO_2e$)			Eligible activities[†]		
	2008	2009	% all '09	A/R	REDD	Ag
Voluntary Carbon Standard	24.0	16.4	35	Yes	Yes	Yes
Plan Vivo	NA	NA	0.2	N/A	N/A	N/A
Carbon Fix	NA	NA	0.6	N/A	N/A	N/A
Climate Action Reserve	5.3	14.5	31	Yes	Yes	Yes
American Carbon Registry	4.3	1.8	4	Yes	Yes	Yes
Chicago Climate Exchange (CCX)*	1.4	5.5	12	Yes	Yes	Yes
Gold Standard	6	3.2	7	No	No	No
Climate Conservation and Biodiversity Standard (CCB)**	0.5	0.6	3	N/A	N/A	N/A

[†] A/R is afforestation and reforestation. Agriculture includes a range of practices varying according to each standard.
* CCX is no longer trading.
**CCB is a performance certification focused on co-benefits and does not issue carbon credits.

Additional mechanisms

Private-sector supply-chain investments

[40] Agricultural OTC trades 2009 (Hamilton et al. 2010) Hamilton et al. 2010 Building Bridges:State of the Voluntary Carbon Markets 2010, Ecosystem Marketplace, Bloomberg New Energy Finance

A fourth category – private-sector investments in supply-chain GHG management – reflect companies willing to invest in improvements of internal or suppliers' practices and facilities. These investments by individual firms in agricultural GHG abatement are small but growing. They have not been well quantified across sectors. There are multiple examples of investments by multinational firms, Group Danone, General Mills, Nestle, Unilever and Cadbury among them, designed to lower emissions in their supply chain, as well as sector-wide efforts such as the Sustainable Agriculture Initiative Platform to share mitigation opportunities. However, like the regulatory market, this sector is expected to provide some growth and innovation but struggle to achieve scale comparable to economy-wide (or even sectoral) compliance targets.

It is important to note that none of these mechanisms have yet resulted in globally significant agricultural mitigation activities. The World Bank, which is attempting to play a catalytic role investing in projects generating credible emission reductions for land use/change, forestry and agricultural activities including REDD+, devotes only a small fraction of land-use mitigation project investments to agriculture. For soil carbon projects in developing countries, among the most promising climate investments in food security, worldwide investment may only amount to about ~USD5 - 10 million, mostly from the World Bank BioCarbon Fund itself (Newcombe 2009).

7. Engagement: Climate and agriculture

We suggest a strategy that focuses on lifting investment barriers and increasing incentives for sustainable agricultural intensification, while laying the groundwork for carbon-market approaches in the future. An opportunity is emerging for public climate funds to match and influence large-scale private sector agricultural investments that contribute to GHG mitigation and poverty alleviation. The rising demand for agricultural production will accelerate this rate of investment, and broaden the opportunity for climate fiancé. The prioritized categories are:

- Reducing climate-smart agriculture investment barriers
- Addressing risks related to mitigation and adaptation investments
- Harnessing carbon crediting and trading
- Strengthening public sector capacities

These categories cover climate financing options for agricultural practices that meet the multiple aims of GHG mitigation, enhanced productivity and food security, particularly for smallholders and are explained below.

7.1. Reducing climate-smart agriculture investment barriers

Sustainable agriculture transition fund model: Transition funds are designed to subsidize the costs for farmer and agricultural processers to adopt sustainable practices usually connected to industry-wide environmental and social standards. The assumption is that improved productivity and efficiency gains will offset higher costs related to meeting these standards and subsidies can be phased-out over time. Supplies of global agricultural commodities, many of which involve extensive networks of smallholder out-growers, are extremely price-sensitive and difficult to influence through standards with low premiums or significant upfront costs. A transition fund removes this barrier to adoption by providing finance that lowers producers' initial investments in auditing, quality control, and improved practices enabling it to achieve certification and adopt sustainable practices.

This transition fund model could be used to foster the adoption of agricultural mitigation and adaptation practices among smallholder producer associations and agribusinesses, and influence the decisions of domestic and foreign investors. Beneficiaries of this fund would receive performance payments (with upfront financing possible) using a predefined MRV system and respective climate benefit and livelihood indicators and benchmarks. Aid for Trade (AfT) initiatives aiming to reduce the costs for trading (Cali and Te Velde, 2011) could be also employed to introduce market driven sustainability standards including carbon standards. This model appears most promising for cash crops where a quality premium is paid and additional environmental and social costs can be partly covered from this premium. Agricultural producers would commit not to engage directly or indirectly in deforestation or forest degradation.

The beef industry in Brazil is one widely known example for domestic investment in related policies cited in the report. The Brazilian government linked preferential government loans with the condition that land-use plans are enforced and producer do not expand their production area to reduce the direct but also indirect deforestation pressure. MRV systems also monitor performance and enforce policies. Other suitable sector may include cocoa management in West Africa, tobacco production in East Africa or palm oil, soy, and sugar/ethanol agribusinesses globally.

Climate-smart agricultural technology fund model: A major investment barrier is that agricultural research is mainly funded and provided by the public sector in developing countries. A lack of private sector engagement at the research stage often means that innovations subsequently lack the private sector finance needed if they are to be commercialized and applied at scale. A technology fund could fill this void by attracting private sector capital to invest in agricultural mitigation and adaptation innovations designed to meet multiple social and environmental objectives. These include irrigation technology to reduce rainfall vulnerability, improved seed multiplication technology, precision farming technology enabling more efficient fertilizer application particular in emerging economies; and carbon monitoring systems that are simple, cost effective and locally managed by private sector entrepreneurs. Micro-irrigation system entrepreneurs in India represent an effective example for private sector engagement in this space. A systematic overview of agricultural innovations and diffusion pathways is provided in the World Bank's Enhancing Agricultural Innovation study.[41]

The perceived risks of transition and technology funds are that the grants or soft loans interfere with private agricultural funds, public money is deployed for impractical ideas or there is weak competition. However, these risks can be addressed by the fund management. Potential partners for the development of Transition Funds are environmental protection agencies, private sector agribusinesses and funds as well as smallholder producer associations and NGOs supporting agricultural development. Technology funds require a close link with public-private agricultural innovation cluster that already influence the research agenda. Farmer and researcher need to engage in participatory research. Investors need to understand financing gaps, investment risks and technology futures that are worthwhile to invest. Innovation cluster need to engage farmers, farmer associations and NGOs, agribusiness, financial institutions and different government agencies (agriculture, land, environmental protection and trade agencies).

The Africa Enterprise Challenge Fund is a promising example of a respective fund vehicle aiming to deploy limited public funds efficiently to mobilize private low-carbon agricultural capital at scale. Currently the fund is targeting emission reductions related to renewable energy but additional windows to support the implementation of carbon standards, investments that capture soil carbon or reduce livestock related emissions could be added.

Box 3: Africa Enterprise Challenge Fund (AECF)[42]

The AECF provides grants and interest free loans to businesses who wish to implement innovative, commercial viable, high impact projects in Africa. Competitions serve to ensure that viable business ideas that can be risky but provide the strongest impact on climate and rural employment will benefit from the fund. The AECF supports businesses working in agriculture, financial services, renewable energy and technologies for adapting to climate change. It also supports initiatives in media and information services where they relate to these sectors. The AECF is funded by DFID, the Consultative Group to Assist the Poor, the International Fund for Agricultural Development and the Netherlands Ministry of Foreign Affairs.

7.2. Addressing risks related to mitigation and adaptation investments

Farmers, particularly the rural poor, face market volatility and harvest risks with little or no insurance against input loss and crop failure. As a result, farmers reduce inputs as a risk reduction measure triggering a vicious circle as inputs are reduced over time, soil carbon stocks and production declines and vulnerability is increasing. By helping farmers manage these risks through simple but accessible loan guarantees and insurance options, private sector investment can flow into improved agriculture at limited public expense.

Agricultural NAMAs: In particular for soil carbon sequestration activities with multiple benefits for smallholders we recommend establishing a NAMA financing mechanism specifically for soil carbon sequestration and sustainable agricultural intensification targeting small farms. Public funding would be used to establish a respective national policy framework, reference emission levels for food security and a MRV system using activity monitoring and soil carbon models to monitor soil sequestration benefits and efficiency accounting for intensity-based emission reductions. The climate mitigation and adaptation benefits would justify the public investment. Public climate finance should also underwrite some risks for

[41] http://siteresources.worldbank.org/INTARD/Resources/Enhancing_Ag_Innovation.pdf
[42] http://www.aecfafrica.org/

related private sector investment options e.g. loan guarantees for investments in inputs and irrigation technology. Loan guarantees are already widely offered and a climate finance component could be integrated (e.g. the USAID Development Credit Agency and KfW are already considering respective options). Considering that the design, capacity building and implementation of such a NAMA mechanism will take time it is important to support in parallel individual projects that will be integrated in the NAMA over time but will inform the NAMA design. A national registry of the investments and emission reductions as required under the Cancun Agreements will serve to monitor the efficiency and to reward performance.

The Government of Ethiopia (in a submission to UNFCCC) has pointed out that NAMAs need to be country driven but the donor and recipient country should be jointly engaged in the design, implementation and monitoring process.[43] This will encourage mutual understanding and learning and to ensure that the planning process is efficient and fast. Farmers, civil society and relevant government agencies also need to be involved.

Risk insurance mechanisms: A second important element to reduce climate-related agricultural production risks are insurance strategies. Good precedents exist with private sector initiatives related to input insurance systems that employ smart mobile phone technology to address the challenge to reduce transaction costs (see Kilimo Salama model presented in this report). Weather index based insurance mechanisms have been also tested in a number of countries[44]. The Harita system in Ethiopia is linking the weather index based insurance with the government food for work programme which is in particular useful for regions with frequent drought events[45]. Private sector insurance is not effective if drought events are too frequent, and government safety nets providing alternatives to farming may be the most effective adaptation strategy. The starting points for engagement are existing partners involved in the insurance business. To understand the scaling potential, public leverage options and related risk a detailed analysis of existing schemes is required.

7.3. Harnessing carbon crediting and trading

Currently, the demand for carbon credits in the agricultural sector is limited (particularly those with productivity and smallholder benefits), while protocols for measuring, reporting and verification at the national-scale are not yet in place. The political environment for new market mechanisms affecting food security is also not favourable, according to stakeholders. Carbon market financing may therefore become a viable long-term strategy, but it is not a short to medium-term option at scale. To support the development of viable agricultural carbon projects and contribute to beneficial agricultural research that might be scaled through other means, we recommend strategic purchases of agricultural carbon credits and/or direct finance of strategic projects in cases where efforts lay the scientific and institutional foundation for broader activities.

Carbon credits/markets: Project-based carbon crediting mechanisms such as the CDM are suitable for agricultural emission reduction options in the energy sector e.g. related to methane emissions from animal waste or open lagoons and biomass residue fuel-switch programs. Programme of Activities (PoAs) or standardized baselines can contribute to reduce transaction costs. Therefore, it is important that the CDM is reformed and continues beyond 2012.

A number of developing countries are considering to develop domestic carbon trading systems as a cost effective means to reduce emissions and in particular to stimulate low carbon development in the agricultural sector. The Panda Standard described below is an example. Although it is currently designed as a voluntary carbon standard, it is supported by the government and may eventually be used for compliance carbon trading.

[43] http://unfccc.int/resource/docs/2011/awglca14/eng/misc07a01.pdf
[44] http://www.ifpri.org/publication/innovations-rural-and-agriculture-finance
[45] http://www.ukcip.org.uk/business/business-case-studies/harita/

Box 4: Panda Standard[46] and evolving carbon trading systems in China[47]

The Panda Standard is the first voluntary carbon standard in China with a focus on agriculture and forestry. It was announced in December 2010 and the first transaction took place in March 2011. It aims to compliment China's regulatory efforts to increase carbon efficiency targets and to advance its objective to reduce rural poverty. In addition China will set up carbon trading systems in 5 provinces (Guangdong, Hubei, Liaoning, Shaanxi and Yunnan) to develop standards and mechanisms for market-based carbon trading mechanisms and to support the development of green economies.

Carbon trading systems can generate carbon credits or define binding targets and allocate allowances to different sectors. To develop allowances in the agricultural sector, low-emission agricultural development strategies need to be developed reflecting future reference emission levels. Subsequently reduction targets need to be agreed. Assuming a cost effective system can be established domestic and global carbon markets represent a deep source of finance for low carbon agriculture.

Short term engagement options from our perspective should be considered only in countries that have a demonstrated commitment to develop domestic carbon crediting and trading systems. Some of the work required to develop NAMAs such as building agricultural monitoring and evaluation capacity and MRV systems are also highly relevant for carbon trading systems. Therefore, capacity building of respective institutions

7.4. Strengthening public sector capacities

Public sector support for national climate-smart agricultural initiatives: International climate finance can be used to support countries that have a demonstrated commitment to establish the infrastructure and capacity to monitor agricultural emissions, along with policies and measures to reduce agricultural emissions. Financial support could be provided for an agricultural readiness process, the establishment of national agricultural GHG monitoring systems including national reference emission levels and related capacity building support. Financing could be linked to milestones related to the MRV system development and reporting accuracy. Performance payments for emission reductions achieved would provide incentives not only to set-up monitoring systems but also to adopt agricultural mitigation activities. The fast-start financing committed under the Cancun Agreements could provide suitable financing pathways such as NAMAs or bilateral initiatives.

As outlined in the report, there are a number of widely accepted no regret mitigation options with strong food security and adaptation benefits that could be implemented immediately using the available public climate finance. Preventing land-use changes, encouraging crop rotations with legumes to enhance soil nutrient status and carbon sequestration on smallholder farms are Agroforestry and the development of low energy and water efficient irrigation systems are among the most attractive options. However, a respective agricultural climate investment programmes would need to be developed tailoring different climate financing mechanism to tackle specific investment barriers and risks.

[46] http://www.pandastandard.org/
[47] http://www.chinadaily.com.cn/china/2010-08/19/content_11174407.htm

Work Cited

ACIL Tasman, 2009. Agriculture and GHG mitigation policy: options in addition to the CPRS. Prepared for the Victorian Department of Primary Industries NSW Department of Industry and Investment. Melbourne, Australia.

AGRA 2010, Innovative Financing for African Agriculture. www.agra-alliance.org

Angelsen, A. 2010. Policies for reduced deforestation and their impact on agricultural production. PNAS, Vol. 107, No. 46, 19639–19644

AWG-LCA, 2009, Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention, Draft conclusions proposed by the Chair, Addendum, Draft decision -/CP.15, Cooperative sectoral approaches and sector-specific actions in agriculture, URL: http://unfccc.int/resource/docs/2009/awglca8/eng/l07a09.pdf

Babkova, E. 2010. Part I. Food Crisis Looming? Center for Strategic and International Studies. Sep 28, 2010. URL: http://csis.org/blog/part-i-food-crisis-looming.

Baker, J.M., Ochsner, T.E., Venterea, R.T., and T.J. Griffis. 2007. Tillage and soil carbon sequestration – What do we really know? Agriculture, Ecosystems and Environment, 118(2007): 1-5.

Balmford, A., R.E. Green and J.P.W. Scharlemann 2005. "Sparing land for nature: exploring the potential impact of changes in agricultural yield on the area needed for crop production". Global Change Biology 11 (10): 1594-1605.

Bruinsma, J. 2009, *The Resource Outlook to 2050. By how much do land, water use and crop yield need to increase by 2050?* Technical paper from the Expert Meeting on How to Feed the World in 2050, FAO Rome.

Burney, J. A., Davis, S. J., Lobell, D. B. 2010. "Greenhouse Gas Mitigation by agricultural Intensification," PNAS. URL: http://www.pnas.org/content/early/2010/06/14/0914216107.abstract

Burton, I. And B. Lim. 2005. Achieving Adequate Adaptation in Agriculture. Climate Change, 70(2005): 191-200

CAADP 2010. URL: http://www.nepad-caadp.net/about-caadp.php

Cali, M. and Te Velde C.D. 2011. Does Aid for Trade Really Improve Trade Performance? World Development Vol. 39, No. 5, pp. 725–740.

Canadell, Raupach and Houghton. 2009. Anthropogenic CO2 emissions in Africa. Biogeociences 6:463-468

Coalition on Agricultural Greenhouse Gases (C-AGG), 2010, Agriculture in the UNFCCC: Post-Cancun/COP16 Perspectives on Agricultural Issues within the UNFCCC. Draft memo. December 2010.

CSM 2008, "The Monitor's View: Price Shock in Global Food," 7 April 2008. The Christian Science Monitor.

Deutsche Bank Group 2009, Investing in Agriculture: Far-Reaching Challenge, Significant Opportunity An Asset Management Perspective June 2009 Deutsche Bank Group.

DeFries, R. and Rosenzweig, C. 2010. Toward a whole-landscape approach for sustainable land use in the tropics. PNAS, Vol. 107, No. 46, 19627–19632

Dioné, J. 2010. Presentation Agriculture and Rural Development Day 2010, Director of Food Security and Sustainable Development Division of the United Nations Economic Commission for Africa (ECA),Cancun Mexico.

ECA (Economic Commission for Africa) 2009, Economic Report on Africa 2009: Developing African Agriculture Through Regional Value Chains Economic Commission for Africa. Addis Ababa, Ethiopia.

EPRI 2010. Brazil's Emerging Sectoral Framework for Reducing Emissions from Deforestation and Degradation and the Potential to Deliver Greenhouse Gas Emissions Reductions from Avoided Deforestation in the Amazon's Xingu River Basin. Palo Alto.

European Commission 2011, Communication from the Commission to the European Parliament, the Council, the Europena Economic and Social Committee and the Committee of the Regions: A Roadmap for moving to a competitive low carbon economy in 2050 Brussels, {SEC(2011) 287 final}.

FAO 2005, The UN Food and Agriculture Organization Committee on Food Security. Report of 31st Session

FAO 2008. Climate Change Adaptation and Mitigation in the Agricultural Sector, available at: ftp://ftp.fao.org/docrep/fao/meeting/013/ai782e.pdf

FAO 2009c. Harvesting agriculture's multiple benefits: Mitigation, adaptation, development and food security. Policy Brief, Food and Agriculture Organization of the United Nations, Rome.

FAO 2010a "No food crisis seen, but greater market stability needed: FAO Assistant-Director General on current food situation." 7 September 2010, Rome. URL: http://www.fao.org/news/story/tr/item/45178/icode/en/

FAO 2010b Towards a Work Progamme on Agriculture: A submission to the AWG-LCA by the Food and Agriculture Organization of the United Nations URL: http://unfccc.int/resource/docs/2010/smsn/igo/081.pdf

FAO 2010c "Climate-Smart" Agriculture Policies, Practices and Financing for Food Security, Adaptation and Mitigation", 2010.

FAO 2010d "Agriculture, Food Security and Climate Change in Post-Copenhagen Processes: An FAO Information Note," FAO.

Foresight 2011, "The Future of Food and Farming: Challenges and choice for global sustainability." Government Office for Science, London, UK.

Frankhauser, S., and Ward, J., 2010, "Regional Implications of the AGF recommendations: Africa." Climate & Development Knowledge Network. November 2010.

Ghanem, H.2009, "World Food Security and Investment in Agriculture," Internatoinal Economic Bulletin, Weekly Economic Commentary and analysis from the Global Think Tank. URL: http://www.carnegieendowment.org/ieb/?fa=show&id=23850.

Govaerts, B., Verhulst, N., Castellanos-Navarrete, A., Sayre, K.D., Dixon, J., and Dendooven, L. 2009. Conservation Agriculture and Soil Carbon Sequestration: Between Myth and Farmer Reality. Critical Reviews in Plant Science, 28: 97-122.

Grieg-Gran, M., 2010, Beyond forestry: why agriculture is key to the success of REDD+, iied briefing, iied.

HAGCCF (High-Level Advisory Group on Climate Change Financing), 2010, "Report of the Secretary-General's High-Level Advisory Group on Climate Change Financing." 5 November 2009. URL: http://www.un.org/wcm/webdav/site/climatechange/shared/Documents/AGF_reports/AGF%20Report.pdf

iisd 2009. "Expanding Agriculture's Role in a Post-2012 Climate Change Regime." International Institute for Sustainable Development (iisd), March 2009. URL: http://www.iisd.org/pdf/2009/agriculture_post_2012.pdf

IPCC 2007, Fourth Assessment Report Intergovernmental Panel on Climate Change, URL: http://www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html

IPCC 2007(b). Climate Change 2007: Synthesis Report. Intergovernmental Panel on Climate Change (IPCC), Valencia, Spain

Larson, D.F., Dinar, A., Frisbie, J.A., 2011 "Agriculture and the Clean Development Mechanism," Policy Research Working Paper 5621. The World Bank, Development Research Group, April 2011. URL: http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2011/04/04/000158349_20110404091922/Rendered/PDF/WPS5621.pdf

Lobell et al. 2008. Science. Prioritizing climate change adaptation needs for food security in 2030. February 2008

Luo, Z., Wang, E., 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.

Lybbert, T. and Sumner, D. 2010. Agricultural Technologies for Climate Change Adaptation in Developing Countries: Policy Options for Innovation and Technology Diffusion. International Center for Trade and Sustainable Development.

Martino, D. 2009. Mitigation in Agriculture: Main Findings of IPCC AR4. Presented to AWG-LCA In-Session Workshop: Opportunities and Challenges for Mitigation in the Agricultural Sector. Bonn, Germany. 4 April 2009.

Moorhead, A., 2009, "Climate, agriculture and food security: A strategy for change." Consultative Group on International Agricultural Research (CGIAR) December 2009.

Nair, C.T.S. and Rutt, R., 2009, "Creating forestry jobs to boost the economy and build a green future," article developed from background paper "Impacts of Global Economic Turbulence on the Forest Sector" at the nineteenth session of the FAO Committee on Forestry, Rome, 20 March 2009.

Nelson, G.C., Rosegrant, M.W., Palazzo, A., Gray, I., Ingersoll, C., Robertson, R., Tokgoz, S., Zhu, T., Sulser, T.B., Ringler, C., Msangi, S., and You, L., 2010a, Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Option. International Food Policy and Research Institute, Washington DC.

Nelson, G.C., Rosegrant, M.W., Koo, J., Robertson, R., Sulser, T., Zhu, T., Ringler, C., Msangi, S., Palazzo, A., Batka, M., Magalhaes, M., Valmonte-Santos, R., Ewing, M., and Lee, D. 2010b. The Costs of Agricultural Adaptation to Climate Change. Discussion Paper 4: Development and Climate Change. World Bank.

Nepstad, D., B. S. Soares, F. Merry, A. Lima, P. Moutinho, J. Carter, M. Bowman, A. Cattaneo, H. Rodrigues, S. Schwartzman, D. G. McGrath, C. M. Stickler, R. Lubowski, P. Piris-Cabezas, S. Rivero, A. Alencar, O. Almeida, and O. Stella. 2009. The End of Deforestation in the Brazilian Amazon. Science 326 (5958):1350-1351.

New, M., D. Liverman, H. Schroder, and K. Anderson, 2011, Four degrees and beyond: the potential for a global temperature increase of four degrees and its implications. Phil Trans R Soc A January 13, 2011 369:6-19

NRC, 2001, "Climate Change Science: An Analysis of Some Key Questions." Committee on the Science of Climate Change, Division on Earth and Life Studies, National Research Council. Washington, DC., National Academy Press. URL: http://books.nap.edu/openbook/0309075742/html/ index.html.

Nwanze, K.F., 2009, "Agriculture and Rural Development Day 2009 Keynote Statement." Copenhagen, 12 Dec 2009.

OECD 2007, "Agricultural policies in non-OECD countries: Monitoring and Evaluation." Organization for Economic Co-operation and Development; Paris, France.

Olofsson, J. and T. Hickler, 2008, Effects of human land-use on the global carbon cycle during the last 6,000 years. Vegetation History and Archaeobotany 17:605–15.

Padgham, J., 2009. "Agricultural Development Under a Changing Climate: Opportunities and Challenges for Adaptation." Joint Departmental Discussion Paper – Issue 1. Agricultural and Rural Development and Environment Departments. August 2009.

Parry et al., 2004, Effects of climate change on global food production under SRES emissions and socio-economic scenarios. Global Environ. Chang., 14, 53-67.

Parker, C., Brown, J., Pickering, J., Roynestad, E., Mardas, N., and Mitchell, A. W., 2009, The Little Climate Finance Book. Global Canopy Fouyndation. Oxford. December 2009.

Paustian, K., C.V. Cole, D. Sauerbeck and N. Sampson,1998, CO_2 mitigation by agriculture: An overview. Climatic Change 40:135–62

Perez, C., Roncoli, C., Neely, C., and J.L. Steiner. 2007. Can carbon sequestration markets benefit low-income producers in semi-arid Africa? Potentials and challenges. Agricultural Systems 94(2007): 2-12

Pingali, P. 2007. Agricultural Growth and Economic Development: a view through the globalization lens. Agricultural Economics 37: 1-12

Popp, A., Lotze-Campen, H. & Bodirsky, B. 2010. Food consumption, diet shifts and associated non-CO2 greenhouse gases from agricultural production. Global Environmental Change 20, 451-462.

Project Catalyst, 2009, "Scaling up climate finance".

Raupach, M.R. Marland, G. Ciais, P. Le Que, C., Canadell, J.G., Klepper, G. and Field, C.B., 2007, "Global and regional drivers of accelerating CO2 emissions," 10288–10293 _ PNAS _ June 12, 2007 _ vol. 104 _ no. 24

Schmidhuber, J. Bruinsma, J. Boedeker, G., 2009. "Capital requirements for agriculture in developing countries to 2050." Food and Agriculture Organization of the United Nations; Economic and Social Development Department. Rome, Italy. ftp://ftp.fao.org/docrep/fao/012/ak974e/ak974e00.pdf

Seeberg-Elverfeldt, C. and M. Tapio-Bistrom. 2010, "Global Survey of agricultural mitigation projects." FAO August 2010, Rome, Italy.

Christina Seeberg-Elverfeldt, 2010. Carbon Finance Possibilities for Agriculture, Forestry and Other Land Use Projects in a Smallholder Context. FAO, Rome, Italy.

Sharma, S., 2010, "Agriculture in the climate talks: Tianjin, October 18, 2010." Institute for Agriculture and Trade Policy. URL: http://www.iatp.org/iatp/commentaries.cfm?refid=107749

Sheeran, J., 2010, "Statement by Ms. Josette Sheeran, Executive Director, United Nations World Food Programme, (Delivered by Sheila Sisulu, Deputy Executive Director), New York, 8 March 2010

Smith, P., D. Martino, Z. Cai, D. Gwary, H.H Janzen, P. Kumar, B. McCarl, S. Ogle, F. O'Mara, C. Rice, B. Scholes, 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 [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Smith, P., D. Martino, Z. Cai, D. Gwary, H.H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O'Mara, C. Rice, R.J. Scholes, O. Sirotenko, M. Howden, T. McAllister, G. Pan, V. Romanenkov, U. Schneider, S. Towprayoon, M. Wattenbach, and J.U. Smith, 2007a, Greenhouse gas mitigation in agriculture. Philosophical Transactions of the Royal Society, B., 363. doi:10.1098/rstb.2007.2184.

Smith, P. and Martino, D., 2007, Agriculture. In: Climate Change 2007 (IPCC, 4th Assessment Report);

Stehfest, E., Bouwman, L., van Vuuren, D., den Elzen, M., Eickhout, B. & Kabat, P. 2009. Climate benefits of changing diet. Climatic Change 95, 83-102.

TCG 2009, "Tools for Setting Reference Emission Levels A review of existing tools that can be used to set a benchmark for rewarding reduced emissions and increased sequestration of greenhouse gasses in the terrestrial system." Policy Briefs II, Discussion Draft June 2009.

Thornton, P.T. Jones, P.G., Ericksen, P.J., Challinor, A.J., 2011, Agriculture and food systems in sub-Saharan Africa in a 4°C+ world doi: 10.1098/rsta.2010.0246 Phil. Trans. R. Soc. A 13 January 2011 vol. 369 no. 1934 117-136.

Towprayoon, 2007, Policy and technological constraints to implementation of greenhouse gas mitigation options in agriculture. Agriculture, Ecosystems & Environment, 118(1-4): 6-28.

U.S. EPA, 2006a, Global Mitigation of Non-CO2 Greenhouse Gases. U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA. 2006b, Global Anthropogenic Non-CO2 Greenhouse Gas Emissions: 1990–2020. U.S. Environmental Protection Agency, Washington, DC.

UNFCCC 1992, United Nations Framework Convention on Climate Change, United Nations. FCCC/INFORMAL/84 GE.05-62220 (E) 200705. URL: http://unfccc.int/resource/docs/convkp/conveng.pdf

UNFCCC 1998, Kyoto Protocol to the United Nations Framework Convention on Climate Change. URL: http://unfccc.int/resource/docs/convkp/kpeng.pdf.

UNFCCC, 2007. Bali Action Plan. Decision 1/CP.13 United Nationas Framework Convention on Climate Change, Bali, Indonesia. FCCC/CP/2007/6/Add.1.

UNFCCC 2010a Outcome of the work of the Ad Hoc Working Group on long-term Cooperative Action under the Convention. Draft decision/CP16. United Nations Framework Convention on Climate Change, Cancun Mexico.

Vermeulen, S.J., Aggarwal, P.K., Ainslie, A., Angelone, C., Campbell, B.M., Challinor, A.J., Hansen, J., Ingram, J.S.I., Jarvis, A., Kristjanson, P., Lau, C., Thornton, P.K, and Wollenberg, E., 2010, Agriculture, Food Security and Climate Change: Outlook for Knowledge, Tools and Action. CCAFS Report 3. Copenhagen, Denmark: CGIAR-ESSP Program on Climate Change, Agriculture and Food Security.

Vitousek, P.M., H.A. Mooney, J. Lubchenco and J.M. Melillo, 1997, Human domination of earth's ecosystems. Science 277: 494–9.

Vlek, P.L.G., G. Rodriquez-Kuhl and R. Sommer, 2004, Energy use and CO2 productoin in tropical agriculture and means and strategies for reduction or mitigation. Environment, Development and Sustainability, 6(1-2): 213-233.

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

World Bank, 2007, World Development Report 2008: Agriculture for Development. Washington DC.

World Bank, 2009, The Global Agriculture and Food Security Program (GAFSP) Questions and Answers. URL: http://siteresources.worldbank.org/NEWS/Resources/GAFSPQuestionsAnswers_ext042210.pdf

World Bank, 2009b, World Development Report 2010: Development and Climate Change, Washington DC.

World Bank, 2010, Rising Global Interest in Farmland: Can it Yield Sustainable and Equitable Benefits. 7 September 2010.

8. Annexes

8.1. Stakeholders

A selected list of interviewees includes Misha Wolsgaard-Iversen (CGIAR), Dr. Joan Kagwanja (Alliance for a Green Revolution in Africa), Dr. Harun M. Warui (Kenya Agricultural Research Institute, Gerald Nelson (IFPRI). Genito Maure (University of Cape Town), Dr. Lindiwe Majee Sibanda (FANRPAN) and Maria M. Mulinidi (Alliance for a Green Revolution in Africa) and a number of government officials and negotiators from developing countries who spoke on condition of anonymity given the political sensitivity of the subject.

8.2. Funds

Table 17: Agriculture-relevant funds with a focus on climate change adaptation[48]

Funds	Description	Approved projects	Fund size million (USD)
UN Adaptation Fund (AF)	The AF was established under the Kyoto protocol to finance concrete adaptation projects and programmes in developing countries that are party to the Kyoto protocol	2	197
Least Developed Countries Fund (LDCF)	The LDCF assists the 49 least developed countries under the UNFCCC to prepare and implementing national adaptation programmes of action (NAPAs)[49]	92 (including NAPA preparation)	262
Special Climate Change Fund (SCCF)	The SCCF finance and implement activities that increase resilience of national development sectors to the impacts of climate change in non-Annex I countries; significant agricultural component.[50]	30	149
Pilot Program for Climate Resilience (PPCR)	WB initiative to pilot and demonstrate approaches for integration of climate risk and resilience into development policies and planning with 9 country programs and 2 regional programs. All 9 country programs mention agriculture as a component.	9 pilot countries 2 pilot regions	1,036

Table 18: Agriculture-relevant funds with a focus on climate change mitigation

Funds	Description	Approved projects	Fund size million (USD)
Global Environment Facility (GEF)	The GEF receives funding from multiple donor countries and provides grants and concessional loans to cover the "incremental costs" associated with	2644[52]	GEF-5 (2010-2014): USD 4.35

[49] Decision 5/CMP.7. NAPAs provide a process for LDCs to identify priority activities that address their urgent and immediate needs to adapt to climate change—those for which further delay would increase vulnerability and costs.
[50] Decision 7/CP.7, Funding under the Convention, paragraph 1 (c)

Trust Fund	transforming a project with national benefits into one with global environmental benefits. Projects and funding for agriculture relatively low between 2006 and 2010 but future potential.[51]		billion
EU Global Climate Change Alliance (GCCA)	The Global Climate Change Alliance (GCCA) aims at supporting the poorest and most vulnerable countries with respect to their capacity to adapt to the effects of climate change. Only 2 agricultural related between 2008 and 2009 although other projects deal with related aspects (food security, forestry, land use) for mitigation and adaptation.[53]	18	~205 (EUR 141.2 million)
BioCarbon Fund	The BioCarbon Fund provides carbon finance for projects that sequester or conserve greenhouse gases in forests, agro- and other ecosystems.	15	N/A
Forest Investment Program (FIP)	The Forest Investment Program (FIP) is a targeted program of the Strategic Climate Fund (SCF) within the Climate Investment Funds (CIF). It was established to catalyze policies and measures and mobilize funds to facilitate REDD and promote improved sustainable management of forests.	8 pilot countries in the FIP	620
UN-REDD Programme Fund	The UN-REDD Programme was launched in September 2008 to assist developing countries prepare and implement national REDD+ strategies. Currently it has 29 partner countries spanning Africa, Asia-Pacific and Latin America, of which 12 are receiving support to National Programme activities.	12 supported countries	112
Forest Carbon Partnership Facility (FCPF)	Partnership created by the World Bank to support developing countries in their REDD efforts, activities and policy development. There are 37 developing countries in the partnership. There are two separate funds in the FCPF, a readiness fund (for REDD readiness) and a carbon fund (for performance based payments).	13 countries have been awarded formulation grants[54]	221

8.3. CSA project & programme inventory

There are few high quality global surveys of agricultural mitigation and adaptation projects. The two most extensive global surveys are the i) UNEP Risoe CDM/JI pipeline and ii) FAO agriculture, forestry and other land use (AFOLU) projects database.[55] Regional assessments are also available.[56] We have reviewed and presented a summary of the findings below. The UNEP Risoe database follows the CDM classification of project activities, which underestimates the amount of agriculture related projects because methane capture or projects using agricultural residues are considered as energy projects. In the FAO database,

[52] As of January, 2011
[51] Selection whether projects are solely or partly focusing on agriculture, based on project outlines in GEF reports; 4th replenishment period.
[53] In 2010, the beneficiary countries are: Belize, Mozambique, Nepal, the Pacific region plus the Solomon Islands, Ethiopia, The Gambia and Sierra Leone.
[54] As of November, 2010
[55] (Varming et al. 2010; Seeberg-Elverfeldt, C. and Tapio-Bistrom, M., 2010)
[56] World Agrogorestry Centre (ICRAF) inventory (Chomba and Minang 2009)

listed projects highlight that many sustainable agricultural land management practices have mitigation and adaptation benefits. However, in most of the projects the benefits are not quantified against a baseline or reference scenario and projects are not additional because they are funded already for other purposes. Nevertheless the FAO database shows that there are a number of effective climate smart technologies that are available to be scaled.

UNEP Risoe CDM/JI pipeline

A survey of agricultural projects in the CDM/JI pipeline (TO BE RELEASED) found agriculture represents 17% (964 projects) of the 5,824 recorded projects, and is expected to reduce 582 mtCO2e by 2020 (or a 7% share). Agricultural projects in this survey are defined according to FAO guidelines as "a project that uses agricultural systems or residuals/outputs from agricultural processes to directly or indirectly reduce greenhouse gas emissions. The cumulative mitigation of agricultural projects, when combined with all land use activities such as forestry, represents about 3% (50 MtCO2e) of the estimated 1,629 MtCO2e potential abatement believed to exist in developing counties by the IPCC. The average mitigation per project is about 604,000 tCO2e through 2020. Most of these projects are concentrated in just five countries (like the CDM at large) with China, India, Brazil, Mexico and Malaysia accounting for 79% of all agricultural projects. The results are summarized in the Table 20 below.

Table 19: CDM projects by type and expected mitigation impact by 2012 and 2020 (WORLD BANK, 2011)

Projects		Mitigation impact by 2012	Mitigation impact by 2020	Average project impact ((ktCO2e))	
Project type	**number**	**ktCO2e**	**ktCO2e**	**2012**	**2020**
Agriculture	964	219,507	582,081	228	604
Forests	58	16,638	69,109	287	1,192
Non-agriculture					
Hydro	1,558	482,160	1,894,491	309	1,216
Alternative energy	1,221	326,170	1,154,888	267	946
Energy Efficiency	837	332,619	1,139,571	397	1,361
Methane avoidance	340	191,296	596,638	563	1,755
Landfill gas	326	204,097	537,122	626	1,648
Assorted gases	145	340,797	904,581	2,350	6,238
Biomass energy	141	36,958	101,004	262	716
Fossil fuel switch	133	191,523	585,274	1,440	4,401
Cement	44	35,444	76,590	806	1,741
Transport	34	10,157	39,160	299	1,152
HFCs	23	476,541	1,100,353	20,719	47,841
Total	5,824	2,863,906	8,780,862	492	1,508
Agriculture	964	219,507	582,081	228	604
Forests	58	16,638	69,109	287	1,192

Table 20: CDM projects expected mitigation impact by core set of activities (WORLD BANK, 2011)

Type of projects	Number of projects	Expected mitigation (ktCO2e)	
		2012	**2020**
Agricultural residues	615	153,768	428,634
Manure	288	52,837	119,486
Composting	60	12,883	33,861

Land use	57	16,614	69,054
Irrigation	1	18	100
Mangroves	1	24	55
Total	1,022	236,145	651,189

FAO database: AFOLU projects

The FAO database on projects that target agriculture, forestry and other land uses (AFOLU) has recorded 497 AFOLU mitigation projects from various registries and crediting regimes. "Agriculture" is defined broadly here to encompass on-farm and off-farm activities but excludes all processing activities (including those from residues) and thus does not account for projects include in the CDM analysis above.

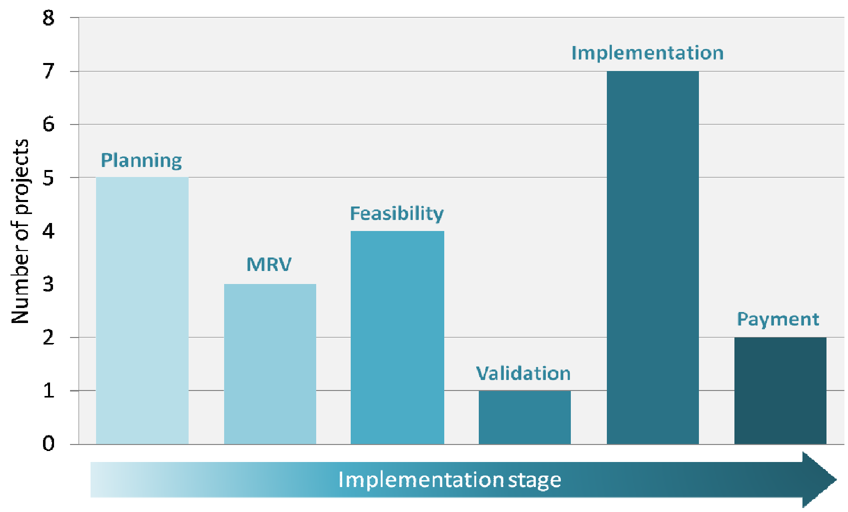
The 2010 data 74 (less than 10%) of projects were defined as agricultural (and only 50 adequately adequately responded to the surveys).[57] The rate of new project creation in agriculture is slowing, affected by the same economic challenges and political uncertainty dampening the supply of other AFOLU credits. AFOLU projects between 2007-2009 shifted toward forestry (after a peak in 2006 dominated by swine manure/methane projects) and diversified away from CDM standards toward voluntary regimes. This growth halted in 2010. As of July 2010, only 19 new AFOLU projects, mostly REDD+ and A/R, were identified compared to a total of 100 in 2009 – on track for a 60% decease.

The primary mitigation activities were off-farm land rehabilitation with benefits to farmers (30.3%); on-farm practices, agroforestry and soil management (27.6%); REDD with benefits to farmers (7.9%); others (7.9%). CSA practices employed were restoration of degraded soils, and agroforestry, along with cropland management and improved livestock management. Projects were generally at early stages of development (some consist only of proposals or project information notes) and lacked private sector involvement – most are sponsored by international and domestic NGOs, universities, and research institutions (See Figure 20). A summary description of the projects follows (Varming *et al. 2010*):

- Geographic distribution: Latin America and Caribbean (14), Asia (5), Africa (2), Eastern Europe (1).
- Area: average size is 8,000 ha to 300,000 ha (with two largest projects included)
- Project duration: 2-50 year (17 average)
- Number households: 20 – 150,000 (20,000 average)
- Categories: annual crops and/or grazing (11), Perennial corps (5), grazling (3), and other (3)

Figure 20: Implementation stages of registered agricultural project with mitigation component (FAO 2010)

[57] The projects listed are therefore all directly related to land use and livestock keeping, and include carbon sequestration from agriculture and forestry activities, as well as manure treatment from livestock. Processing activities such as slaughter, milling or sawmilling are not included, nor are projects involving agricultural residues such as rice husk or bagass.



8.4. NAMA and sectoral approaches

NAMAs have been submitted by all major developing country emitters. Of the more than 27 agricultural submissions by developing countries, seven are non-sector specific and 11 involve mitigation actions in the agricultural sector (FAO 2010d). Activities include i) crop residue management; ii) cropland-related mitigation practices in specific areas; iii) build capacity and conduct research to identify and develop good agricultural practices for reducing GHG emissions at the farm level; iv) develop carbon projects in forestry and agriculture; v) 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. Two countries have issues specific agricultural mitigation targets but noted these are voluntary domestic reductions and may include the Clean Development Mechanism. Four countries submitted quantitative agricultural reduction targets

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 21.

Table 21: Agricultural NAMA submissions to the UNFCCC (13 Jan 2011)

Country	Mode	Activity	Implementation
Brazil	GHG cuts & sinks	Cropland and livestock management	Integrated crop-livestock system (range of estimated reduction:18 to 22 million tons of CO2 eq in 2020
			No-till farming (range of estimated reduction: 16-20 million tons eq in 2020
			Implementation of agroforestry practices and systems on 261,840 square 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 popularisation in 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 popularisation 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 population with regard to improved techniques and crops better adjusted to global warming"
Eritrea	GHG sinks	Sustainable land management	Implement projects and programmes which enhance soil carbon stocks in agricultural soils
	N/A	Sustainable land planning	Develop and elaborate appropriate and integrated plans which are supportive of 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 agroforestry	Application of compost on 8000 square km of agricultural land of rural local communities for increased carbon retention by the soil
			Implementation of agroforestry practices and systems on 261,840 square 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 is targeted and with application of diverse international mechanisms 1900,000 ha is targeted."
Ghana	GHG cuts & sinks	Sustainable land management	Uncontrolled burning (promote spot and zero burning practices); Improved land preparation (promote minimum tillage ; incentivise use of bio-fuels for mechanised 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	i) Growing perennial forages in Badia region; ii) Best management practices in irrigated farming fertilization applications)
	GHG cuts	Methane capture	Use of methane emitted from livestock and chicken farming production and slaughter houses
Macedonia	GHG cuts	Enabling conditions for GHG emission reduction	i) Completion of institutional and legal reforms in irrigation sector; ii) increasing institutional and individual capacity for applying international funds iii) development of systems to apply "good agricultural practices" 5) financial incentives for mitigation technologies.

		Mitigation technologies	i) Installation of methane recovery and flaring systems at selected farms; ii) Research support program for development of new mitigation technologies and transfer of existing ones; iii) Program of introduction of practices that use the agriculture potential for renewable energy and carbon sequestration; iv) programmatic CDM projects
	Capacity	Carbon finance capacity building	National and local training and capacity strengthening for i) training for CDM potential in agriculture; ii) training for preparation of CDM documentation
		Mitigation technologies and capacity building	Training of farmers/decision makers in i) GHG mitigation issues (upgrade to current curricula and syllabuses); ii) Training of farmers for adopting new technologies; iii) familiarization of public and institutions with the problems of climate mitigation
Madagascar	N/A	Crop improvement and fertilization	i) Increase forage seeds and ensure their popularization; ii) Intensify the production of enhanced agricultural seeds; iii) 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: i) promote public transportation; ii) utilize butane gas as a replacement of the use of wood products; iii) 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 2025 $KtCO_2e$/year
Papua New Guinea	GHG cuts	N/A	High-level policy objectives for GHG reductions in agriculture sector of 15-27 $MtCO_2e$/year relative to BAU projections of 31 - 58 Mt CO2/year by 2030 (estimates in 2010 of 25-38 $MtCO_2e$/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 programmes for energy production
Togo	GHG cuts	Efficiency	"i) Reduction of energy consumption by use of common transportation; ii) use of gas as a replacement to fuel; iii) Replacing non-energy efficient lamps with energy-efficient ones"
Tunisia	GHG cuts & sinks	Sustainable land management and efficiency	i) Expand "biological farming" to 500,000 hectares by 2014; ii) Upgrade farms to "international standards" and promote water-saving irrigation on ≥ 200,000 hectares vs. 120,000 hectares in 2009; iii) Support brackish water desalinization of treated wastewater for agriculture using recycling and efficient technologies