Agriculture and Climate Change

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Agriculture's Contribution to Climate Change

With estimated global emissions of 5,969-6,615 Mt CO_2-eq. per year, agriculture accounts for about 13.5% of total global anthropogenic emissions of greenhouse gases (U.S. EPA, 2006; IPCC, 2007b). N_2O emissions from soils, through activities such as applying fertilizers and livestock manure, and methane emissions from enteric fermentation in livestock make up the majority of emissions from agriculture, as shown in Table 1. Although agricultural soils emit and absorb large amounts of CO_2, the net flux is close to zero. CO_2 emissions from agricultural electricity and fuel use are typically counted as building and transportation sector emissions rather than agriculture emissions (IPCC, 2007c).

Table 1: Global GHG emissions from agriculture

	Mt CO_2-eq. per year	**% of agriculture emissions**	**% of total GHG emissions**
Soil emissions (N_2O)	2513.7	38%	5.1%
Enteric fermentation (CH_4)	2116.8	32%	4.3%
Biomass burning (N_2O and CH_4)	793.8	12%	1.6%
Rice production (CH_4)	727.7	11%	1.5%
Manure management (N_2O and CH_4)	463.1	7%	0.9%
Total	6615	100%	13.5%

Sources: Compiled from IPCC (2007b), IPCC (2007c)

Land use changes, including deforestation, are estimated to account for about 15% of anthropogenic CO_2 (Smith et al., 2007). Deforestation contributes about 11.8% of total greenhouse gas (GHG) emissions, releasing about 5,800 Mt CO_2 per year (IPCC, 2007d). Researchers caution that reliable assessments of emissions from land use change and forestry practices are particularly difficult to make given large spatial and temporal variability and simultaneous emissions and removals of CO_2 in different areas (Smith et al., 2007).

In the fisheries sector, CO_2 emissions from harvesting and shipping of fish and fish products are estimated at 50 Mt per year (FAO, 2009). As shown in Table 2, agriculture, deforestation, and fisheries account for about 25% of total global GHG emissions.

Table 2: Global GHG emissions from agriculture, forestry, and fisheries

	Mt CO_2-eq. per year	**% of total GHG emissions**
Agriculture[1]	6615	13.5%
Deforestation[2]	5800	11.8%
Fisheries[3]	50	0.1%
Total	12465	25.4%

[1] IPCC (2007b), IPCC (2007c); [2] IPCC (2007d); [3] FAO (2009)

Developing countries are largely responsible for emissions from agriculture and deforestation, with the developing countries of South Asia and East Asia accounting for 17% and 25% of global agricultural emissions respectively (Smith et al., 2007). Sub-Saharan Africa (SSA) accounts for about 13% of global emissions from agriculture and 15% of emissions from land use change and forestry (Smith et al., 2007; Bryan et al., 2008).

Globally, emissions from agriculture have increased by 14% from 1990 to 2005. The greatest increases have come from N_2O emissions from soils (21% increase), N_2O emissions from manure management (18% increase), and CH_4 from enteric fermentation (12% increase). Emissions of N_2O and CH_4 from biomass burning have declined 8% and 6% respectively. Agricultural emissions are forecast to accelerate for the period 2005 to 2020, with N_2O from soils and CH_4 from enteric fermentation rising most rapidly. The Middle East, North Africa, and SSA will experience the highest growth, with a combined 72% increase in GHG emissions from agriculture during the period 1990-2020 (Smith et al., 2007).

It should be noted that the most recent data available on global agricultural GHG emissions comes from 2004. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment, published in 2007, cites emissions data from 2004 and uses non-CO_2 emissions forecasts calculated by the U.S. EPA in 2006. The EPA used data from 2000 to make its forecasts. In preparation for the 2009 Climate Change Conference in Copenhagen, the United Nations Framework Convention on Climate Change (UNFCCC) released GHG inventory data for the period 1990 to 2007 for Annex 1 (industrialized) countries only. The new data show that Annex 1 countries emitted 1,300 Mt CO_2-eq. from agricultural activities in 2007, about 7% of total Annex 1 emissions (UNFCCC, 2009).

Agriculture's Mitigation Potential

Smith et al. (2008) estimate that global technical mitigation potential from agriculture by 2030 is 5,500 – 6,000 Mt CO_2-eq. per year. Due to political, economic, and other constraints, the realized potential will likely be lower than the technical potential. The price of carbon equivalents will play a role in the amount of realized mitigation, with the following ranges possible:

- 1,500 – 1,600 Mt CO_2-eq. per year at prices up to 20 US$ t CO_2-eq.
- 2,500 – 2,700 Mt CO_2-eq. per year at prices up to 50 US$ t CO_2-eq.

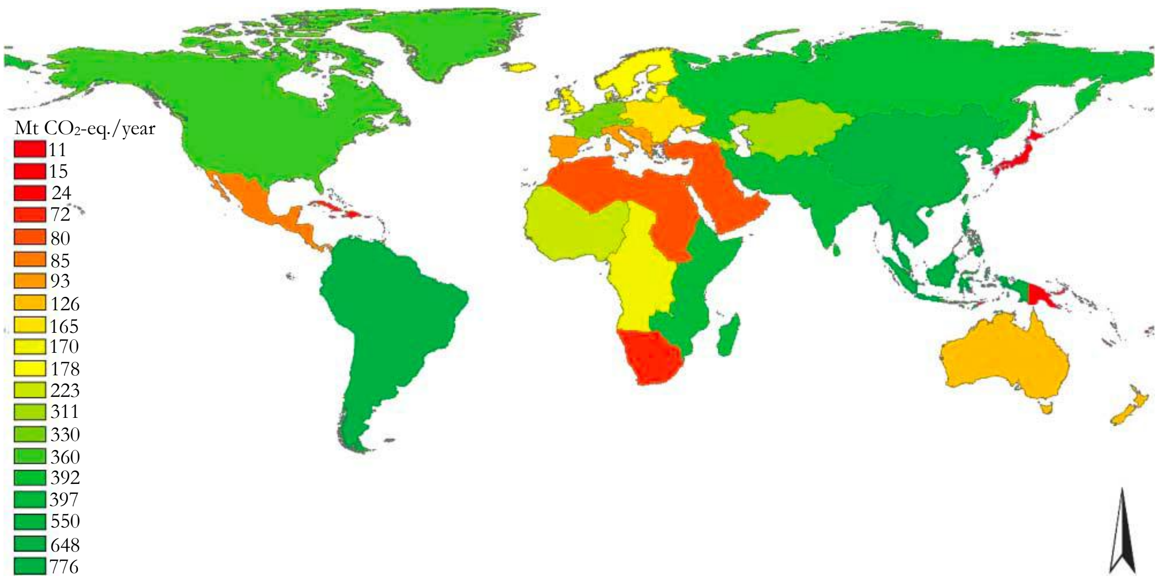
- 4,000 – 4,300 Mt CO_2-eq. per year at prices up to 100 US$ t CO_2-eq.

To give context to this potential, annual GHG emissions from all sources during the 1990s were approximately 29,000 Mt CO_2-eq. At full biophysical potential, agriculture could offset 20% of total annual emissions, with offsets of about 5, 9, and 14% at prices of up to 20, up to 50, and up to 100 US$ t CO_2-eq. respectively. Approximately 89% of agriculture's mitigation potential is the result of reducing soil emissions of CO_2, 9% is from mitigating CH_4 emissions, and 2% is from mitigating soil N_2O emissions (Smith et al., 2008).

Total biophysical mitigation potentials for each region are shown in Figure 1. According to Smith et al. (2008), technical mitigation potentials vary by region based on:

- Climate zones within each region;
- Areas of crop, crop mix, and grassland in each climate zone in each region;
- Area of cultivated organic soils in each climate zone in each region;
- Area of degraded land in each climate zone in each region; and
- Area of rice cultivation for each region.

Figure 1: Total biophysical mitigation potentials (all practices, all GHGs) for each region by 2030.



Source: Smith et al., 2008.

Bryan et al. (2008) estimate biophysical mitigation potential from Africa to be 970 Mt CO_2-eq. per year by 2030, with an economic potential of 265 Mt CO_2-eq. at prices up to 20 US$ t CO_2-eq. East, West, and Central Africa have the largest economic mitigation potential, at 109, 60, and 49 Mt CO_2-eq. per year, respectively. Cropland management, which includes practices such as use of improved crop varieties to generate higher inputs of carbon, more efficient application of nitrogen fertilizer, and reduced or no tillage systems, offers the greatest mitigation potential, at 69 Mt CO_2-eq. per year at prices up to 20 US$ t CO_2-eq. (Bryan et al., 2008; Smith et al., 2008). Grazing land management, with mitigation potential of 65 Mt CO_2-eq. per year, and restoration of organic soils, with potential of 61 Mt CO_2-eq. per year, are also significant mitigation options (Bryan et al., 2008).

Estimates of mitigation potential from forestry vary widely due to uncertainty about baseline emissions from the sector. Using three global forestry and land use models, Kindermann et al. (2008) estimate that mitigation from avoided deforestation could amount to the following during the period 2005 to 2030:

- 1,600 – 4,300 Mt CO_2-eq. per year at prices up to 20 US$ t CO_2-eq.
- 3,100 – 4,700 Mt CO_2-eq. per year at prices up to 100 US$ t CO_2-eq.

Benítez et al. (2007) suggest that within 20 years, afforestation and reforestation could sequester up to 6,900 Mt CO_2-eq. per year at prices of 50 US$ t CO_2-eq. The study's model takes risk into account and finds that factors such as political, economic, and financial risks could reduce sequestration potential by 60% due to deterred investment. The authors stress the importance of including country risk in global assessments to prevent an over-estimation of mitigation potential.

Carbon Markets

The global carbon market reached a total value transacted of about US$126 billion at the end of 2008, double the 2007 value (Capoor & Ambrosi, 2009). As shown in Table 3, the overall carbon market consists of project-based transactions, such as projects under the Clean Development Mechanism (CDM) and Joint Implementation (JI), and allowances trading markets, including the European Union Emissions Trading Scheme (EU ETS), Chicago Climate Exchange (CCX), Regional Greenhouse Gas Initiative (RGGI), and Assigned Amount Units (AAUs).

Table 3: Carbon markets at a glance, volumes and values in 2007 and 2008

	2007		**2008**	
	Volume ($MtCO_2$eq.)	Value (MUS$)	Volume ($MtCO_2$eq.)	Value (MUS$)
Project-based Transactions				
CDM	792	12,884	1,461	32,796
JI	41	499	20	294
Voluntary market	43	263	54	397
Subtotal	876	13,646	1,535	33,487
Allowances Markets				
EU ETS	2,060	49,065	3,093	91,910
New South Wales	25	224	31	183
CCX	23	72	69	309
RGGI	na	na	65	246
AAUs	na	na	18	211
Subtotal	2,108	49,361	3,276	92,859

Total	2,984	63,007	4,811	126,346

Source: Capoor & Ambrosi, 2009

MUS$ = millions U.S. dollars

CDM provides the largest market for carbon offset projects in developing countries. Similar to previous years, China was the dominant seller of CDM projects in 2008, accounting for 84% of confirmed transactions. India and Brazil ranked second and third, respectively, with 4% and 3% of transactions (Capoor & Ambrosi, 2009). African countries accounted for 2% of CDM projects, down from 7% in 2007. While South Africa has been the site of most CDM investments in Africa in the past, since 2008 other participating countries have included Tanzania, Senegal, Cameroon, Congo DR, Ethiopia, Liberia, Madagascar, Rwanda, Swaziland, Syria, and Zambia (Bryan et al., 2008, Capoor & Ambrosi, 2009). As of 2009, 36 CDM projects were registered in Africa, or about 1.5% of the 1,946 total projects (CDM, 2009).

From 2008 to 2012, expected demand for offsets from industrialized countries seeking to achieve Kyoto Protocol compliance is 1,634 $MtCO_2eq$. CDM and JI projects will likely meet most of this demand, with the potential to provide 1,430 – 1,974 $MtCO_2eq$. in offsets based on projects in the pipeline (Capoor & Ambrosi, 2009). Depending on domestic policy developments and international climate negotiations, post-2012 demand for international offsets stands to be larger than what the market has seen to date. However, Capoor and Ambrosi (2009) caution that regulatory uncertainties over issues such as project type eligibility, certification standards, and fungibility across regimes may slow the momentum of project-based carbon markets.

Please direct comments or questions about this research to Leigh Anderson, at eparx@u.washington.edu.

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