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IFPRI Discussion Paper 01004

July 2010

Potential of Carbon Markets for Small Farmers

A Literature Review

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PARTNERS AND CONTRIBUTORS

IFPRI gratefully acknowledges the generous unrestricted funding from Australia, Canada, China, Denmark, Finland, France, Germany, India, Ireland, Italy, Japan, the Netherlands, Norway, the Philippines, South Africa, Sweden, Switzerland, the United Kingdom, the United States, and the World Bank.

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ABSTRACT

While agriculture accounts for an estimated 10 to 14 percent of total greenhouse gas emissions, its role as a mitigating force is receiving increasing attention. This discussion paper provides a quick overview of the literature on the climate change mitigation potential of agriculture, the regulatory and voluntary frameworks under which such a contribution could be rewarded, and the economic literature that focuses on agriculture's participation in climate change mitigation efforts. While there is general agreement on the potential for mitigation, several barriers have prevented farmers from entering the so-called carbon markets. The paper reviews the main challenges faced by smallholder farmers in accessing such markets.

Keywords: smallholder farmers, carbon markets, carbon sequestration

ABBREVIATIONS AND ACRONYMS

AR4	IPCC fourth assessment report
AWG-LCA	ad hoc working group on long-term cooperative action under the convention
CCX	Chicago Climate Exchange
CDM	clean development mechanism
CER	certified emission reduction
CFI	carbon financial instrument
COP	conference of the parties
ERU	emission reduction unit
EU ETS	European Union Emission Trading Scheme
GHG	greenhouse gas
IPCC	intergovernmental panel on climate change
JI	joint implementation
LULUCF	land use, land use change, and forestry
NAMAs	nationally appropriate mitigation actions
OECD	Organization for Economic Co-operation and Development
OTC	over the counter
REDD	reducing emissions from deforestation and forest degradation
SALM	sustainable agricultural land management
SRES	special report on emissions scenarios
UNFCCC	United Nations Framework Convention on Climate Change
VER	verified emission reduction

1. INTRODUCTION

In just the few years since markets for greenhouse gas (GHG) emission reductions have been established, their combined value has increased to more than US$100 billion[1] (Capoor and Ambrosi 2009). However, agriculture has been largely excluded from both formal and informal carbon markets, chiefly because of the high level of uncertainty surrounding agricultural mitigation and the transaction costs associated with smallholder agriculture, which manages most of the agricultural carbon. Key uncertainties include the amount of carbon that can be sequestered by agricultural soils, the reduction in emissions obtainable from the agricultural sector, and the length of time that carbon can be stored in the soil. Transaction costs depend on the costs of monitoring, reporting, and verifying changes in soil carbon and emissions and on the cost of aggregating and organizing farmers. This paper reviews these challenges and some of the proposed methods to ensure that smallholder farmers gain access to the markets that reward climate change mitigation activities. The paper first provides an overview of GHG emissions and the associated mitigation potential of the agricultural sector. This is followed by an overview of the regulatory and voluntary carbon markets that are currently available for emission abatement. After a brief review of the economic literature that analyzes the potential contribution of agriculture to climate change mitigation, the paper describes the opportunities and challenges for smallholders to access payments for environmental services, such as carbon markets, and ends with a series of final considerations and conclusions.

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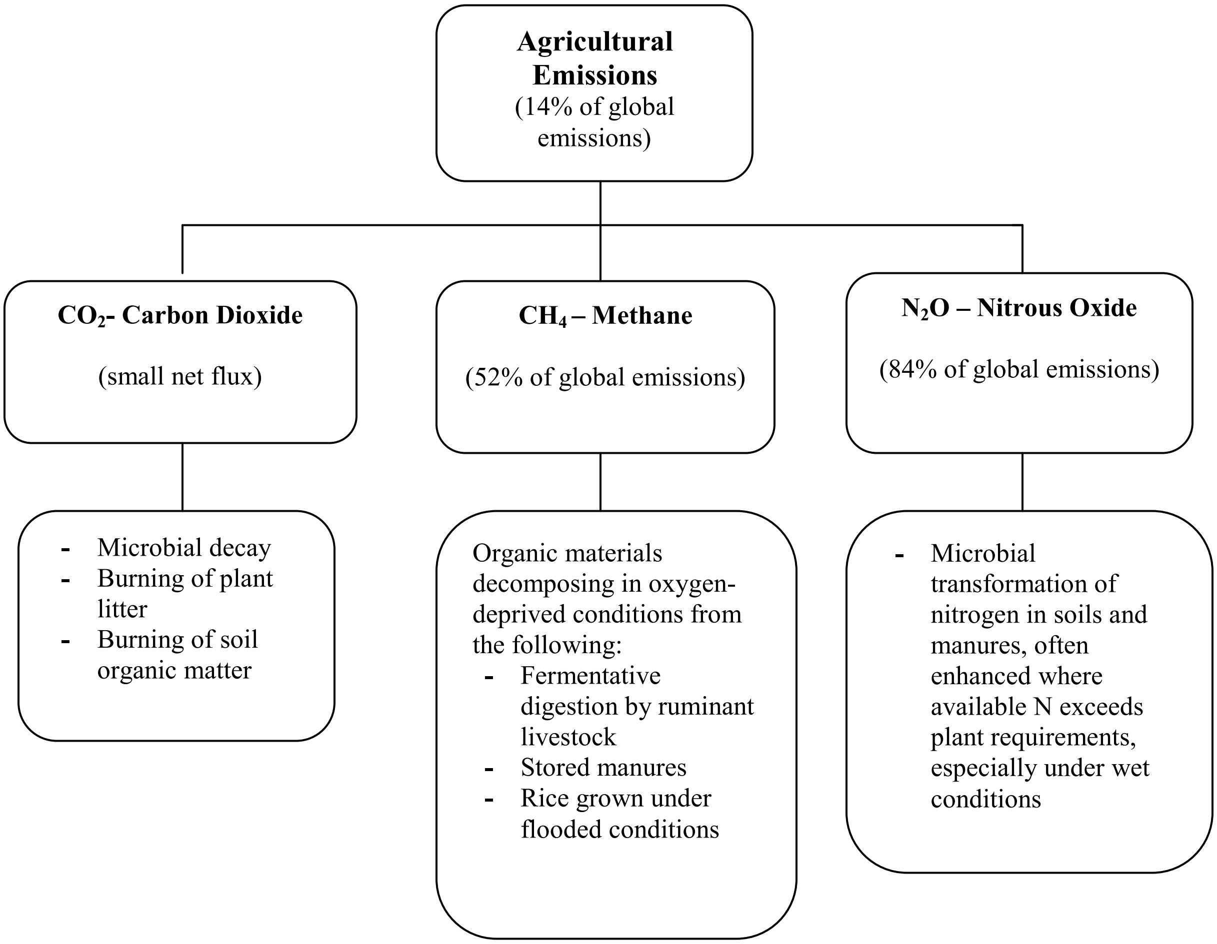
[1] All dollar amounts in this paper are expressed in U.S. dollars.

2. AGRICULTURAL EMISSIONS AND AGRICULTURAL MITIGATION POTENTIAL

Agriculture's contribution to global GHG emissions is estimated to be 10 to 14 percent of total emissions (Smith et al. 2007b; Baumert, Herzog, and Pershing 2005; FAO 2009b). Furthermore, agriculture is the largest source of non–carbon dioxide GHG emissions, generating 52 percent and 84 percent of total methane and nitrous oxide emissions, respectively. Methane (CH_4) emissions come from organic materials decomposing in oxygen-deprived conditions such as irrigated rice fields, while nitrous oxide (Nh_2O) emissions are a result of nitrogen that exceeds plant requirements (Smith et al. 2008). Carbon dioxide (CO_2) comes from microbial decay, burning of plant litter, and burning of soil organic matter. However, the net flux of this gas in agriculture is thought to be small (Figure 1).

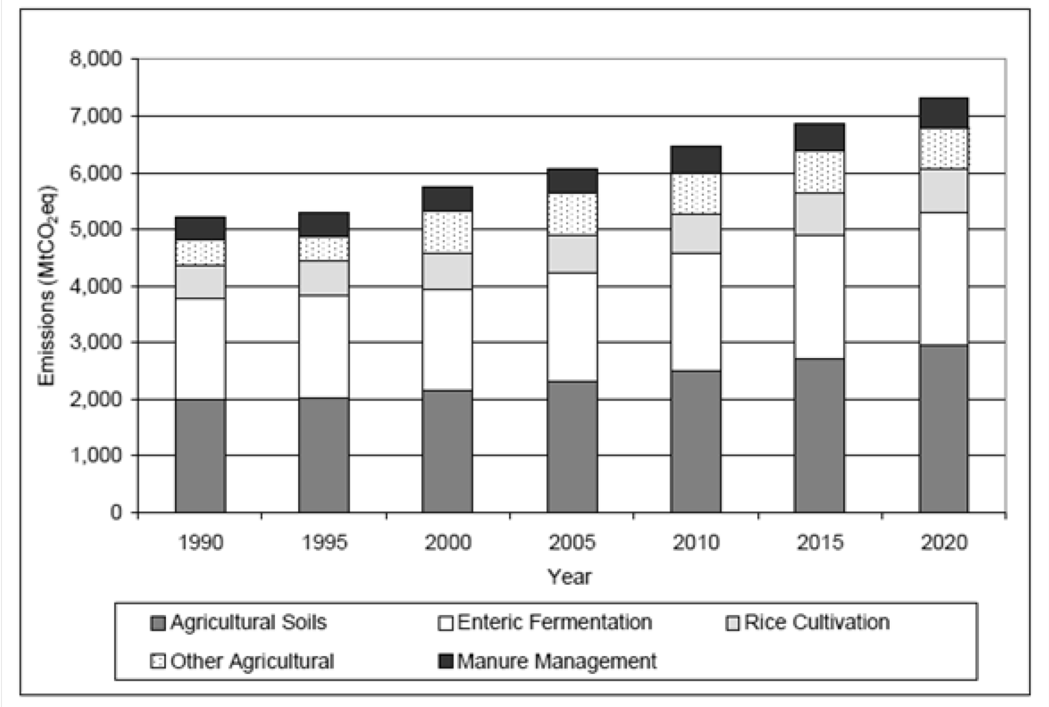
Figure 1. Agricultural GHG emissions



Sources: Smith et al. 2008; USEPA 2006b.

Emissions from agriculture are increasing rapidly and are expected to continue to increase over the next decades. According to USEPA (2006a), agricultural emissions are expected to increase from less than 6,000 metric tons[2] of CO_2 equivalent ($MtCO_2eq$) in 2005 to over 7,000 $MtCO_2eq$ by 2020. The largest sources of GHG emissions in agriculture are agricultural soils and enteric fermentation (Figure 2).

Figure 2. Total emissions from the agricultural sector by source (MtCO2eq)



Source: USEPA 2006a

Compared to 2000 levels, N_2O emissions from agricultural soils are projected to increase by 37 percent by 2020, enteric livestock CH_4 emissions by 30 percent, manure CH_4 and N_2O emissions by 24 percent, and CH4 emissions from rice cultivation by 22 percent (USEPA 2006b). According to these estimates, emissions will continue to be mainly from agricultural soils and enteric fermentation.

China, India, Brazil, and the United States are the largest emitters of non-CO_2 GHGs from agriculture (Verchot 2007). By 2020, those countries are still projected to be the main emitters of non-CO_2 GHGs from agriculture. However, the cumulative growth rate in business-as-usual emissions of non-CO_2 GHGs is expected to be largest in the Middle East (increasing by 197 percent), followed by Africa, Latin America, South and Southeast Asia, and China and other Asia with growth of 104 percent, 86 percent, 64 percent, and 58 percent, respectively, compared to 1990 levels. Non-CO_2 GHG emissions from China and India, the top two emitters in the world, are projected to increase by about 62 percent and 72 percent from 1990 to 2030 (Verchot 2007). In developed countries, emissions will increase much more slowly, with emissions from member countries of the Organisation for Economic Co-operation and Development (OECD) expected to grow at 10 percent over the same period (USEPA 2006a). Higher emission rates are mostly due to population and income growth, rising per capita caloric intake, and changing diet preferences in developing countries (that is, choice of meat and dairy products over grains and vegetables) (USEPA 2006b).

According to Rosegrant et al. (2009), global cereal production is projected to increase 0.9 percent per year during 2000–2050, with faster growth through 2025 followed by a slowdown. Demand for meat

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[2] Throughout this paper, tons refers to metric tons.

products (beef, sheep and goat, pork, and poultry) will grow more rapidly but also slow somewhat after 2025, from 1.8 percent to 1.0 percent annually. Total cereal demand is projected to grow by 1.048 billion metric tons, or 56 percent; 45 percent of the increase is expected to be for maize, 26 percent for wheat, 8 percent for rice, and the remainder for millet, sorghum, and other coarse grains. Rapid growth in meat and milk demand in most of the developing world will put strong demand pressure on maize and other coarse grains used as feed. Globally, cereal demand for feed will increase by 430 million metric tons during 2000–2050, a staggering 41 percent of total cereal demand increase. Slightly more than 60 percent of total maize will be used as animal feed and a further 16 percent for biofuels. China and India will account for 12 percent and 10 percent, respectively, of the total increase in cereal demand.

Although agriculture is an emitter of GHGs, it can also play an important role in mitigating the progression of global warming. Smith et al. (2008) assessed the economic potential of agricultural mitigation of GHG emissions, including cropland- and livestock-based options. They estimated the global technical GHG mitigation potential for agriculture by 2030 to be about 5,500 to 6,000 $MtCO_2eq.$ per year. The global economic mitigation potential is presented in Table 1 for various levels of carbon prices.

Table 1. Economic mitigation potential of agriculture by 2030

Quantity: $MtCO_2eq.yr^{-1}$	Carbon Prices: US\$ t CO_2-eq.$^{-1}$
1,500–1,600	0–20
2,500–2,700	0–50
4,000–4,300	0–100

Sources: Smith et al. 2008.

Despite the fact that the net flux of CO_2 from agriculture is small, much of the GHG mitigation potential in agriculture comes from soil carbon sequestration, particularly through cropland management, grazing land management, and restoration of cultivated organic soils and of degraded lands (Smith et al. 2008). Table 2 (at the end of this paper) summarizes some possible mitigation opportunities according to Smith et al. (2008). Rice management and livestock practices have the highest potential for the reduction of methane emissions (Figure 3).

Table 2. Mitigation opportunities in agriculture

Mitigation opportunity	Category	Examples	Mitigative effects	Problems
Cropland management	Improved agronomic practices	- Improved crop varieties - Extending crop rotation - Avoiding or reducing use of bare (unplanted) fallow - Adding more nutrients (fertilizers) when deficient - Less intensive cropping systems (reduced reliance on pesticides and other inputs) - Temporary vegetative cover between agricultural crops	- Increased soil C storage	Benefits from adding N fertilizer can be offset by higher emissions of N_2O from soils and CO_2 from fertilizer manufacture

Table 2. Continued

Mitigation opportunity	Category	Examples	Mitigative effects	Problems
	Nutrient management (higher N use efficiency)	- Precision farming - Using slow-release fertilizer forms or nitrification inhibitors - Avoiding time delays between N application and plant N uptake - Placing the N more precisely into the soil to make it more accessible to crop's roots - Avoiding excess N applications or eliminating N applications where possible	- Reduced emissions of N_2O - Indirectly reduced emissions of CO_2 from N fertilizer manufacture	
	Tillage/residue management	- Reduced tillage - No-till farming - Systems that retain crop residues - Avoiding the burning of residues	- Soil C gain	- Reduced or no till may affect N_2O emissions but net effects are inconsistent
	Water management	- Expanding irrigation areas - Using more effective irrigation measures	- C storage in soils	- CO_2 from energy used to deliver water may offset gains -N_2O emissions might increase as a result of higher moisture and fertilizer N inputs
	Rice management	- Draining the wetland rice once or several times during the growing season - Rice cultivar with low exudation rates - Keeping the soil as dry as possible and avoiding waterlogging during off-rice season - Adjusting the timing of organic residue additions - Composting the residues before incorporation or producing biogas for use as fuel for energy production	- Reduced emissions of CH_4	- Drainage might increase N_2O emissions and practice may be constrained by water supply

Table 2. Continued

Mitigation opportunity	Category	Examples	Mitigative effects	Problems
	Agroforestry	- Production of livestock or food crops on land that also grows trees for timber, firewood, or other tree products.	- Higher stock of C above ground - C sequestration	- Effects on N_2O and CH_4 emissions are not well known.
	Land cover (use) change	- Converting arable cropland to grassland -Converting drained croplands back to wetlands	- Increased storage of C	- Converting drained croplands back to wetlands might stimulate CH_4 emissions - Loss of agricultural productivity
Grazing land management and pasture improvement	Grazing intensity	-Optimally grazed lands (not ungrazed or overgrazed)	-Increased storage of C	
	Increased productivity (including fertilization)	-Alleviating nutrient deficiencies by fertilizer or organic amendments -Irrigating grasslands	-Increased storage of C	-Adding nitrogen may stimulate N_20 emissions -Net effect of irrigating grassland also depends on emissions from energy use
	Nutrient management	-Practices that tailor nutrient additions to plant uptake	-Reduced emissions of N_2O	-Management of nutrients on grazing lands may be complicated by deposition of faeces and urine from livestock
	Fire management	-Reducing the frequency and extent of fires through more effective fire suppression -Reducing the fuel load by vegetation management Burning at a time of year when less CH_4 and N_20 are emitted.	-Reduced emissions of CH_4 and N_2O	
	Species introduction	-Introducing grass species with higher productivity or C allocation to deeper roots	-Increased storage of C	

Table 2. Continued

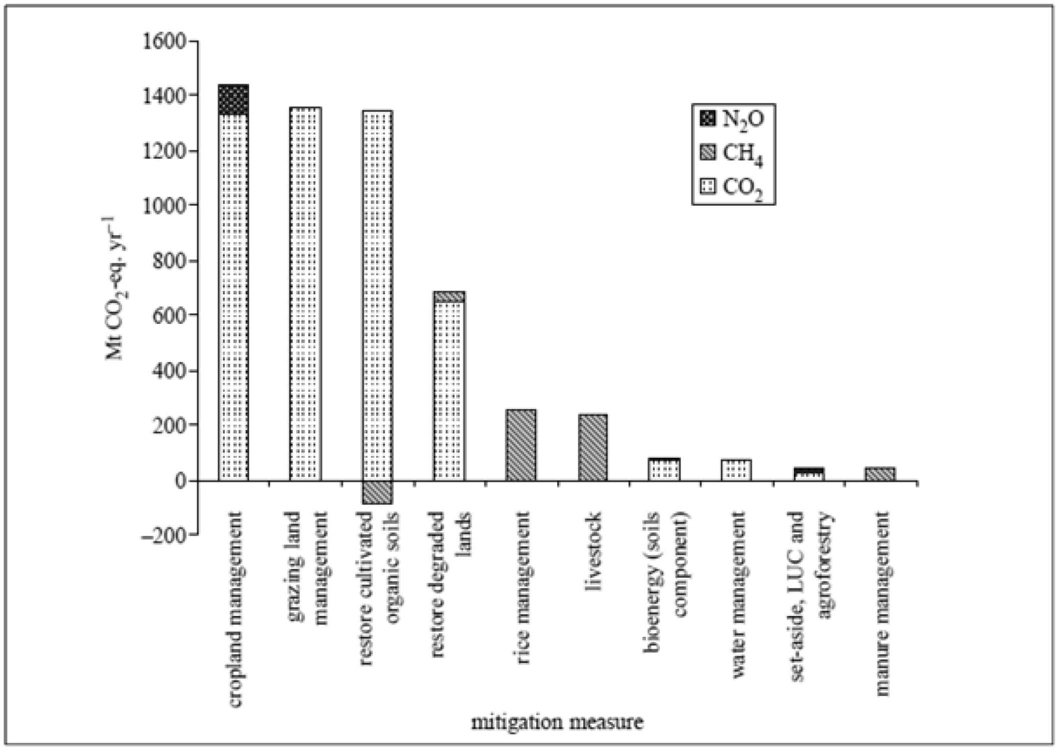
Mitigation opportunity	Category	Examples	Mitigative effects	Problems
Management of organic soils		- Avoiding row crops and tubers - Avoiding deep plowing - Maintaining a shallower water table - Avoiding the drainage of these soils or re-establishing a high water table where GHG emissions are still high	- Reduced emissions of CO_2 and N_2O	
Restoration of degraded lands		- Revegetation (planting grasses) - Improving fertility through nutrient amendments - Applying organic substrates, such as manures, biosolids, and composts - Reducing tillage and retaining crop residues - Conserving water	- Restoration of C storage	- Where practices involve higher N amendments, the benefits of C sequestration may be partly offset by higher N_2O emissions.
Livestock management	Improved feeding practices	-Feeding more concentrates, normally replacing forages -Adding oil to the diet -Improving pasture quality -Optimizing protein intake to reduce N excretion and N_20 emissions	Reduced emissions of CH_4	
	Specific agents and dietary additives	-Specific agents, mostly aimed at suppressing methanogenesis (ionophores, halogenated compounds, probiotics, propionate precursors, vaccines, bovine somatotrophin)	Reduced emissions of CH_4	
	Longer term management changes and animal breeding	-Increasing productivity through breeding and better management practices spreads the energy cost of maintenance across a greater feed intake	Reduced emissions of CH_4	

Table 2. Continued

Mitigation opportunity	Category	Examples	Mitigative effects	Problems
Manure management		-Cooling or covering the sources of manure stored in lagoons or tanks -Manures digested anaerobically -Storing and handling manures in solid rather liquid form	Reduced emissions of CH_4	Storing solid manure may increase N_20 formation.
Bioenergy		-Agricultural crops and residues as sources of feedstocks for energy to displace fossil fuels	The net benefit to atmospheric CO_2 depends on energy used in growing and processing the bioenergy feedstock	

Source: Smith et al. 2008.

Figure 3. Global biophysical mitigation potential ($MtCO_2eq.yr$-1) by 2030 of each agricultural management practice



Source: Smith et al. 2008.
Note: The figure shows the impacts of each practice on each GHG stacked to give the total for all GHGs combined (B1 scenario is shown[3] ; the pattern is similar for all SRES scenarios).

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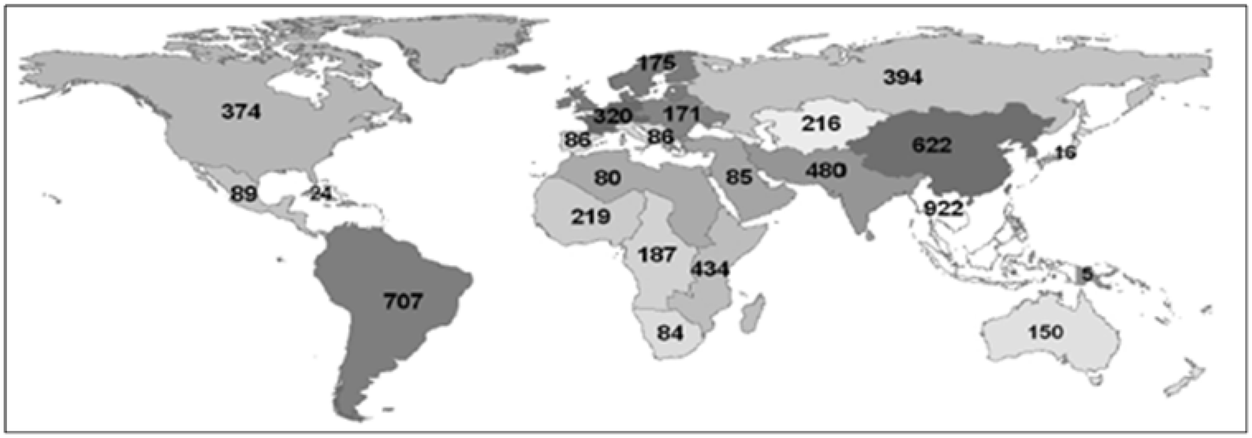
[3] Projections of climate change are run against different scenarios that make assumptions about possible economic

Soil carbon sequestration is generally considered more viable than N_2O reductions (USEPA 2006b). Almost 90 percent of the mitigation potential presented in Table 1 is from reduced soil emissions of CO2, about 9 percent from mitigation of CH_4, and about 2 percent from mitigation of soil N2O emissions (Smith et al. 2008). It is important to note that the estimates for the reduction of non-CO2 gaseous emissions are highly uncertain: the 95 percent confidence interval around the mean of 5,800 $MtCO_2eq$ obtained by Smith et al. (2008) is 300–11,400 $MtCO_2eq$ (Verchot 2007). Moreover, according to Kim and McCarl (2009), the effect of stochastic factors on soil carbon also makes the quantity of carbon generated under a sequestration project uncertain, so projects should have a discount rate for uncertainty.

Figure 4 reports agricultural mitigation potential by location. Among all regions, Southeast Asia has the largest mitigation potential.

Figure 4. Total technical mitigation potential (all practices, all GHGs: $MtCO_2eq/yr$) for each region by 2030, showing mean estimates



Source: Smith et al. 2007a.
Note: based on the B2 scenario; the pattern is similar for all SRES scenarios.

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development paths, greenhouse gas emission level, technological development and others. The B1 scenarios assume an integrated and environmentally friendly world.

3. OVERVIEW OF THE REGULATORY AND VOLUNTARY CARBON MARKETS

Carbon markets can be divided into two categories: the regulatory (compliance) market and voluntary markets. The 2009 United Nations Climate Change Conference in Copenhagen left the regulatory market, which had been created under the auspices of the Kyoto Protocol, unaltered. Important promises of new funding—$30 billion a year for three years increasing to $100 billion a year by 2020 to help poorer countries mitigate and adapt to climate change—were made in the Copenhagen Accord (UNFCCC 2009a). At this stage, it is unclear how these changes will affect the market mechanisms for helping poor countries and if the new monitoring, reporting, and verification actions agreed upon in the same Accord will actually help to build trust in the carbon markets.

Currently, the only land use, land use change, and forestry (LULUCF) practices accepted by the regulatory market are afforestation and reforestation. Soil carbon sequestration projects and projects that reduce emissions from agricultural soils, such as changes in rice management practices, are excluded. However, other projects related to agriculture such as biogas digesters are allowed, and to date more than 50 agricultural projects have been registered under the Clean Development Mechanism (CDM). In the voluntary market, where there are no legally binding agreements, agricultural soil projects represent a small share of the total volume of projects. As shown below, in 2008 such projects represented 15 percent of Chicago Climate Exchange (CCX) projects, but only 0.5 percent of the over-the-counter voluntary market. This might be due to problems related to permanence, monitoring, and other barriers presented in the section on ”Challenges for Smallholder Farmers in Accessing Carbon Markets,” below.

The Regulatory Market

The regulatory market was implemented under the Kyoto Protocol, which was adopted in 1997 and enforced in 2005. A main feature of the Kyoto Protocol is the commitment of industrialized countries (Annex I countries)[4] to reduce GHG emissions by an average 5.2 percent below their 1990 baseline over the five-year period 2008–2012 (UNFCCC 2009b). Three market-based mechanisms were offered by the Kyoto Protocol to help countries meet their emission targets:

- Emission Trading. This is a system that allows countries to buy carbon credits from other countries. The EU Emission Trading Scheme (EU ETS) is the largest market for GHG emission allowances. In 2008, the EU ETS market traded 3,093 $MtCO_2eq$, and the market was valued at $91.910 billion (Capoor and Ambrosi 2009).
- Joint Implementation (JI). This mechanism allows Annex B emitters[5] to purchase carbon credits from emission-reduction or emission-removal projects in another Annex B party. In 2008, 20 $MtCO_2eq$ of ERUs (Emission Reduction Units) were transacted, valued at $294 million, which represents a 50 percent decrease in volume compared to 2007 (Capoor and Ambrosi 2009).
- Clean Development Mechanism (CDM). The CDM is also a project-based transaction system that allows Annex I parties to accumulate carbon credits by financing carbon reduction projects in Non–Annex I parties (Hamilton et al. 2009). Certified Emission Reduction (CER) credits are issued for CDM projects.

The CDM accounts for the vast majority of project-based transactions. In 2007, it accounted for 87 percent of the volume of carbon transacted and 91 percent of its total value (Capoor and Ambrosi

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[4] Annex I countries are industrialized countries (members of OECD in 1992) and countries with economies in transition. Non–Annex I countries are developing countries

[5] Annex B countries are those included in Annex B in the Kyoto Protocol that have agreed to a target for their GHG emissions, including all the Annex I countries (as amended in 1998) with the exception of Turkey and Belarus (see Intergovernmental Panel on Climate Change glossary available at http://www.ipcc.ch/ipccreports/tar/wg3/454.htm).

2008). In 2008, the CDM market was valued at $6.519 billion, corresponding to a volume of 389 $MtCO_2eq$. Furthermore, the secondary market for CER was valued at $26.277 billion in 2008 (Capoor and Ambrosi 2009). In 2007, 73 percent of CDM projects (in terms of volume supplied) were located in China, followed at a distance by Brazil and India (6 percent each).

Countries in Africa, such as Kenya, Uganda, and Nigeria, and other countries in Asia, such as Malaysia, Philippines, Thailand, and Uzbekistan, have also emerged in the carbon market and increased their transaction volumes. In 2007, buyers (in terms of volume supplied) were mainly from the United Kingdom (59 percent), followed by Europe–Baltic Sea (12 percent) and Japan (11 percent) (Capoor and Ambrosi 2008).

Currently, the mitigation potential of the agricultural sector cannot be fully exploited under the CDM. Participation of agricultural projects has proven difficult due to the uncertainty present in measurements of carbon sequestration potential and reduction of GHG emissions. Furthermore, according to Capoor and Ambrosi (2009), the European Commissionintends to continue to exclude CDM credits from LULUCF from the EU ETS as a result of issues such as non-permanence, monitoring and reporting requirements (for more details on reasons for exclusion, see the next section).

The CDM has approved only a few methodologies that are directly viable for the agricultural sector. All but one of the approved methodologies target methane emissions through improved manure and agricultural waste management. In addition, a methodology using an inoculant on legumes in a legume-grass rotation on acidic soils targets CO2 emissions via avoided production of nitrogen fertilizer.

Voluntary Markets

The voluntary carbon markets encompass all exchanges of carbon offsets that are not under regulation. A survey conducted by the Ecosystem Marketplace and New Carbon Finance assessed the state of the voluntary carbon markets in 2008 (Hamilton et al. 2009). This study broke down the carbon market into two categories: the CCX and the “over-the-counter” (OTC) market. The CCX is the world’s only voluntary cap-and-trade system, while the OTC market is the non-binding offset market.

The unit of trade of the CCX is the Carbon Financial Instrument (CFI), which represents 100 $MtCO_2eq$. In order to comply with this market, participants acquire CFIs either as allowance-based credits or as offset-based credits from emission-reduction projects. However, only 4.5 percent of a member’s total emission-reduction requirement can be met through offset-based credits. Therefore, most of the credits traded are allowance-based credits (Hamilton et al. 2009).

In the CCX market, registered projects in 2008 came mostly from coal mine, forestry, and renewable energy projects. The United States and Canada had most of the registered projects; however, their market share decreased from 79 percent in 2007 to 60 percent in 2008 while registered projects in Latin America and Asia increased. The CCX is the only market with a considerable share of agricultural soil projects. However, from 2007 to 2008, this share fell from 48 to 15 percent. According to Hamilton et al. (2009), the drop in agricultural soil projects was due in part to the growth of the program itself and in part to modifications made to the agricultural soil protocol, which has led to a slowdown of the verification process.

Typical registered and verified agricultural soil carbon sequestration projects in the CCX include continuous conservation tillage, conversion to grassland, and sustainably managed rangeland. The baseline default rates are 0.12 to 1.0 $MtCO_2eq$ per acre per year, depending on location and project type (Michaelowa 2009).

The vast majority of carbon credits in the OTC market come from emission-reduction projects. The unit of trade in this market is called Verified Emission Reductions (VERs), but CDM units can also be used for voluntary offsetting purposes (Hamilton et al. 2009).

According to the results of the Hamilton et al. survey (2009), in 2008 the United States was the largest country supplying carbon credits in the OTC market, accounting for 28 percent of the total, while Asia was the region with the highest market share, supplying 45 percent of the transaction volume. In Africa, which accounts only for 1 percent of the OTC market, countries with the greatest OTC transaction volume were Madagascar, Uganda, Mali, South Africa, Tanzania, and Eritrea. According to Hamilton et al. (2009), lack of capacity is one of the main reasons that project development is more difficult in Africa.

In 2008, most projects in the OTC market were related to renewable energy (hydropower, wind energy, and biomass energy) and landfill gas capture, which had 51 percent and 16 percent of the market share, respectively. Just as in the regulatory market, land-based credits do not constitute a large share of the voluntary market. In 2004, the land-based share of the OTC market was 29 percent while in 2008 it fell to 11 percent (Hamilton et al. 2009). Projects based on agricultural soils had 1 percent of the voluntary market share in 2007 and 0.5 percent in 2008 (Table 3).

For the voluntary carbon standard, two methodologies have been submitted: the "Adoption of Sustainable Agricultural Land Management (SALM)" methodology submitted by the World Bank (based on two carbon sequestration projects in Kenya) and a "General Methodology for Quantifying the Greenhouse Gas Emission Reductions from the Production and Incorporation into Soil of Biochar in Agricultural and Forest Management Systems." Neither of these has been approved to date (Michaelowa 2009).

Table 3. Land-based credits sold in OTC market, 2007 vs. 2008

Project Type	Volume of land-based credits (ktCO$_2$eq)		Market share of land-based credits relative to the total (%)	
	2007	**2008**	**2007**	**2008**
Aff./Reforestation Mix	673	646	2	1
Aff./Reforestation Mono	2,157	3,399	8	7
Avoided Deforestaion (REDD)	1,421	730	5	1
Forestry Management	-	431	-	1
Agricultural Soil	820	267	1	0.5
Other Land-based Projects	-	130	-	0.3
Total	5,071	5,603	16	11

Source: Hamilton et al. 2009

The Potential of Nationally Appropriate Mitigation Actions (NAMAs)

Nationally Appropriate Mitigation Actions (NAMAs) were defined in the Bali Action Plan under the United Nations Framework Convention on Climate Change (UNFCCC)[6] as voluntary mitigation activities formulated and implemented in developing countries but enabled and supported through finance, technology, and capacity building from developed countries (UNFCCC 2009a). A three-page political agreement (the Copenhagen Accord), initially drafted by Brazil, China, India, South Africa, and the United States and endorsed by several other countries, reinforced the importance of financial, technological, and capacity-building support to enable the implementation of mitigation and adaptation actions in developing countries. The funding for mitigation actions is expected to come from public and private sources, bilateral and multilateral, including alternative sources of finance.

Since NAMAs are voluntary actions, there is no binding obligation for developing countries. However, NAMAs are commonly thought to have the potential to substantially increase carbon mitigation opportunities for developing countries, and several of the already submitted NAMAs[7] include plans to

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[6] The Bali Action Plan established the Ad Hoc Working Group on Long-Term Cooperative Action under the Convention (AWG-LCA), which, among other things, defined the scope of NAMAs.

[7] Submitted NAMAs are available on the UNFCCC website: http://unfccc.int/home/items/5265.php.

adopt actions in the agricultural sector, which confirms the potential role of agriculture in NAMAs (FAO 2010). It is unclear at this stage what institutional mechanisms and government arrangements will be created to implement the NAMAs. It is essential, therefore, that a more clearly defined and structured document about NAMAs and potential funding be elaborated before the next Conference of the Parties of UNFCCC (COP16) takes place in November, 2010, in Mexico City.

Given the lack of clarity on NAMAs, a debate is currently taking place in the international arena on the opportunity of broadening their definition and scope. Among the proposals discussed are Unilateral NAMAs, which are autonomous actions taken by developing countries with domestic funds and therefore no outside support (Levina and Helme 2009), and Credit-Generating NAMAs, which are actions that build on supported NAMAs and that—by exceeding an agreed-upon crediting baseline—produce offsets for sale in the global carbon market. The Conference of the Parties is responsible for developing the modalities and guidelines for participation in international emission trading (Levina and Helme 2009; UNFCCC 2009b).

4. A BRIEF REVIEW OF THE ECONOMIC LITERATURE ON AGRICULTURE AND CLIMATE CHANGE MITIGATION ACTIVITIES

While agriculture has been widely recognized as a fundamental force in the reduction of poverty, the active role of agriculture in slowing down or even reversing ecosystem degradation is a somewhat new idea. For many years, the problem was framed in terms of a tradeoff between development and environmental degradation. More recently, scientists from different disciplines have posited that the two objectives are not mutually exclusive and that agriculture has the potential to generate both poverty reduction and ecosystem services (Lipper et al. 2009). Economists have studied the use of market forces, as opposed to command-and-control policies, to obtain desirable environmental outcomes. While the literature about payment for environmental services was initially mostly focused on forest and water resources, more recently, attention turned to agricultural landscapes and the rural poor who live in environmentally degraded areas. Climate change mitigation activities are just one of the many environmental services that farmers can provide to the global community and, as such, they could be rewarded. In this section we briefly review the economic literature that focuses on climate change mitigation activities. There is a growing literature that analyzes the economics of farmers' participation and possible involvement in regulatory and voluntary carbon markets. Most of the empirical literature concentrates on cases in the United States and Europe. However, some of the findings are general and potentially applicable to small farmers in developing countries.

Conditions for Adoption of Mitigation Practices

The literature that looks at the conditions for adoption of mitigation practices is relatively simple. Stavins (1999), Antle (2002), and Gonzáles-Estrada et al. (2008), among many, assume that a risk-neutral farmer will try to maximize the present value of net benefits deriving from farming land. Therefore, a farmer will adopt mitigation practices when the net present value of farming with these practices is greater than that of alternatives. Still, farmers might incur additional costs or there might be a temporary decrease in productivity when adopting mitigation practices. In these cases, some form of payment could be made available to farmers to overcome the reduction in profit. Even though a considerable amount of research has addressed the impact of risk, uncertainty, and risk aversion on farmers' adoption of technology, particularly in developing countries (Sunding and Zilberman 2001), the literature that concentrates on climate change mitigation activities has so far ignored these issues.

Costs of Adoption and Barriers

Many studies have noted substantial barriers that hinder the adoption of climate change mitigation practices and sustainable land management practices in general—Otsuka and Place (2001), Barrett et al. (2002), and Nkonya et al. (2004), to name a few. These barriers may be due to lack of knowledge, imperfectly functioning markets and consequent lack of credit, or even a drop in yields during the first years of adoption. At the project level, there are important costs that need to be considered. Negotiation, organization, management, monitoring, and enforcement act as potential barriers to the implementation of projects. This is an area characterized by a considerable lack of data; the project-level data available show up-front costs that range from $12 to $600 per hectare (FAO 2009a). In a review of the literature that reports CDM transaction cost estimates, Cacho (2009) finds that ex-ante costs vary from $34,000 to $280,000 (negotiation and project approval) and that ex-post costs vary from some $6,000 to $280,000 (project monitoring, verification, and insurance).

From an economic standpoint, we can differentiate between two types of costs associated with the implementation of contracts for the provision of an environmental service: farm opportunity costs and transaction costs. Farm opportunity costs are the costs of resources used on the farm to provide the service. These include the forgone returns from possibly more profitable activities. Transaction costs are costs associated with negotiating and implementing contracts, which also include brokerage fees and monitoring of compliance with the terms of the contract (in terms of changing practices or carbon accumulation). Contracts are likely to involve a high number of farmers and institutional structures that work as intermediaries between sellers and buyers. These intermediaries will need to group contract agreements from large numbers of farmers to construct a commercially viable contract (for example, the unit of trade for the Chicago Climate Exchange is the CFI, representing 100 MtCO2eq). Since these intermediaries act as a go-between, the payments that farmers receive per ton of sequestered carbon are dependent on transaction costs. Cacho (2009) provides a theoretical demonstration of how increasing the total project area could allow higher payments to farmers. However, this result relies on keeping transaction costs "relatively fixed," while the costs of negotiation could be increasing with the number of farmers participating in the contract. As Antle (2002) points out, negotiation costs—negotiation with buyers and negotiation with farmers—will also be affected by the total amount of carbon sequestered and sold on the market, the type of soil where the sequestration activity is undertaken, and the institutional setting in which the transactions take place. As of today, not enough pilot projects have been implemented and not enough data are available to assess the optimal number of farmers that should be organized to participate in soil carbon contracts to minimize transaction costs.

From an economic modeling perspective, while farm opportunity costs enter implicitly into the economic analysis of adoption of mitigation activities (Stavins 1999; Parks and Hardie 1995), transaction costs have been either assumed equal to zero (Gonzáles-Estrada et al. 2008) or simulated for a sensitivity analysis (Antle and Stoorvogel 2008). When the transaction costs are included in the model, simulations show that they have a considerable effect on the adoption of the most desirable practices, such as the incorporation of 50 percent of plant residue into the soil: these costs can drive participation down to zero.

Types of Contracts

The recent literature on carbon sequestration in both agriculture and forestry sectors supports the view that it would be more efficient to implement contracts that pay farmers per ton of carbon sequestered rather than for the adoption of specified prescribed management practices. Parks and Hardie (1995) use the opportunity costs of forgone agricultural output to show that the least-cost policy for sequestering carbon by converting agricultural lands to forest is associated with bids offered on a per-ton basis rather than on a per-acre basis. Pautsch et al. (2001) analyze the potential for carbon sequestration using different tillage practices and reach a conclusion similar to that of Parks and Hardie (1995) regarding the efficiency of per-ton versus per-acre payment schemes.

A dissenting voice is Stavins (1999), whose analysis of carbon sequestration in forests finds that a contract based on tons of carbon sequestered would be prohibitively expensive to implement due to the costs associated with quantifying the carbon sequestered. Antle et al. (2003), however, estimate that the costs to implement the per-ton contracts are at least an order of magnitude smaller than the efficiency losses of the per-acre contract. The increased cost of measuring carbon sequestration is counterbalanced by a higher return per dollar spent.

A direct implication is that, given a certain carbon sequestration goal, contracting parties should bear the higher costs of the per-ton contracts in order to achieve a lower total cost of abatement. The structure and length of a contract can also play a significant role (Lewandrowski et al. 2004). Lewandrowski et al. propose to structure farmers' compensations as a rental contract for sequestering an amount of carbon for a commitment period. The payment is based on the annualized value of a permanent reduction of a ton of carbon. There are two advantages to structuring in this fashion rather than as an asset payment (Antle 2002; Pautsch et al. 2001), which assumes that sequestration is permanent. First, it rewards storage of carbon and contractually stops when the carbon is released into the atmosphere. Second, given that the decision to adopt mitigation practices generates an opportunity cost, shorter, renewable contracts linked to the market price of carbon would reflect the changing opportunity cost and encourage farmers' participation. Nelson et al. (2009) suggest using the type of contract used in the U.S. Conservation Reserve Program, in which farmers submit a bid to adopt a set of conservation practices and the bids with the lowest cost per unit of environmental service are accepted. Similar to the scheme described by Parks and Hardie (1995), this type of contract would ensure cost-efficiency.

Role of Marginal Land

Models of farmers' participation in carbon contracts can provide an important insight into the role that marginal land can play in climate change mitigation. The condition for the adoption of mitigation practices is that the net present value of farming using those practices is greater than the net of possible payments from alternative uses. In other words, a farmer incurs an opportunity cost any time she or he decides to practice mitigation activities. Antle and Diagana (2003) show that the opportunity cost of alternative land uses is inversely proportional to the soil potential for carbon sequestration. Given that fertile land may also have the highest potential for carbon sequestration, marginal lands are not necessarily more economically efficient at sequestering carbon. For example, land that produces greater quantities of crop residues provides farmers with larger amounts of organic material that can be incorporated into the soil. Tschakert (2004) and Tschakert, Coomes, and Potvin (2006), using a cost–benefit analysis approach, find that initial resource endowment has a strong effect on the profitability of recommended carbon sequestering practices. Graff-Zivin and Lipper (2008) reach a similar conclusion. The authors analyze the impact that changes in land quality have on equilibrium soil carbon levels. The impact depends fundamentally on how the marginal benefit from an additional unit of soil carbon and the marginal benefit from additional sequestration activities change with land quality. Their results indicate that farmers who live on land of intermediate quality will sequester the most carbon. This result has important implications regarding the farmers that should be engaged and, in particular, regarding poor farmers, who most often work on land of poor quality (Lipper 2001). According to this study, poor farmers would not be good candidates for a carbon sequestration program.

Monitoring and Compliance

Another issue that has attracted considerable attention is the problem of how governments should design compliance monitoring strategies when environmental compliance requirements are not self-enforcing. Payments for climate change mitigation services generally have two common features. First, they are voluntary, and second, participation involves a contract between the buyer, an intermediary agent, and the landowner. The landowner agrees to manage the land according to agreed-upon practices and receives a payment conditional on compliance with the contract.

Arising from the mainstream economics area of principal–agent theory with imperfect information, there are two major issues that need to be dealt with when implementing payment for environmental services such as climate change mitigation activities: adverse selection and moral hazard. Adverse selection arises when negotiating the contract. Landowners have better information than the buying agent about the opportunity costs of supplying environmental services. Landowners can thus secure higher payments by claiming their costs are higher than they actually are. More precisely, landowners use their private information as a source of market power to extract informational rents from conservation agents. These rents are payments above the "true" minimum payment necessary to engage the landowner in a program. Adverse selection has been the subject of theoretical analyses in the context of agri-environmental payment schemes but has not been directly applied to climate change mitigation (Bourgeon, Jayet, and Picard 1995; Fraser 1995; Wu and Babcock 1996; Latacz-Lohmann and Van der Hamsvoort 1997; Moxey, White, and Ozanne 1999; Ozanne, Hogan, and Colman 2001; Peterson and Boisvert 2004).

The problem of adverse selection is potentially important because the buying agents might obtain fewer environmental services per dollar spent than they would in a world with perfect information. In contrast, the moral hazard problem arises after a contract has been negotiated; it is due to imperfect information about compliance. The certification process may require that farmers be monitored for contract compliance, but the intermediary may find monitoring costly and thus may be unwilling to verify compliance with certainty. Thus, the landowner has an incentive to avoid fulfilling contractual responsibilities. Hidden action in agri-environmental payment schemes has also been the subject of theoretical analyses (Choe and Fraser 1998, 1999; Ozanne, Hogan, and Colman 2001; Fraser 2002; Hart and Latacz-Lohmann 2004). Most of the economic literature on the subject concentrates on cases in the United States and Europe. In the context of agri-environmental policy, Choe and Fraser (1999) derive optimal monitoring strategies and incentive payments when farmers can exert either low or high compliance effort and monitoring is costly. Kampas and White (2004) examine the impacts of monitoring costs on the relative efficiency of alternative agri-environmental policy mechanisms. Fraser (2002) investigates the effects of penalties for non-compliance but does not consider monitoring costs. More recent studies have applied the results of this type of economic analysis to the problems of payments for environmental services, including carbon sequestration (Grieg-Gran, Porras, and Wunder 2005). However, several important empirical issues remain unaddressed and should be tested. For example, theoretical analysis by Ozanne, Hogan, and Colman (2001) and Fraser (2002) find that risk aversion among farmers ameliorates the moral hazard problem in relation to agri-environmental policy compliance. The implications of their findings are still untested in developing countries.

5. CHALLENGES FOR SMALLHOLDER FARMERS IN ACCESSING CARBON MARKETS

Challenges to Participation in Informal and Formal Carbon Markets

Even though the mitigation potential of the agriculture and forestry sector is documented (see Smith et al. 2007a, 2008), some experts remain ambiguous about its benefits. The IPCC fourth assessment report (AR4) remains ambiguous about the benefits of soil carbon sequestration, for example, for no-till farming and restoration of agricultural lands. Moreover, the range of uncertainty over more proven agricultural mitigation practices remains very large, on the order of plus or minus 50 percent for nutrient management and rice management, for example.

Several other obstacles prevent developing countries from taking full advantage of growing carbon markets. Among others, barriers are biophysical, economic, social, institutional, and political in nature.

Peskett, Luttrell, and Brown (2006) review the potential benefits and challenges that small farmers encounter when they participate in carbon offset forestry projects. Uncertainty in the flow of benefit potential and high transaction costs are cited as the two major constraints. The authors mention that under both the CDM and voluntary mechanisms, uncertainty regarding who owns the carbon emission reductions can generate disputes and conflicts. Another problem stems from farmers' being tied into land use patterns that diverge from local practices known to be effective, which might increase their vulnerability to shocks and economic fluctuations.

Lack of education and of access to information may also challenge the effectiveness of projects, giving rise to obstacles, abuses, and conflicts (Roncoli et al. 2007). Other issues relate to infrastructural and institutional weaknesses, poor systems of governance, and poor political representation (Roncoli et al. 2007).

According to Bryan et al. (2008), there are other impediments—besides exclusion from the CDM—that can prevent developing countries from taking advantage of existing carbon markets. These include the need to establish an accurate baseline and demonstrate that emission reductions would not have occurred in the absence of the project (a concept often referred to as additionality). Cost-effectiveness, irreversibility, transaction costs, property rights, and uncertainty are also often cited as important obstacles (Smith and Scherr 2003).

Baseline Scenario

Gaining access to formal carbon markets requires the formulation of an accurate baseline scenario. The baseline scenario describes GHG emissions in the absence of a project. For many developing countries, lack of knowledge and technical training as well as poor data availability are major obstacles that need to be overcome to define an adequate baseline (Kelly 1999).

Additionality

A project is said to meet the additionality criterion if the carbon sequestration or emission reductions achieved by the project would not have been obtained in absence of the project. The carbon credits earned are determined by the difference in emissions with and without the project. To demonstrate that the additionality criterion is satisfied, plausible alternative scenarios need to be identified. Also, an investment analysis needs to be performed to demonstrate that the proposed project is not the most financially attractive even without carbon payments. Additionality can be difficult to demonstrate for agriculture projects since many mitigation possibilities are financially viable and may be concurrent. It is therefore difficult to determine how much of an activity can be attributed to the CDM (Smith et al. 2007b).

In addition to problems related to generating a baseline and satisfying the additionality requirement, participation by developing countries in carbon offset markets is constrained by a number of other factors.

Leakage

The adoption of certain agricultural practices may reduce emissions in a given area or region; however, these emission savings could be negated if the type of agricultural production a project is trying to prevent shifts to other regions where little effort is expended on mitigation measures in agriculture or forest conservation efforts (Smith et al. 2007b). Community-based agriculture and forestry projects will result in leakages if the project takes over community land and does not adequately compensate the community. For example, projects that displace significant annual crop production need to simultaneously increase the productivity of the remaining agricultural land through labor-intensive technologies. Thus, livelihood-enhancing projects that are likely to adequately meet the needs of local communities reduce the risk of leakage. In practice, however, considerable difficulties may occur in fulfilling community needs in developing countries.

Cost-Effectiveness

It is difficult to determine the cost-effectiveness of alternative projects. Production cost should include transaction, carbon sequestration, and carbon storage costs. Even though the level of carbon benefits used for calculating production costs should be adjusted for additionality and leakage, very few estimates do so. Therefore, most of the figures reported in the literature should be taken as underestimates of the cost of supplying carbon services.

Irreversibility

Developing countries should be aware that they may be facing their own emission-reduction commitments in the future. Since many emission-abatement measures are irreversible, ignoring possible future commitments could lead to problems. Notably, the cheapest abatement measures will be implemented first, leaving developing countries with only more expensive measures when they have to meet their own commitments in the future.

High Transaction Costs

The cost of carbon projects includes the cost of providing information about carbon benefits to potential buyers, communicating with project partners, and ensuring that parties fulfill their contracted obligations. Measurement and monitoring costs are also considerable. These transaction costs per unit of emission reduction seem likely to be much higher for projects involving local communities since costs of negotiating land use decisions with a large number of geographically dispersed local people with different land use objectives—such as one finds in developing countries—will tend to be higher than for most projects that are strictly for forest protection or industrial plantation. It has therefore been recommended to pool the projects of smaller communities in order to reduce project development, marketing, certification, and insurance costs (Noble 2003; Smith and Scherr 2003).

Moreover, livelihood-enhancing projects (such as agroforestry) and community land uses often face significant institutional barriers, such as difficulties in financing establishment costs and obtaining planting materials and lack of technical assistance or marketing infrastructure.

Uncertainty

Uncertainty about emissions, carbon storage processes, and measurements make investors more wary of these options and more likely to choose clearly defined industrial mitigation activities (Smith et al. 2007b). Thus, a greater effort needs to be made to demonstrate significant savings through agriculture and forestry projects.

Property Rights

Currently, land titling is absent in many developing countries. As a result, in the absence of supportive legislation, revenues may be captured only by those who have formal land titles, while communities with customary rights are excluded (White and Martin 2002).

Lack of Development

In developing countries, mitigation opportunities through clean development are limited because not much industry has been developed and, for example, less than 10 percent of the population has access to the grid for electricity.

Table 4 presents a summary of barriers to implementing agricultural GHG mitigation options, compiled by Smith et al. (2007b).

Table 4. Barriers to implementing agricultural GHG mitigation options

Barrier type	Description
Permanence	There is a maximum amount of carbon that ecosystems can hold. Therefore, carbon sequestration removes carbon only until that maximum capacity is reached. Changes in management practices can reverse the gains in carbon sequestration (in contrast, N_2O and CH_4 emission reductions are non-saturating).
Additionality	Some mitigation options are well known and financially viable. Therefore, the GHG net emission reductions need to be additional to what would have happened in the absence of a market.
Uncertainty	Mechanism uncertainty: uncertainty regarding biological and ecological processes involved in trace gas emissions and carbon storage might make investors opt for more clear-cut industrial mitigation activities (there should be more investment in research). Measurement uncertainty: variability between seasons and locations of agricultural systems can translate into high variability in offset quantities at farm level (increasing the geographical extent and duration of the accounting unit can reduce variability).
Leakage	The adoption of agricultural mitigation practices may shift production to other regions where such practices do not exist, resulting in no net reduction of emissions.
Transaction costs	Brokerage cost (getting the commodity to the market) can be a significant fraction of carbon market prices, especially for small farmers, rendering transactions not economically viable.
Measurement and monitoring costs	There are disagreements about the size of these costs. Measurement costs per carbon credit sold decrease as quantity of carbon sequestered and area sampled increase in size.
Property rights	Property rights and lack of clear land ownership can be impediments for the implementation of management changes.

Source: Smith et al. 2007b.

6. FINAL CONSIDERATIONS AND CONCLUSIONS

Emissions from agriculture are important contributors to climate change, accounting for approximately 10-14 percent of the global total. The share of these emissions is far larger in developing countries and largest in the least developed countries. If emissions from land use change (18 percent) were included, total agricultural emissions would be even larger.

There are two potential ways to enhance the pro-poor impact of climate change policy: first, by transforming climate change policy into a pro-poor development strategy to create value for small farmers and investment flows into rural communities in developing countries; and second, by effectively integrating smallholder farmers into the carbon trading process. These policies would require that producers and investors be provided with incentives to improve agricultural practices and yields in sustainable ways, conserve watersheds to reduce erosion and enhance water filtration, and reforest denuded areas. It is important to note that the benefits that can derive from the implementation of these new policies are both environmental and economic. While agricultural carbon mitigation for smallholder farmers is challenging to implement—as the various barriers to implementation reviewed in this paper have clearly demonstrated—the implementation of smallholder agricultural mitigation has so many additional benefits that it should not be difficult to find investors interested in "charismatic carbon," that is, carbon credits with clear poverty reduction, food security and nutrition, and environmental sustainability benefits.

The key components of a successful climate change mitigation project include the capacity to measure and monitor carbon stocks and emission reduction accurately and at a low cost, the capability to aggregate farmers so that pools of carbon mitigation in tradable amounts are formed, and the existence of financial mechanisms that efficiently connect the demand for and supply of carbon offsets. The long-term sustainability of a project, however, might depend not only on farmers' receiving payments for the environmental services provided (whether carbon sequestration or ecosystem conservation) but also on the capability of the project to improve their welfare.

The performance of projects has been correlated with the presence (success) or lack (failure) of the following elements: financial assistance, funding, extension services, access to seeds and fertilizers, education and information access, off-farm economic alternatives, participatory planning and implementation, capacity building, good governance, conflict management, political stability, participation by civil society organizations, market access, among others (Jindal, Swallow, and Kerr 2006; Zhang, Tu, and Mol 2008; Grieg-Gran, Porras, and Wunder 2005; Hall 2008; Roncoli et al. 2007; Perez et al. 2007).

A policy environment that facilitates the necessary institutional mechanisms for community participation in carbon trading is needed. This could require clarifying resource tenure and removing the incentives that promote land degradation (Roncoli et al. 2007). On the other hand, lack of a suitable institutional arrangement might hamper the process of aggregation of carbon credits to be sold in the carbon market as well as the processes of monitoring and verification (Perez et al. 2007).

In general, when payment for environmental service schemes involve governmental actors, these schemes can fall short of funding, be subject to political bias in the choice of target areas, and experience poor cross-sector coordination and limited implementation capacity (Hall 2008). Therefore, besides appropriate allocation of financial and human resources, a strong political commitment is also needed (Hall 2008). Donor and research institution commitment to promoting reforms, building capacity, and ensuring accountability are all necessary (Roncoli et al. 2007). In projects in Africa, nonprofit institutions and local governments have taken additional responsibilities besides looking for funds to finance projects, such as capacity building of community representatives and monitoring and supervision (Jindal, Swallow, and Kerr 2006).

Insecure access to land is one of the factors that might contribute to failures of payment schemes for environmental services, especially if there are no off-farm economic opportunities (Zhang, Tu, and Mol 2008). Private investors may be reluctant to supply capital when projects are implemented in areas with insecure land rights (Jindal, Swallow, and Kerr 2006); further, secure access to land has been positively associated with adoption of improved management practices (Perez et al. 2007). However, based on case studies, Jindal, Swallow, and Kerr (2006) find that even in areas under customary tenure and on land held as common property by entire communities, carbon projects could work.

Lack of coordination and cooperation among different institutions and actors can cause conflicts and duplication of actions (Zhang, Tu, and Mol 2008). Ongoing tensions over land access and natural resources can lead to further degradation and require dispute resolution mechanisms. Institutional mechanisms are needed for improved conflict management and negotiations among decisionmaking agents at multiple levels as well as protection of the interests of marginalized groups (Roncoli et al. 2007).

Carbon sequestration projects benefit from context-specific analysis that takes into account the local realities; they could also benefit from knowledge about past and current land management practices, local ecology, and social dynamics as well as information about the interactions of social, political, and economic forces (Roncoli et al. 2007).

Project feasibility studies should take into account the disparities in resource endowments, size of the farm, educational level, access to information, and financial resources, among other factors. For instance, Tschakert (2004) shows that the cost of adapting management practices to sequester soil carbon can be higher for poor farmers than for middle- and higher-income farmers. For poor farmers, many management practices can be unaffordable as a result of high initial investment required.

Transaction costs can work as a barrier to the implementation of climate change mitigation projects. Simplified guidelines for the design and formulation of carbon sequestration projects could reduce transaction costs. Transaction costs can also be reduced if projects are located in communities with active local organizations and where participatory development processes exist (Jindal, Swallow, and Kerr 2006).

In this paper we have reviewed the existing literature on farmers' involvement in carbon markets. This review indicates that, while the potential for climate change mitigation in agriculture is not as large as the potential for savings from fossil fuels, the contribution is still substantial. The barriers that prevent small farmers from benefiting from carbon markets are not insurmountable and deserve further study. Finally, we would like to note that the potential returns on farmers' involvement are not their only contribution to the problem of climate change. The agricultural practices recommended to sequester atmospheric carbon and reduce emissions also have important environmental co-benefits such as improved quality and flow of ecosystem services. Furthermore, their adoption could contribute to farmers' food security and resilience to climate change.

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