



Mitigation Action Plans & Scenarios

RESEARCH PAPER

Mitigation Potential in the Agriculture Sector

The case of Argentina, Brazil, Chile, Colombia, Peru and South Africa

ISSUE 16



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Date: May 2014

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The following citation should be used for this document:

Rojas A., Rahlao S., Alfaro M., Engel W., Dubeux C., Gomez C., Gutman V., Jarvis A., Kebreab E., Rosales R. 2014. An assessment of mitigation potential of GHG in the agriculture sector: The case of Argentina, Brazil, Chile, Colombia, Peru and South Africa. MAPS Programme



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ABSTRACT

Agriculture is key to rural livelihoods and economic development in many developing countries in Africa and South America. Unfortunately, it is also a substantial source of greenhouse gases (GHG) emissions in many of these countries. This paper examines the socio-economic importance of the agriculture sector in six emerging economies (Argentina, Brazil, Chile, Colombia, Peru and South Africa) and compares their GHG emissions profiles. Further, it assesses the mitigation actions that are being developed or have been implemented in the agricultural sector at the national level in these six countries. Our analysis shows the importance of the sector on the socio-economic development, poverty alleviation, food security, job creation and GHG emissions of each country. It also suggests that given their agriculture GHG profiles, four out of the six countries could focus their efforts on mitigating GHG emissions in the agriculture sector ensuring that the mitigation does not exacerbate inequality, nor reduce rural employment and income. Despite the contribution of this sector to GHG emissions, only partial efforts have been made to develop appropriate mitigation actions. Further research is needed to better understand mitigation potential within the general development planning in these countries. In this sense, lack of detailed activity data and information regarding specific emission factors have been identified as a major barrier for implementing mitigation actions in the agriculture sector of these countries.

Key Words: Agriculture emissions, Climate Change Mitigation, Emissions Profile, MAPS Programme, Mitigation Actions

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INTRODUCTION

Agriculture contributes to economic growth, food security and poverty reduction and it is a key income source for rural populations in most developing countries. The sector is not only important from an economic point of view (contribution to GDP, exports and regional employment) but also in some cases from a social perspective (high incidence of subsistence agriculture).

The agriculture sector, including crop and livestock production, is also identified as a major source of greenhouse gases (GHG) emissions (IPCC, 2006). The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) reported that agriculture accounted for estimated emissions of 5.1 to 6.1 GtCO₂eqyr⁻¹, which is about 13.5% of total anthropogenic GHG emissions in 2005. The sector is the largest contributor (58%) to global non-carbon dioxide emissions, producing 84% of total nitrous oxide (N₂O) emissions and 47% of total methane (CH₄) emissions (IPCC 2007; US EPA 2006). For comparison purposes, CH₄, N₂O, CO and NO_x emissions in the agriculture sector are converted to emissions of CO₂ equivalent.

According to the IPCC (2006), the sector's major emission sources come from enteric fermentation (natural digestive process in ruminant animal), manure (manure management, manure applied to soil and manure left on pasture), synthetics fertilizers, rice cultivation, crop residues, cultivated organic soil and CO₂ eq emission from burning crop residues and pastures. In this sense, the sector exhibits a relatively high potential for GHG mitigation (Smith *et al.* 2007). According to the IPCC, mitigation in the sector can be tackled in several ways, namely; (i) emissions reduction; (ii) emissions avoidance or displacement and (iii) enhancement of sinks, also referred to as 'emissions removal' (Smith *et al.* 2007).

On the other hand, the increase in the frequency of climate change extreme events such as droughts and floods has increased the pressure on water and arable land, two critical inputs in agricultural production. It is expected that this will result in a decrease of sectoral production yields. Recent studies assessing the impact of climate change on agricultural productivity estimate that Latin American countries will experience a change in grain yields of between a 30% decrease to a 5% increase by 2080. This includes a 12 – 27% decrease in rain-fed wheat production (Christensen *et al.* 2007; IPCC, 2007; Ruosteenoja *et al.* 2003). In Sub-Saharan Africa, average cereal yields are expected to decrease 3.2% by 2050 (Gerald *et al.* 2009, Ringler *et al.* 2010) with wheat, corn, sorghum and millet yields decreasing by 17%, 5%, 15% and 10% respectively (Knox *et al.* 2012). These impacts will negatively affect the development goal of achieving food security, impacting on low-income household livelihoods and increasing vulnerability.

Historically, there has been a trade-off between agricultural development and GHG emissions reduction in developing countries; hence the international policy focus within the agriculture sector has been on adaptation in developing countries, and mitigation in developed economies. However, recent studies are increasingly showing that some low-carbon farming options may not only reduce GHG emissions (and even enhance carbon sinks in agricultural lands) but, at the same time, generate important economic, environmental and development benefits mainly through increased productivity, enhanced food security and adaptation to climate change (FAO 2012a; 2012b; 2009; Giacomo *et al.* 2011; Niggli *et al.* 2009; Smith *et al.* 2007a; Cole *et al.* 1997).

The agriculture sector has received limited attention in the United Nations Framework Convention on Climate Change (UNFCCC) negotiations, despite its significant contribution to global emissions and its mitigation potential. It was only during the 17th Conference of Parties (COP) held in 2011 that the Parties requested the Subsidiary Body on Scientific and Technical Advice (SBSTA) to scope a potential work program for the agriculture sector. During the 18th UNFCCC COP held in 2012, governments were urged to further consider the crucial role of agriculture in the global effort to adapt to climate change and reduce GHG emissions. However, the importance of agriculture was not included explicitly in any decision or text. More discussion is expected for the 19th UNFCCC COP that will be held in 2013.

Although limited progress has been achieved in international climate change negotiations, some mitigation efforts are currently being made at the national level. These efforts seek to identify and assess mitigation action potential and low-carbon farming options that might reduce emissions and enhance carbon sinks in agricultural lands. In some countries, mitigation efforts in the agriculture sector are being considered within the general design of broader development planning.

Significant uncertainties regarding the benefits of implementing different mitigation actions still remain. The Mitigation Actions Plans and Scenarios (MAPS) Programme aims to assess developing countries' climate change mitigation potential that align economic development with poverty alleviation¹. In this context, this paper aims to explore the efforts that are being undertaken in six developing countries or emerging economies with regard to mitigation in the agricultural sector²: Argentina, Brazil, Chile, Colombia, Peru and South Africa. The paper addresses the importance of the agriculture sector both at the socio-economic level and from a GHG emissions perspective, and explores the mitigation initiatives that are currently being developed in each of the countries.

METHODOLOGY AND DATA SOURCES

This paper focuses on five Latin American developing countries (Argentina, Brazil, Chile, Colombia and Peru) and South Africa, located in Sub-Saharan Africa. They are all non-Annex 1 countries, responding to the global call for mitigating anthropogenic GHG emissions and they are also part of the MAPS community (hereafter to be referred to as 'MAPS countries').

We base our analysis on data taken from the Second National Communications (SNC) submitted by these MAPS countries to the UNFCCC as well as from official statistics from public institutes. We also consider secondary information from academic literature and private sector assessments and documentation related to macroeconomic variables, GHG emissions profiles, agriculture sources and mitigation actions being fostered in each of the countries. These multiple sources are then analyzed systematically on a country-by-country basis to ascertain:

- the importance of the agriculture sector in the countries under consideration
- GHG emissions profiles
- agriculture emission sources in these countries
- mitigation actions that are being developed and/or implemented at the national level in the selected countries
- additional benefits that mitigation actions could achieve when implemented
- challenges the six countries are facing at implementing mitigation actions in the agriculture sector

¹ www.mapsprogramme.org

² This paper excludes the assessment of mitigation potential of GHG of the Forestry and Land Use and Land Use Change sector.

- the main research opportunities for mitigation actions
- preliminary policy recommendations.

In this sense, the data from each country is assessed comparatively to provide a broader vision of the opportunities and challenges for mitigation in the agricultural sector in these developing countries and emerging economies.

NATIONAL IMPORTANCE OF THE AGRICULTURE SECTOR

In the following section we assess the economic and social importance of the agriculture sector in the MAPS countries. The variables considered include contribution to GDP, exports and regional employment from the economic point of view and incidence of subsistence agriculture from the social perspective.

In Argentina, although agriculture contributes to less than 10% of GDP (9.5% in 2011), the sector accounts for 58% of national exports (primary products explain 24% of the total exports and processed agricultural products explain the remaining 34%) (National Institute of Statistics and Census – INDEC, 2012). With regards to employment, agriculture accounts for 6% of total national jobs. However, in some provinces of the country agriculture-related employment accounts for about 20% of provincial jobs (National Ministry of Employment and Social Security – MTEySS, 2012). Small-scale production explains 53% of jobs within the sector at the national level (more than 400.000 jobs according to 2001 Census) (Obschatko *et al.* 2007). It is worth highlighting that in Argentina small agricultural producers account for 66% of total agricultural output (13.5% of the total agricultural area) and explains 20% of total agricultural production value.

In Brazil, agriculture is significant to the economy mainly due to the export revenue. Agribusinesses are even more important because of the positive impacts they generate on the economic production chain. The contribution of the agricultural sector to total GDP was around 5% in 2011 (IPEADATA, 2013), and when combined with agribusinesses contributed 22% of total GDP in the same year (CNA and CEPEA-USP, 2012).

In Chile, it is estimated that the direct contribution of agriculture to national GDP was 5% on average for the 2007 – 2011 period (World Bank, 2012). Agriculture employs 9.8% of the total labor force in Chile reaching up to 757,000 people and contributing US\$2.3bn on average to the GDP (Odepa, 2012). When the whole food system is considered, 23% of total output in the Chilean economy is related to the agricultural activities (Holland *et al.* 2001).

In Colombia, the importance of the agricultural sector for future economic growth is reflected in the National Development Plan for 2010-2014, which identifies and establishes agriculture as one of the five "locomotives" for achieving economic development (DNP, 2010). The share of the agriculture sector in the total GDP declined from 10.1% in 1990 to 6.5% in 2010. This result was mainly a consequence of a slower sectorial growth compared with the rest of the economy (driven largely by growth in the mining and hydrocarbons and the decline in coffee production) (DANE, 2011). The sectoral GDP has been recovering in recent years and a growth rate close to 4% is expected for 2013. The sector accounts for 18.7% of national employment and 67% of rural employment (DANE, 2011). Agriculture also plays an important role for implementing a land-restitution policy to the rural population displaced by the armed conflict. The Rural Development Act (2012) and the land issue rank first within the subjects of discussion in the current peace negotiations between the Government and the guerrillas.

Peru is a growing economy with an average GDP growth rate of 7.2% for the last five years. In 2011, the agriculture sector contributed with 7.5% to total GDP and employed 25.1% of the total economic active population, the highest share amongst all sectors (INEI, 2011). Agriculture is also the main source of income for 2.3 million families representing 34% of Peruvian households. Within the agricultural GDP, 60% is cropland production while 40% is related to livestock production (INEI, 2011).

In South Africa, the agriculture sector's direct contribution of less than 5% to gross domestic product (GDP) and 13% to employment appears low but increases to 12% and 30% respectively when agribusinesses income and labour are included (National Department of Agriculture, Forestry and Fisheries; 2012).

In most of the countries described above, agriculture's contribution to GDP is relatively small. Only Argentina and Brazil base an important part of their economy on agricultural exports. However, the social role of agriculture in all of the MAPS countries is fundamental. Agriculture-related employment accounts for most of the rural employment in the six countries as well as for large shares of national employment in some of them. In countries like Colombia and Peru, agriculture remains mostly a subsistence activity and provides households their main source of income. In addition, when we consider agriculture and agribusiness together, the economic and social relevance of the sector increases significantly.

Hence, the improvement of economic and social conditions within the agriculture sectors in these countries emerges as a key condition not only for enhancing economic growth but also socio-economic development, poverty alleviation, food security and job creation. Any mitigation actions within this sector must therefore take into account social factors and ensure that mitigation does not exacerbate inequity, nor reduce rural employment and income.

EMISSIONS PROFILES IN MAPS COUNTRIES

The previous section considered the socio-economic importance of the agriculture sector in the six countries selected for this paper. In this section we assess their national GHG emissions profiles and analyze the contribution of emissions from the agriculture sector.

The countries analyzed in this paper are all signatories to the UNFCCC and have submitted their Second National Communications to date. National Communications are in most cases based on national GHG inventories. As these countries are preparing their Third National Communications (TNC), most of the available and official (or published) data dates back to the year 2000. Most countries are still using Tier 1³ levels of IPCC to estimate emissions although some of them (e.g. South Africa) have used the Tier 2 approach for agriculture (South Africa Agricultural GHG Inventory for 2004 in Otter *et al.* 2010).

As shown in Table 1, in Argentina the agriculture sector explained 44% of the national emissions in year 2000. The energy sector (including transport) explained 47% while waste management and industrial processes contributed the remaining 9% (5% and 4% respectively). The main sources of GHG emissions from the agriculture sector were cropland emissions⁴ (52%) and enteric fermentation (46%). Manure management, rice cultivation and field burning of agriculture residues explained

³ A tier represents a level of methodological complexity to estimate GHG. In Tier 1 national emissions are calculated with default coefficients often applicable globally or at regional level.

⁴ Cropland emissions hereafter will be referred to as agriculture soils emissions following the IPCC classification of sectorial GHG sources.

less than 2% of sectoral emissions (República Argentina, 2007). Argentina's GHG emissions were estimated using the 1996 IPCC guidelines for the National Inventory.

In Brazil, the emissions share in 2005 is shown in Table 1 (MCT, 2013)⁵. Brazil's agriculture GHG emissions were estimated at 20.5% using the 1996 IPCC guidelines for the National Inventories between the years of 1995 and 2005. In this period, total emissions decreased 22%, the reduction attributed to a large decline in the deforestation rate (-40%). Agriculture, industrial processes and product use and waste emissions increased almost 24% each while energy emissions increased 41.5%.

The Chilean GHG inventory was mainly based on the Tier 1 method, although emissions from enteric fermentation, manure management and N₂O emissions from direct grazing were calculated using Tier 2. The 1996 IPCC and good practices guidelines (2000, 2003) were used for the last National Communication. Results indicate that in Chile, the agriculture and livestock farming activity represents 17% of the overall emissions (13,401 Gg CO₂ eq in 2006) –far behind the energy sector, which contributes 73% of the total emissions– and showing a 2% increase for the period 2000 – 2006 (MMA, 2001). When the agriculture sector is analyzed together with the forestry sector, the overall contribution is considered carbon neutral, as GHG emissions from the agricultural and livestock activity are lower than the carbon sequestration reported by the forestry sector (-19,386 Gg CO₂ eq in 2006) (MMA, 2011).

In Colombia, the agricultural sector is the largest national GHG emitter with a share of 38%, followed by the energy sector with 37%. Land use change and forestry generates 14% of the national emissions. Waste treatment and industrial processes contribute with 5% and 6% respectively. Of the total emissions from the agriculture sector, 96% come from enteric fermentation (48.5%) and agricultural soils (47.5%). Also, 94% of emissions within the enteric fermentation category are due to emissions from beef cattle (91%) and dairy cattle (3%) (IDEAM, 2011). It is important to point out that the country needs to make a greater effort to get more precise measurements of GHG emissions. Tier 1 emission factors were used, meaning that (significant) regional differences within the country could not be taken into account.

In Peru, according to the 2000 GHG inventory, the main source of GHG emissions is land use, land use change and forestry (LULUCF) (47.5%), mainly attributed to the deforestation of the Amazon rainforest. The second category corresponds to energy (21%), being transport the main emission source. Agriculture emits about 22,544 Gg of CO₂ eq (19%) with the largest contribution of emissions coming from enteric fermentation (46%), agricultural soils (43%), manure management (4%) and rice production (4%). Peru's 2000 GHG emissions were estimated using the 1996 IPCC guidelines and Tier 1 emission factors, so as in Colombia, regional differences were not included in the estimation (MINAM, 2010).

In South Africa, the main source of national GHG emissions is energy (86%) followed by agriculture (9%) and industrial processes (7%). When the agriculture sector is analyzed together with the forestry sector, the overall contribution decreases, as the LULUCF sector is a carbon sink (-4%). In the agriculture sector the main source of emissions is enteric fermentation (50%), followed by indirect nitrous oxide from managed soils (45%) and manure management (5%) (Department of Environmental Affairs, 2009).

⁵ Recent estimates show that emissions from land use change have been decreasing significantly since the Second National Communication (MCTI, 2013).

Table 1: Sources of emissions for MAPS countries

		COUNTRY					
		ARGENTINA	BRAZIL	CHILE	COLOMBIA	PERU	SOUTH AFRICA
Base year	Unit	2000	2005	2006	2004	2000	2000
Total GHG (Gg CO ₂ eq) – with LULUCF	Gg CO ₂ equivalent	238,703	2,032,260	59,672	179,899	120,024	442,484.54
Sector contribution (%) to total GHG							
Agriculture	%	44	20.5	17	38	19	9
Energy	%	47	16	73	37	21	86
Industrial Processes and Product Use	%	4	4	7	5	7	7
Land-Use, Land Use change and Forestry	%	-18	57.5	-24.5	14.5	47	-4
Waste Management	%	5	2	3	6	6	2

The relatively high percentage of emissions generated by the agriculture sector reflects the productive profile (main sectors and industries) of two of the countries considered: Argentina (44%) and Colombia (38%). In Brazil and Peru the LULUCF sector contributes with most of the emissions: 58% and 47%, respectively. Most of these emissions come from the deforestation of the Amazonian rainforest⁶. The new land available from the deforestation is expected to be used, in part, for agricultural activities, potentially increasing GHG emissions in the future. A recent estimation of GHG in Brazil (MCTI, 2013) shows an increase on agriculture emissions (5%) and a significant drop on LULUCF emissions (-76%) mainly explained by variations in agricultural output prices and controlling and preventing deforestation policies in the Amazon (Assunção *et. al* 2012).

In South Africa and Chile most of GHG emissions come from the energy sector; 86% and 73% respectively. Both countries have industrial-based economies, which explain their emissions profiles. However, in Chile the contribution of the agricultural sector to national GHG emissions increased 8%, 10% and 18% in the 1990 – 2000, 1990 – 2006 and 1984 – 2006 periods respectively, mainly associated to increases in emissions from agricultural soils and enteric fermentation (MMA, 2011).

AGRICULTURAL EMISSIONS SOURCES

Agricultural emissions are split into two main categories: cropland emissions and livestock emissions. The sources of cropland emissions are mainly three (IPCC, 2006):

- Field burning of agricultural residues, which generates CH₄ emissions as well as carbon monoxide (CO), nitrogen oxides (NO_x) and N₂O.

⁶ In Brazil, 50% of the emissions of the LULUCF sector come from the deforestation of the Amazonian rainforest and 40% of the emissions come from the deforestation of the savannas or “Cerrado” region.

- Use of synthetic fertilizers, biological nitrogen fixation (BNF) and final underground disposal of agricultural residues, which generate direct and indirect N₂O emissions.
- Rice production in flooded soils, which generates CH₄ emissions.

With regards to livestock, there are four main sources of GHG emissions (IPCC, 1996 and 2006):

- Enteric fermentation, which generates CH₄ emissions.
- Nitrogen excreted by livestock on grasslands and grazing lands, which generates direct N₂O emissions from soils.
- Volatilization and lixiviation of the nitrogen contained in the urine and faeces of livestock, which generate indirect N₂O emissions of soils.
- Manure management, which generates CH₄ and N₂O emissions.
- The main sources of emissions identified in the agriculture and livestock sectors of the six MAPS countries under consideration are enteric fermentation, agricultural soils and manure management. They represented on average 47%, 45.1% and 5% of total agricultural emissions respectively in the year for which they were reported in the Second National Communications. When accounted together, these three categories explain between 93% and 100% of total agricultural emissions within the MAPS countries (eg. 93% in Peru and 100% in South Africa). In this sense, mitigation efforts related to livestock and cropland production are most likely to have a bigger mitigation potential.

AGRICULTURAL MITIGATION AND IMPLEMENTATION AT NATIONAL LEVEL

The following section describes the mitigation efforts that MAPS countries are evaluating and/or implementing in the agriculture sector at the national level. The analysis of these options in most of the countries presents challenges regarding the costs required to assess their GHG reduction potential. These challenges include variation in spatial and temporal dimensions resulting from local biophysical and management conditions, complexity of interactions between multiple gases emitted, lack of regional and farm level cost estimates and implementation difficulties related to financial incentives (Beach *et al.* 2008).

Table 3 presents a list of the mitigation actions that the academic literature recommends for the agriculture sector (IPCC, 2007; McKinsey & Company, 2010; FAO, 2011; UNFCCC, 2012; Wilkes *et al.* 2013) and shows if the six countries being study have considered or implemented them. Public policies, programs and available literature from government were included to build the table as well as secondary literature by academic researchers and the private sector

Table 2: Mitigation actions in the agriculture sector for the MAPS countries

SUBSECTOR	MITIGATION ACTION	COUNTRY									
		ARGENTINA	BRAZIL		CHILE*		COLOMBIA		PERU	SOUTH AFRICA	
		Under consideration	Under consideration	Implemented	Under consideration	Implemented	Under consideration	Implemented	Under consideration	Under consideration	Implemented
LIVESTOCK	Pasture Improvement and Grazing land Management			Recovery of Degraded Pastures and Integration of Crops and Livestock and Agro-forestry Systems	X		X	Integration of agricultural systems, livestock and forestry to improve productivity and greater carbon storage	X	X	
	Silvipastoral Systems				X						
	Agropastoral Systems						X				
	Strategic supplementation of cattle with specific agents and dietary additives	X					X				
	Animal Improvement	X									
	Better livestock practices	X					X			X	
AGRICULTURAL SOILS	Chemical Inhibitors	X			X						
	Nutrient Management / Nitrogen reduction	X		Biological Fixation of Soil Nitrogen	X		X		X		
	Bioenergy	X					X			X	
	Rice Management							Efficient water use in irrigated rice	X		
	Agroforestry	X					X				
	Low - Zero Tillage	X		Zero tillage practices	X		X				X
	Cogeneration	X						Use of agricultural crop residues for power generation			X
	Composting	X			X						X
	Water Management	X					X			X	
	Manure management	X		Power generation and production of organic fertilizer from swine manure	X			Use of manure for generation of biogas and energy			

Regarding these six MAPS countries, some of them are more advanced than others in sector-specific emissions reductions efforts. Brazil has already been making efforts to limit its national GHG emissions, including reducing emissions from deforestation and large investments in renewable energies, amongst others. These actions, together with others in the industrial and waste sectors were officially recognized as an instrument to reduce between 36.1% and 38.9% of the country's GHG emissions projected to 2020.

Mitigation initiatives in the agriculture sector were established by decree and included in the Low Carbon Agriculture Plan (Plan ABC), a governmental tool dedicated to finance farmers to implement national mitigation actions and to support the adoption of new agriculture practices. The mitigation actions presented in Table 3, together with forest plantations and adaptation strategies should mitigate between 133 and 166 million (m) tons of CO₂eq in 2020⁷. For each action, the Plan ABC adopts a series of activities as for example, strengthening of technical assistance, training and information, technology transfer strategies, lectures, seminars, workshops, etc. The activities are also planned to provide economic incentives and funding to producers to implement the mitigation actions. According to Gurgel et al (2013), around 78,000 financing contracts need to be set up to 2020 to accomplish the targets.

In Argentina, a Technology Needs Assessment (TNA) has been recently undertaken, which considers better practices and low-carbon options for the agriculture sector (Ministerio de Ciencia, Tecnología e Innovación Productiva, 2013). The scientific and academic sectors have been working on sectorial emission-reduction options. The National Institute of Agriculture Technology (INTA) and the Ministry of Science, Technology and Innovation are undertaking research aimed at analyzing potential mitigation options both in the agriculture and livestock sectors and they are also working on the estimation of country-specific emission factors. The main GHG mitigation technologies that are being analyzed are: nitrogen inhibitors, more efficient fertilizer application technologies, biological nitrogen fixation in some crops, crop rotation and changes in livestock feeding (Taboada, 2012; Vázquez Amábile, 2012). With regards to soybean, zero-tillage is being widely expanded and (soy) biodiesel production is being promoted (Molina, 2012). However, neither zero-tillage practices nor biofuel-boost policies are being conceived as mitigation actions *per se*.

Recently, the focus of the Argentinian agriculture sector has been on adaptation, as a response to climate variability and impacts the country has experienced (specifically an increasing trend in annual average precipitations specially in the northeast and central regions). This has been linked to the expansion of the agriculture frontier towards western and northern areas, causing environmental damage and increasing the rate of deforestation and soil degradation (República Argentina, 2007).

In Chile, the MAPS Chile strategy, led by the Ministry of Environment and the University of Chile, is assessing scenarios and options for climate change mitigation. Also, the National Institute for Agricultural Research (INIA) is developing country specific emission factors and analyzing potential mitigation options for the sector.

The Chilean Government has established a voluntary target of reducing 20% of the countries CO₂eq emissions by 2020, using the emissions of 2007 the base year. The assessment developed by MAPS Chile will include mitigation actions in the agriculture sector that will contribute towards achieving the 10% reduction goal (MMA, 2011).

In Colombia, the development of mitigation actions are mainly based on outputs of the Colombian Low Carbon Development Strategy (CLCDS), the Ministry of Environment and Sustainable Development and specifically the Climate

⁷ An assessment of the mitigation potential is available in La Rovere et al. (2011).

Change Mitigation Group, with the support of the Ministry of Agriculture and Rural Development, the farmers and other agencies. The initiative is designing and implementing policies, plans, programs, regulations and targets to mitigate the effects of GHG generated by the agricultural sector.

Currently, the Colombian Low Carbon Development Strategy is considering and assessing most of the actions presented in Table 3. During 2013 and 2014 the country is planning to develop Mitigation Action Plans for the agriculture sector and to create and promote tools for their implementation. Additionally, livestock producers, rice producers and some agribusinesses have started implementing mitigation efforts to improve productivity, increase profitability and reduce risks on water availability.

The technologies of potential abatement of implemented mitigations actions in Colombia in the case of silvipastoral systems are related with the integration of agricultural systems, livestock and forestry to improve productivity and greater carbon storage. In the case of efficient water use in irrigated rice, the technologies aims to decrease the time of flooding and the depth of the water surface to reduce the anaerobic decomposition of organic material; and in the case of cogeneration, technologies seek to use the agricultural crop residues and the use of manure for generation of biogas and energy.

In Peru, the Ministry of Environment in coordination with private, public and non-governmental institutions is developing the Planning for Climate Change Project (PlanCC). The main purpose of the project is to set the scientific and political bases and the knowledge to explore the feasibility of a low carbon economy and incorporate a climate change approach in the development planning. The next stages of the project include the design, assessment and implementation of mitigation actions of GHG emissions in the agriculture sector. These actions not only evaluate impacts on agriculture's emissions but also include considerations of co-benefits (social, economic and environmental).

The actions listed in Table 3 are those that have been identified as having greater potential impacts on emission sources: enteric fermentation (use of cultivated pasture instead of natural pasture) and better management of agricultural soils (training to avoid over nitrogen fertilization). The Ministry of Agriculture, the National Agriculture University "La Molina" and the farmers are the main stakeholders involved in the process.

In South Africa, the national Department of Agriculture, Forestry and Fisheries (DAFF) is drafting the Climate Change Sector Plan, the most recent institutional arrangement for policy development within the sector. Prior to that, agriculture was included in the Long-Term Mitigation Scenarios (LTMS) process for South Africa, in national research and development strategies on climate change and in national Technology Needs Assessment (Taviv *et al.* 2007). Otter *et al.* (2010) published the first national GHG inventory for agriculture's emissions in 2004 with intention that results will inform development of a mitigation strategy. A valuable insight from this inventory is that disaggregated GHG emissions data at provincial level rather than national level is required to increase mitigation potential. Private sector initiatives at farm level to measure and reduce GHG emissions have been undertaken primarily as response to export market access requirements most notably in fruit and wine sector.

However, as is the case with Argentina, in South Africa the agriculture mitigation efforts listed in Table 3 are being developed mainly at the scientific and academic level. A considerable amount of research has been published, which tends to focus on climate change impacts and adaptation. A study from the Centre for Environmental Economics and Policy in Africa (CEEPA) at the University of Pretoria assesses economic instruments to mitigate climate change in key sectors aiming to understand policy mechanisms and potential impacts within the context of South Africa's industrial policy framework

(Cloete *et al.* 2010). Key findings relevant and applicable to agriculture address the lack of data on costs and emissions at sector and sub sector level, which highlights the need for research on agriculture technologies and country specific emission factors. This would enable stakeholders to meaningfully engage in debate on GHG mitigation strategies.

Mitigation in the agriculture sector was also considered in the national Long Term Mitigation Scenario process that included reduction in livestock herd size, transferal of free-range livestock to feedlots, increase in feedlot manure that is currently scraped and dried and adoption of reduced tillage (Winkler *et al.* 2007). A challenge in assessing implementation and quantifying reductions of GHG emissions of agriculture mitigation actions in South Africa is that many of the recommended practices have been in existence for quite some time; are known to farmers, researchers and policy makers and have been adopted at various levels. It is however difficult to determine the effect they have had on reducing GHG emissions, as most of the actions implemented have not have an explicit aim of mitigating climate change.

CO-BENEFITS OF AGRICULTURAL MITIGATION

Agricultural emissions reduction initiatives such as reduced tillage, improved soil management and livestock management can improve agricultural productivity, contribute to food security, improve water, soil and air quality, protect biodiversity and wildlife habitats, generate employment, alleviate poverty and contribute to adaptation to climate change (Wlokas *et al.* 2012; FAO 2012a, 2012b, 2009; Giacomo *et al.* 2011; Niggli *et al.* 2009).

In this context, efforts to reduce agricultural GHG emissions can support long-term environmental sustainability and could also contribute to economic development. This means that direct emissions can be reduced while enhancing at the same production efficiency. This has the advantage of increasing farmers' profitability, thus reducing poverty, as well as reducing negative environmental impacts on soils, water and air.

In the MAPS countries that have family-based agriculture systems, social co-benefits of the sector's mitigation actions play a special role, as they directly target poverty alleviation, food security and job creation. However, the potential of mitigation actions in the agriculture sector to generate co-benefits vary according mainly to the characteristics of the climate zone and the socioeconomic conditions of the region that is being considered (FAO 2012a, 2012b, 2009; Giacomo *et al.* 2011; Niggli *et al.* 2009; IPCC, 2007b). Labitan *et al.* (2013) found that in Kenya, emissions from the agricultural sector contributed to improvements of the country's agricultural productivity between 1965 and 2010. In that sense, mitigation actions in the agriculture sector could have a negative impact on sectorial productivity in some countries.

ASSESSING AGRICULTURAL MITIGATION ACTIONS

Key challenges

Although progress has been made at the research level worldwide to develop cost-effective agriculture mitigation options, in most developing countries the potential for mitigation remains unclear as effectiveness varies depending on soil and weather conditions as well as according to specific characteristics of the different productive systems. In these countries, little information is available on local emission factors. Most developing countries have used Tier 1 approaches to quantify country emissions (Table 1), limited both by the availability of local emission factors and the availability of detailed activity data, so that the quantification of potential reductions associated to the use of mitigation options will be also limited. However, as described in section five, specific efforts to assess potential reduction and costs of mitigation actions at the

regional level are being made, and even mitigation plans with assessments of mitigation potential and costs are being implemented.

Implementation barriers are also identified as a key challenge for mitigation options in the agriculture sector (Smith *et al.* 2007b). Funding for these options is essential as in many cases neither farmers nor governments are able to afford the costs of implementing mitigation alternatives since they face more urgent needs (e.g. health, education).

The development of technical information and capacity building in the research area is also necessary, mainly for the generation of local emission factors and as part of the national inventory elaboration programmes. The availability of detailed agricultural census and activity data for the sector requires further advances.

An additional barrier related to modelling the sector is that although many models exist that measure or estimate GHG emissions in the agriculture sector, few have been specifically designed to assess mitigation actions within the sector. No single model can fully address all of the potential mitigation actions in the agriculture sector, but a combination of different models can be used to give more accurate assessment (Rahlao, 2013). More research is needed to determine appropriate ways to model the agriculture sector in each country.

Future research

Investment in agricultural research needs to be strengthened in many of the MAPS countries as part of a mitigation strategy that will lead to sustainable development. More research needs to focus on non-carbon dioxide (CH₄ and N₂O) potential for mitigation.

The Food and Agriculture Organization of the United Nations (FAO) estimates that agricultural N₂O emissions will increase 35 – 60% up to 2030 due to increased nitrogen fertilizer use and increased animal manure production (FAO, 2003). Also, if CH₄ emissions are likely to grow in direct proportion to increases in livestock figures and the latter are expected to increase, global livestock-related methane production is hence expected to rise by 60% up to 2030 (FAO, 2003). These projections are also supported by the increasing demand for food production, mainly from Asia and Latin American countries.

More research needs to focus on CH₄ and N₂O potential for mitigation, as the particular characteristics of the different productive systems make it difficult to incorporate information generated elsewhere, as discussed previously. Joint efforts could be made in strengthening specific relevant areas, including the adaptation and implementation of methodologies and the formation of critical mass within specific agricultural sectors. One example is the “Climate change and beef cattle production: Quantification and mitigation of methane and nitrous oxide emissions from grazing beef cattle” project funded by FONTAGRO, which aims to develop local emissions factors for both N₂O and enteric CH₄ from livestock systems based on grazing of permanent pastures. The projects include Argentina, Colombia, Chile, Uruguay and The Dominican Republic and are currently being undertaken with positive impacts.

COMPARATIVE ANALYSIS ACROSS COUNTRIES

Although the contribution of agriculture to the national GDP ranges between 5 to 10% in the countries covered in this paper, the relative contribution to GHG emissions can be as much as 44%. While land use change contributes significant amount to GHG emissions, some countries are implementing specific plans to reduce emissions. It is expected that countries such as Brazil and Peru, with significant emissions from land use change will achieve significant reduction through

legislation and implementation of regulations. In agriculture, up to half of the emissions arise from enteric fermentation by cattle. Although there are many mitigation actions reported in the literature (for a comprehensive review see Hristov *et al.* 2013), mitigation potential, duration of impact and cost effectiveness have not been researched in detail. Key issues include the adaptability of the rumen ecosystem, cost of mitigation actions and possible negative health and productivity effects. The most promising mitigation actions for countries covered in this paper can be grouped into three categories: Feeding practices, supplements and additives, and herd management and breeding.

Relevant feeding practices include improved forage and feeding of concentrates. Brazil is one of the largest beef producers globally. Stocking rates are very low in large part because pasture land is degraded. Improved pasture management, improvement forage, and more dense production systems can reduce emissions per unit of meat produced and also sequester carbon in the soils. More efficiency of production may also reduce pressure on forest conversion. Similarly, Argentina and Chile have also sizable beef producers. They tend to have higher stocking densities than Brazil, but still have opportunity to improve pasture management and forages. Peru perhaps has a larger emission reduction potential than any of the other countries because most of livestock are kept in native grasses, which can improve productivity and reduce emissions. Improved forages may reduce emissions by up to 30% and the cost of implementation can be low to moderate depending on location and techniques adopted (Gerber *et al.* 2013).

Addition of lipids to diet may reduce emissions by 10 to 30%, however, it is difficult to implement in extensive systems and the cost depends on availability and price of oil products. Appuhamy *et al.* (2013) showed that addition of ionophores to diet can reduce emissions by up to 10% and also improved efficiency of feed conversion. This is possible to implement in the more intensively managed systems examples of which can be found in Brazil and South Africa. Improved productivity due to genetics is estimated to reduce net enteric methane emissions by about 3% in cattle (Hristov *et al.* 2013). However, selecting cattle directly for reduced methane emissions has not been practical. Nevertheless, New Zealand researchers are making progress in selecting low methane emitting sheep in extensive systems (Pinares Patino *et al.* 2011) that is directly applicable in the countries covered in this paper.

In summary there are a wide range of mitigation options for reducing GHG emissions in our target countries, but many have some mitigation uncertainty, poorly understood interactive effects with other emission sources, or some associated risk. The group of mitigation options that have relatively little risk and are uniformly associated with increased productivity are improved feeding practices which are expected to yield significant GHG reductions while also providing a steady or growing supply of animal products. It is important to note that many of these practices are not complementary or “additive” – the optimum combination of practices will vary locally and has not been well-studied in many regions.

CONCLUSIONS

This paper presents evidence on the importance of the agriculture sector both at the socio economic level and from a GHG emissions perspective, and explores the efforts that are being undertaken in Argentina, Brazil, Chile, Colombia, Peru and South Africa with regard to mitigation in the agricultural sector.

Our assessment suggests that the six countries considered in this paper would benefit from prioritizing policies in the agriculture sector as they impact economic development, poverty alleviation, job creation and food security. Hence, mitigation policy design in the agriculture sector should take carefully into account the importance of neither strangling productivity nor generating negative impacts on economic yields.

Moreover, the emission reduction, the cost and the potential co-benefits generated by a mitigation actions in the agriculture sector vary according to the characteristics of the climate zone and the socioeconomic conditions of the region that is being considered. More research focused on understanding the cost of mitigation actions is needed, its implications in the sector productivity and in co-benefits. In this sense, it seems key for developing countries, and specifically for the MAPS countries considered in this paper, to focus climate sectorial strategies on identifying and exploiting synergies among GHG emissions reduction, adaptation to climate change and sustainable development goals.

ACKNOWLEDGMENTS

MAPS International funded this work and the workshop on “Methodology to model mitigation actions in the agriculture” held in Bogota, Colombia in 2012 that led to the development of this paper.

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