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# PROCEEDINGS of the

# SYMPOSIUM

on

# MITIGATING GREENHOUSE GAS EMISSIONS FROM ANIMAL PRODUCTION: A POLICY AGENDA

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# *AGRICULTURE AND THE CLIMATE CHANGE NEGOTIATIONS: an FAO perspective*

*(Wendy Mann, Senior Adviser, Natural Resources Management and Environment Department)*

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## 1. CURRENT CLIMATE CHANGE NEGOTIATIONS UNDER THE UNFCCC: THE PROCESS

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The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1992 and entered into force on 21 March 1994. It provides a framework for action aimed at stabilizing atmospheric concentrations of greenhouse gases (GHGs) to avoid “dangerous anthropogenic interference” with the climate system. In December 1997, delegates at the third Conference of Parties (COP 3) in Kyoto, Japan, agreed to a Protocol to the UNFCCC that commits industrialized countries and countries in transition to emission reduction targets via market-based cap and trade mechanisms. The Kyoto Protocol entered into force on 16 February 2005.

The UNFCCC Conference of the Parties at its thirteenth session (COP 13) in Bali, December 2007, addressed long-term issues and resulted in the adoption of the Bali Action Plan (BAP). Under this Plan an Ad hoc Working Group on Long-term Cooperative Action (AWG-LCA) was established to focus on four key elements of long-term cooperation identified during the Convention Dialogue: mitigation, adaptation, finance and technology (known as the BAP pillars). The BAP contains a non-exhaustive list of issues to be considered under each of these areas and calls for articulating a “shared vision for long-term cooperative action.” The Bali conference also agreed on a two-year process, the Bali Roadmap, which designated negotiation “tracks” under the Convention and the Protocol (for a post-2012 framework) through an Ad hoc Working Group on the Kyoto Protocol – AWG-KP, setting a deadline for concluding negotiations at COP 15 and COP/CMP 5 (Meeting of the Parties of the Kyoto Protocol), to be held in Copenhagen in December 2009.

## 2. THE IMPORTANCE OF AGRICULTURE TO AN INTERNATIONAL CLIMATE CHANGE REGIME

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Perhaps no other sector has the potential to contribute so directly to the aspirations of the ultimate objective of the Convention (Article 2: the stabilization of GHGs in the atmosphere...at a level that ensures ecosystem resilience... food production is not threatened and enables economic development in a sustainable manner). Moreover, the magnitude of the challenge to stabilize GHG concentrations in the atmosphere and limit average temperature

increases makes it imperative that the contributions of all sectors with significant mitigation potential be tapped to the fullest extent possible. Agriculture is recognized as a sector with such potential.

## 2.1 A MAJOR SOURCE OF GHGS

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According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR4), agriculture accounts for 14 percent of global GHGs or approximately 6.8 Giga tonnes of CO<sub>2</sub> equivalent (e) and is expected to grow driven mainly by population and income increases and changes in diet. GHG emissions from land use change, including deforestation (for which agriculture is a major driver) accounts for another 17 percent. Together, they account for more than one-third of all global GHG emissions. About 74 percent of total GHG emissions from agriculture derive from developing countries.

## 2.2 HIGH MITIGATION POTENTIAL

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The technical mitigation potential of agriculture is high, especially relative to its emissions (IPCC AR4 estimates 5.5 – 6.0 Giga tonnes of CO<sub>2</sub> per year by 2030). About 89 percent of this potential could be achieved through soil carbon (C) sequestration, 9 percent through CH<sub>4</sub> emission reduction (through improvements in rice management and livestock/manure management) and 2 percent through N<sub>2</sub>O emission reduction (primarily through more efficient use of fertilizers and cropland management). Seventy (70) percent of the technical mitigation potential and the majority of the economic potential could be realized in developing countries (Smith, *et al.* 2007).

## 2.3 STRONG CO-BENEFITS

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Some agricultural mitigation practices (low/no till, agroforestry, mulching, switching to perennial crops) have multiple benefits beyond mitigation: contributing to increased resilience, higher agricultural productivity and production. These in turn can underpin heightened adaptation, food security, poverty reduction and economic development.

## 2.4 ABATEMENT<sup>1</sup> AND TRANSACTIONS<sup>2</sup> COSTS

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Different agricultural abatement options and different financing modalities will be relevant for different countries. Carbon sequestration projects differ in terms of cost per unit of carbon emissions avoided or carbon sequestered, which is determined by the opportunity costs of switching land uses. They also differ in terms of other environmental and social benefits provided.

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<sup>1</sup> Abatement costs are defined as the costs of producing one unit of (uncertified) carbon sequestration services. In any given location, abatement costs can be estimated as the opportunity cost of switching from a baseline use to a new land use.

<sup>2</sup> Transaction costs arise in the processes of achieving an agreement and then continuing to coordinate its implementation. These include contracting, monitoring and verification costs. In the case of carbon markets, transaction costs tend to be high because the property right to be exchanged is difficult to measure and its exact size is subject to uncertainty.

Some agricultural abatement practices are cost neutral or net-profit-positive (McKinsey, 2009). This is not to say that their adoption would happen anyway or without cost. Barriers, such as lack of investment capital, lack of information, risk and unclear property rights, often need to be addressed. The transactions costs likely to be involved in agricultural mitigation also vary by type of activity and institutional capacity. Smallholder projects generally involve higher costs and thus aggregation capacity is an important means of reducing costs per emission reduction unit. Innovative financing mechanisms, including front-loaded financing, resources for technology development/transfer, sectoral approaches and capacity building are often needed to encourage adoption by farmers.

### 3. THE POSITION OF AGRICULTURE WITHIN THE NEGOTIATIONS

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Since COP 13 in Bali, agriculture has tended to be somewhat on the margins of the climate change negotiations. It has been overshadowed by its sister land use sector, forestry, which has had a high profile through REDD (reduction of emissions from deforestation, forest degradation, to which has been added conservation and sustainable forest management). This is due to the perception that agriculture is a difficult sector in terms of its extensive and diverse nature, implementation uncertainties (leakage and permanence), difficulties and costs related to measuring, reporting and verifying (MRV) emission reductions, payment schemes and the exclusion of soil carbon sequestration, which is estimated to constitute 89 percent of the mitigation potential of agriculture, from the Clean Development Mechanism (CDM). FAO and others have argued that methodologies have evolved but need testing, inaction is not an option and the scope of the CDM should be broadened.

A technical paper, prepared by the UNFCCC Secretariat, and an in-session workshop on *Opportunities and Challenges for mitigation in the agriculture sector*, requested by the AWG-LCA at its second session, have helped to focus attention on the agriculture sector within the negotiations. At the workshop, held on 4 April 2009 during the last negotiating session in Bonn, 16 developing and 5 developed countries took the floor.

Overall, the majority of these delegations strongly supported the inclusion of agriculture in the negotiations, with some mentioning its importance within the programme of work for the second commitment period. As one country stated at the end of debate, “mitigation in the agriculture sector is definitely on the table” and agreed with other delegations that had stated that it is part of the BAP. However, the absence of a clear position from key emerging economies and from G-77/China was noteworthy. The position of these countries is likely to be important in the context of agriculture as they are countries with a significant agricultural mitigation potential that could be used to offset their emissions in nationally appropriate ways that potentially benefit their sustainable development and strengthen their adaptive capacity.

Within debate on mitigation and financing at the same session in Bonn, some began to speak of the specificities of agriculture and REDD (e.g. current financial mechanisms exclude them, they require mitigation action to be adopted by a large number of smallholders who cannot make upfront payments, both are land use sectors, both face challenges of permanence and leakage, both have strong co-benefits for development, environmental services and synergies between mitigation and adaptation). It is not certain, at this time, how this notion of ‘specificity’ may play out within the negotiations and their outcome (see Section 5 below).

## 4. ISSUES UNDER CONSIDERATION WITHIN THE NEGOTIATIONS OF DIRECT IMPORTANCE TO AGRICULTURE

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All of the pillars of the BAP relate directly or indirectly to agriculture. Issues of special interest include:

### 4.1 FINANCING MITIGATION

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As mentioned above, existing climate change financing mechanisms to support mitigation have so far been highly inadequate in enabling agriculture (and forestry) to contribute, in line with its potential, to GHG reduction and carbon sequestration through activities with robust co-benefits. For example, soil carbon sequestration is excluded from CDM, unless it is adopted in the framework of CDM Afforestation/Reafforestation (A/R) projects. In 2007 only one project out of a total of 1 100 projects addressed A/R. Today there are still only three A/R projects. However, some agriculture and livestock waste management projects have benefited from CDM crediting, although the share of the sector remains small, compared with its potential and *vis-à-vis* other sectors.

Financing options and more appropriate financial delivery systems that enable agriculture, including smallholders, to contribute more effectively to GHG abatement are therefore urgently needed, and would need to be part of a Copenhagen outcome document, if the sector's mitigation potential and co-benefits are to be captured. Such a step would also help to accelerate the development of appropriate accounting/crediting methodologies.

The Food and Agriculture Organization of the United Nations explored in its last submission to the negotiations, and in its presentation to the in-session workshop, possible features required to finance agricultural mitigation in developing countries, including (i) aggregation both to bundle the large numbers of agricultural producers and as a means for upscaling to more practical and cost-effective baseline, accounting and crediting modalities (e.g. sectoral/programmatic approaches); (ii) more integration across and combining of funding sources and mechanisms (existing/new, public/private, Official Development Assistance (ODA)/new and additional climate change resources, compliance/voluntary markets) to heighten flexibility and enable: (a) innovative payment schemes/institutions that address risk, investment and cash flow needs through frontloaded payments, possibly guaranteed through bonds or insurance, and ways of valuing mitigation/development/adaptation synergies; and (b) a phased approach that allows smallholders to transition towards market approaches through public support for capacity building and technology development/transfer; (iii) simplified rules and lower transaction costs to increase farmer participation; and (iv) supportive and fair policies and institutions that recognize individual and community property rights.

### 4.2 MITIGATION IN DEVELOPING COUNTRIES

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Agriculture has entered the negotiations at the same time as developing countries are considering how they might frame nationally appropriate mitigation action (NAMAs), both in the context of their sustainable development and national mitigation strategies, as well as in terms of linking such action with international support. The idea of a register of NAMAs has been proposed to facilitate the matching of action and support.



It has been proposed that NAMAs can be (i) voluntary (or unilateral and would be “recognized”, possibly with some form of crediting); (ii) based on support from developed countries; or (iii) on carbon credits and contained in a registry that matches national action with international support.

As the agricultural sector in developing countries has considerable technical and economic potential to mitigate emissions, and in many cases mitigation practices also improve agricultural productivity and resilience and thus contribute to food security, the agricultural sector is potentially highly relevant to the development of NAMAs in developing countries. Accessing additional carbon finance and technology transfers to combine mitigation with ongoing processes of sustainable agricultural development through the NAMA vehicle could be an important feature of future development and climate change mitigation strategies, policies and programmes. Inclusion of agriculture in developing country NAMAs could also help to provide resources for mitigation from the sector, beyond the Clean Development Mechanism of the Kyoto Protocol, wherein soil carbon sequestration in developing countries cannot provide emission reduction offsets to developed countries.

An approach for funding NAMAs, suggested by a group of developed countries, foresees developing countries preparing low-carbon emissions development strategies that identify actions requiring external resources. These could be listed through the proposed NAMA registry, and developed countries could then match support to the actions. It is not clear whether this support would then qualify as offsets or be more in the nature of development aid. The response of some developing countries was guarded and they cautioned against the idea of a “super-market” approach to mitigation activities from which developed countries could pick and choose. Others felt this proposal was based on a model of donor-client relationships that is not appropriate in this setting.

The positions of developing countries on NAMAs, expressed during the workshop, varied. Some stated that the concepts of offsets and developing country NAMAs needed to be kept distinct. Others indicated that developing country NAMAs are an additional emission reduction activity that would need additional funding. Still others noted that carbon finance could have an important leveraging role but there would be a strong role for public finance as well. One developing country suggested that a registry might be “a NAMA window” of the financial mechanism. A support and accreditation mechanism (SAM) was also proposed.

#### **4.3 TRADE IMPLICATIONS IN THE CONTEXT OF ECONOMIC AND SOCIAL CONSEQUENCES OF RESPONSE MEASURES**

Trade aspects had not figured prominently in the negotiations but came to the fore in discussions under the AWG-LCA, during its in-session workshop on *Economic and social consequences of response measures* at the last negotiating session in Bonn. As examples of negative consequences deriving from climate change responses, developing country Parties referred to: possible trade distortions involving carbon labelling (similar to ecolabelling with the risk of non-tariff barriers to trade); different carbon trading schemes, effects of carbon sequestration on agricultural prices and technology transfers to certain countries (as well as intellectual property rights aspects of such transfers). However, the AWG-LCA session concluded with no consensus on concrete ways of addressing possible consequences and it appeared that more technical work on trade aspects is required to underpin both discussion and possible ways forward.

## 5. HOW MIGHT AGRICULTURE FIGURE IN A COPENHAGEN OUTCOME DOCUMENT?

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At this point it is not clear how agriculture might, if at all, form part of a Copenhagen outcome document, as the shape and content of this document is still unknown. There are various hypothetical possibilities. The document may be composed of some issues on which substantive decisions could be made and other issues on which only procedural decisions could be made with the intent of leaving substantive action thereon to the post-Copenhagen period. As agriculture is only entering the negotiations and has not been the subject of methodological discussion in the Subsidiary Body for Scientific and Technological Advice (SBSTA), it could fall within a procedural decision.

Another possibility is that there could be references to specific sectors under the BAP pillars, where agriculture might be mentioned under mitigation and possibly financing/technology. It would seem doubtful that there would be separate sectoral sections, with the possible exception of REDD.

If REDD is treated as a stand-alone issue, various other possibilities could be considered: (i) the possibility that agriculture might become part of an expanded REDD mechanism, given its role as a driver of deforestation (this has already been mentioned by several countries but might not allow the sector's full mitigation potential to be captured); (ii) agriculture could eventually become a stand-alone sector (probably post-Copenhagen but this might impede optimal management across the two land uses; and (iii) REDD and agriculture could form part of a terrestrial or land-use sector to allow for the management of the trade-offs and synergies across land uses.

## 6. WHAT STEPS MIGHT THE AGRICULTURE COMMUNITY TAKE ON THE ROAD TO COPENHAGEN AND BEYOND?

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Mitigation in the agriculture sector is now on the table within the negotiations. There is a technical paper, prepared by the UNFCCC Secretariat, outlining different mitigation options. An in-session workshop was held that allowed Parties to express their initial views and FAO has made a number of submissions to the AWG-LCA to assist Parties in their consideration of this issue.

### WHAT MIGHT BE THE NEXT STEPS?

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It is important to recall that agriculture is the major economic sector of (i) many developing countries; (ii) most Least Developed Countries; and (iii) the main livelihood of 70 percent of the poor in developing countries. It is the largest manager of natural resources (land, water, domesticated genetic resources). Agriculture is expected to feed a population that will number 9.2 billion in 2050, while providing income, employment, environmental services **and** responding to climate change. It will need to do all of this, following decades of declining investment in the sector and in the context of the current financial crisis. It will therefore be absolutely crucial that agricultural mitigation is placed within the context of agricultural development and food security



and that opportunities for mitigation in this context be appropriately funded. Changes to current climate change funding modalities, which have largely excluded REDD and agriculture, as well as the establishment of more innovative ways of upscaling and integrating multiple funding streams, could already be envisaged in a Copenhagen outcome document.

Nationally appropriate mitigation action relating to agriculture for inclusion in eventual NAMA arrangements could begin to be identified at national level, coordinated through ongoing sector policy and planning initiatives and inserted into national mitigation strategies, where these exist. Initially, these might be inclusive of mitigation action with known benefits for sustainable agricultural development or resilience (adaptation).

Closer cooperation across Ministries of Environment and Agriculture is needed so that the concerns of agriculture with regard to climate change are carried into the negotiating process, to Copenhagen and beyond. Both Ministries could call for donor support of early pilot action to test agriculture-relevant approaches, methodologies and modalities for (i) cost-effective, simple but robust methodologies for measuring, reporting and verifying emission reductions; and (ii) innovative financing/incentive and payment schemes that enable a phased approach towards carbon markets and that are appropriate for agricultural producers, including smallholders.

Relevant international organizations will need to continue to provide technical support on options under negotiation, while responding to country requests to build capacity and readiness to implement the Copenhagen outcome as it relates to agriculture.

Without the contributions of agriculture and REDD, the stabilization goal of the BAP and the ultimate objective of the UNFCCC Convention will not be met. However, the opportunities are great and the challenges daunting. The agriculture community needs to lend its voice and provide leadership both inside and outside the negotiations, in order to ensure that a Copenhagen outcome document contributes positively to enabling agriculture to deliver on its mitigation potential, as well as on the other multiple demands placed upon it.

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# *Livestock sector's growth and its implications for climate change*

*(P. Gerber and H. Steinfeld, Livestock information, sector analysis and policy branch of the Food and Agriculture Organization of the United Nations (FAO) - Livestock Environment and Development (LEAD) initiative)*

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## INTRODUCTION

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The increase in demand for animal products driven by growing populations and incomes is stronger than for most food items. Global production of meat is projected to more than double from 229 million tonnes in 1999/2001 to 465 million tonnes in 2050, and that of milk to increase from 580 to 1 043 million tonnes (FAO, 2006). The bulk of the growth in meat and milk production will occur in developing countries, with Brazil, China and India representing two-thirds of current meat production and India predicted to grow rapidly, albeit from a low base. Poultry will be the commodity of choice for reasons of acceptance across cultures and technical efficiency in relation to the use of feed concentrates. It is expected that intensive systems will contribute to most of the increase in production, as they have done in the past three decades.

The livestock sector has a primary and growing role in the agricultural economy. It is a major provider of livelihoods for the larger part of the world's poor. It is also an important determinant of human health and component of diets. Global demand for livestock products is projected to double by 2050, yet despite this growth, per capita consumption in developing countries will be no more than half that in developed countries (FAO, 2006). But already the livestock sector is a source of instability to many ecosystems and contributes to global environmental problems. Greenhouse gas (GHG) emissions from livestock production and consequent waste, and from pasture expansion into forests are important contributors to climate change (Steinfeld, *et al.*, 2006).

The future of the livestock-environment interface will be shaped by how the balance of two competing demands is resolved: one for animal food products and the other for environmental services such as climate change mitigation. Both demands are driven by the same factors: increasing populations, growing incomes and urbanization. The natural resource base within which these must be accommodated is finite and the continuing expansion of the global livestock sector must, therefore, be accomplished and accompanied by substantial reductions in livestock's environmental impact.

## HUMANITY'S LARGEST LAND USER

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Livestock's land use includes (a) grazing land; and (b) cropland dedicated to the production of feed, and amounts to approximately 70 percent of all agricultural land.

The total land area used for *livestock grazing* is 3.4 billion hectares which is equivalent to 26 percent of the ice-free terrestrial surface of the planet. A large part of this is too dry or too cold for crop use, and only sparsely inhabited. While the grazing area is not increasing on a global scale, in tropical Latin America there is rapid expansion of pastures which encroaches into valuable ecosystems, with 0.3 to 0.4 percent of forest lost to pasture annually. Ranching is a primary reason for this deforestation.

The total area dedicated to *feed crop production* amounts to 471 million hectares, equivalent to 33 percent of the total arable land. Most of this is located in Organisation for Economic Co-operation and Development (OECD) countries, but some developing countries e.g. in South America, are rapidly expanding their feed crop production, notably of maize and soybean. Again, a considerable part of this expansion is taking place at the expense of tropical forests. It is expected that future growth rates of livestock output will be based on matching rates of growth of feed concentrate use (FAO, 2006).

## GASEOUS EMISSIONS AND CLIMATE CHANGE

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### LIVESTOCK SECTOR'S CONTRIBUTION TO GHG EMISSIONS

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Estimates of GHG emissions from the livestock sector throughout the livestock commodity chain are substantial. GHG emissions arise from feed production (via chemical fertilizer production, deforestation for pasture and feed crops, cultivation of feed crops, feed transport and soil organic matter losses in pastures and feed crops), animal production (via enteric fermentation and methane and nitrous oxide (N<sub>2</sub>O) emissions from manure), and as a result of the transportation of animal products. Livestock contribute about 9 percent of total anthropogenic carbon-dioxide emissions, but 37 percent of methane and 65 percent of N<sub>2</sub>O emissions. The combined emissions expressed in carbon dioxide (CO<sub>2</sub>) equivalents amount to about 18 percent of anthropogenic GHG emissions. The commodity chain methodology used in the FAO calculations (Steinfeld, *et al.*, 2006) is not used by the Intergovernmental Panel on Climate Change (IPCC), and there is some variation in the attribution of emissions depending on methodology.

Along the animal food chain, the major sources of emissions are the following:

- land use and land-use change: 2.5 Giga tonnes CO<sub>2</sub> equivalent; including forest and other natural vegetation replaced by pasture and feed crop in the Neotropics (CO<sub>2</sub>) and carbon release from soils such as pasture and arable land dedicated to feed production (CO<sub>2</sub>);
- feed production (except carbon released from soil): 0.4 giga tonnes CO<sub>2</sub> equivalent, including fossil fuel

used in manufacturing chemical fertilizer for feed crops (CO<sub>2</sub>) and chemical fertilizer application on feed crops and leguminous feed crop (N<sub>2</sub>O, NH<sub>3</sub>);

- animal production: 1.9 Giga tonnes CO<sub>2</sub> equivalent, including enteric fermentation from ruminants (CH<sub>4</sub>) and on-farm fossil fuel use (CO<sub>2</sub>);
- manure management: 2.2 Giga tonnes CO<sub>2</sub> equivalent, mainly through manure storage, application and deposition (CH<sub>4</sub>, N<sub>2</sub>O, NH<sub>3</sub>);
- processing and international transport: 0.03 Giga tonnes CO<sub>2</sub> equivalent.

Comparing species, cattle and buffalo make the largest contribution to these emissions, compared with pigs and poultry. Their emissions are predominantly related to land-use changes (such as deforestation) and pasture management, enteric fermentation, and manure management. They contribute an especially large share of the livestock sector's emission in Latin America and South Asia, where they are estimated to account for more than 85 percent of the sector's emissions, mainly in the form of methane.

## MITIGATION OPTIONS

This section summarizes current estimates of potential carbon sequestration in rangelands and potential GHG (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O) emission reduction from range-based and landless animal production systems.

Mitigating GHG emissions from rangeland-based systems. Rangelands capture significant quantities of CO<sub>2</sub>; the tropical savannas and temperate grasslands together account for about 27 percent of global carbon stocks, compared with about 6 percent for the croplands (IPCC, 2000). In the Fourth Assessment Report, there is "medium" agreement that agricultural practices collectively can make a significant contribution at low cost to increasing soil carbon sinks, to GHG emission reductions, and by contributing biomass feedstocks for energy use. Several existing technologies hold promise for their mitigation potential in livestock systems, and these are classified by Smith, *et al.* (2007) according to whether they reduce emissions, enhance removals, or avoid (or displace) emissions. Emissions can be reduced by managing livestock to make more efficient use of feeds, for example, which may reduce methane emissions. Management practices that increase the photosynthetic input of carbon and/or slow the return of stored carbon to CO<sub>2</sub> via respiration, fire or erosion will increase carbon reserves and thus sequester carbon (Smith, *et al.*, 2007).

While technical options for mitigating emissions from grazing systems in developing countries do exist, there are various problems to be overcome, some of which are related to incentive systems, institutional linkages, policy reforms, monitoring techniques for carbon stocks, and appropriate verification protocols, for example. For the pastoral lands, Reid, *et al.* (2004) conclude that mitigation activities have the greatest chance of success if they build on traditional pastoral institutions and knowledge, while providing pastoralists with food security benefits at the same time. More generally, while payments for environmental services have considerable potential for much more widespread application, FAO (2007) identified various other challenges that need to be overcome, in particular clarifying the rights to such services and who should bear the cost of providing these services, and the provision of better information on the linkages between land-management and farming-system decisions and their environmental outcomes.

Mitigating GHG emissions from landless systems. Technical options are also available to mitigate gaseous emissions of intensive systems (UNFCCC, 2008), which are mostly related to manure management (pig, dairy and feedlots) and enteric fermentation (dairy and feedlots). Anaerobic digestion allows methane emissions from animal storage to be reduced while at the same time producing biogas that can substitute for fossil fuel energy. The technology has shown to be highly profitable in warm climates (Gerber, *et al.*, 2008) and recent developments in energy policy have fostered its rapid development in countries such as Denmark and Germany. Manure application practices are also available to reduce N<sub>2</sub>O emissions. Improved livestock diets as well as feed additives can substantially reduce methane emissions from enteric fermentation and manure storage. Energy-saving practices have also shown to be quite effective in reducing the dependence of intensive systems on fossil-fuel energy.

Although not taking place on the production unit, CO<sub>2</sub> emissions associated with feed production, and especially soybean, are also substantial (Steinfeld, *et al.*, 2006). Improved feed conversion ratios have already substantially reduced the amount of feed required per unit of animal product. Limited gains can be expected in this area. A relaxation of the ban on meat and bone meal, a precautionary measure in response to the bovine spongiform encephalopathy (BSE) crisis, could however result in a substantial reduction of soymeal consumption. It is estimated that to compensate for this source of protein, European Union (EU) farmers imported an additional 1.5 million tonnes of soymeal between 2001 and 2003. Options are also available to restore organic carbon in the cultivated soils used for soybean production

## THE CHALLENGE AHEAD

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Given the role of the agricultural sector in providing food for a growing population, the UNFCCC (2008) expects emission reductions in terms of improvements in efficiency rather than absolute reductions in GHG emissions *per se*. Various mechanisms have evolved in relation to the mitigation of GHGs, including direct regulations and taxes or emissions trading, economic instruments that aim to provide incentives for achieving reductions in GHG emissions (see papers by W. Mann and N. Key in this volume). In general, the impact of mitigation measures on farming systems will depend on their current level of emission per unit of product, on their innovation capacity to adapt to new regulations at least cost, and on their ability to take advantage of untapped carbon sinks.

Poultry systems are the most efficient systems in terms of output per unit of GHG emitted, and would thus be the least affected by a carbon constraint. Because the sector is dominated by large corporations, it should also be in the best situation to adapt to a new policy setting.

Pig production is rather less efficient in terms of output per unit of GHG emitted, and pig production systems would have to implement more substantial changes than the poultry sector, particularly in relation to manure management. However, manure management technologies that can substantially reduce emissions at a limited cost are readily available. The production of biogas can offset the implementation costs and in some cases could even generate additional income for the producer.

Extensive ruminant systems are generally fairly inefficient in terms of GHG emissions, primarily due to low offtake rates. When looking at animal products only, the emissions related to herd maintenance and replacement are significant, and high fibre-content diets increase enteric methane emission. Potential efficiency gains could be achieved through intensification, applying the common feeding, genetic and veterinary health technology packages. Although some systems may already be relatively efficient, technical development is often limited by the relatively weak technical, financial and institutional frameworks in which such systems operate. Extensive systems may, however, be able to tap into a vast carbon sink potential, associated with woody vegetation and the soil underneath pastures. As previously noted, the world's grasslands account for some 27 percent of global carbon stocks.

Intensive ruminant production emits less enteric methane per unit of product than extensive ruminant systems, but emissions from manure are generally higher as manure is handled in a liquid form. Although these systems would probably have a stronger innovation potential, cost-effective options to substantially reduce enteric methane emissions are not yet available and anaerobic digestion of the manure is limited by the high lignin content of excreta. In addition, as these systems are not generally associated with large areas, carbon sequestration potential may be limited.

It thus seems likely that the wide-spread implementation of measures and policies aimed at reducing GHG emissions from the livestock sector would not in most situations represent an unmanageable constraint to the growth of the sector. Such measures and policies would, however, be another factor in shifting the sector more towards monogastric species, in particular poultry. New opportunities may also emerge for extensive grazing systems in the form of payment for carbon sequestration in soils and other environmental services. These opportunities bring challenges too, including the difficulties in establishing the baseline from which emission reductions have to be assessed, high transaction costs, and sometimes relatively high measurement and monitoring costs for emission reductions. If the challenges can be overcome, this may represent a major opportunity for diversification and increased income.

Climate change will also have direct and indirect impacts on livestock production systems. It is likely that some of the biggest impacts of climate change will be felt in arid and semi-arid grazing systems, particularly at low latitudes (Hoffman and Vogel, 2008). Impacts on non-grazing systems are likely to be mostly indirect. Reduced agricultural yields and increased competition from other sectors are predicted to result in increased feed prices, both for grain and oilcakes (OECD-FAO, 2008). The different livestock systems exhibit markedly different capacity to adapt to climate change and the vulnerability of households dependent on livestock, particularly in the drier areas, is likely to increase substantially, with concomitant impacts on poverty and inequity. In particular, the capacity of extensive systems in the drylands both to adapt to climate change and to yield up their carbon sequestration potential deserves considerable policy and research attention from organizations with a pro-poor mandate. Priority areas are the development of certification methodologies and payment mechanisms that can reduce transactions costs.



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# *The large variation in greenhouse gas emissions (GHG) from animal food chains and the options for mitigation*

*(Theun Vellinga and Imke de Boer, Animal Sciences Group, Wageningen University and Research Centre, The Netherlands)*

## INTRODUCTION

Rising incomes and continued population growth in developing countries are leading to a rapidly growing demand for meat, milk and eggs and make the livestock sector one of the most dynamic agricultural subsectors. While the demand for meat is projected to double by the year 2050, the resource base is becoming narrower. Livestock currently occupy about 30 percent of the terrestrial surface of the planet, a large part of which is grazing land but also arable land for feed production; a third of the total arable land is used to produce feed. Requirements for food, biofuels, industrial and other purposes create growing competition for land, contributing to a recent strong upward trend in prices for land, feed and agricultural commodities.

Globally, the livestock sector is characterized by sharp dichotomies. Rapidly growing industrial forms of pig and poultry production exist alongside with extensive production of ruminants and backyard production. For an estimated one billion poor people, livestock are an important source of livelihood support. Livestock often sustain the very poor, such as landless people or those living in marginal environments; these people would be unable to survive without their animals.

The recent publication “Livestock’s Long Shadow – Environmental Issues and Options” provided an overview of livestock’s very substantial environmental footprint, affecting climate, water resources and biodiversity in major ways. When taking into account the entire livestock commodity chain, from land use and feed production over livestock production to livestock waste and product processing, about 18 percent of the total anthropogenic greenhouse gas emissions can be attributed to the livestock sector. The most important sources are land degradation and deforestation, manure management and fermentation by ruminants.

**TABLE 1. The share of different sources of GHG emissions of the livestock sector**  
(Steinfeld, et al., 2006)

Source	Share (%)	Type of emission
Land use and land-use change	36	CO <sub>2</sub>
Feed production	7	N <sub>2</sub> O, CO <sub>2</sub>
Enteric fermentation (ruminants only)	25	CH <sub>4</sub>
Manure management	31	CH <sub>4</sub> , N <sub>2</sub> O
Transport	1	CO <sub>2</sub>

Livestock related emissions are often diffuse and indirect and occur at both the high and low end of the intensity spectrum, but is probably highest for beef and lowest for poultry. On average, extensive production has higher emissions per unit of output.

It is obvious that mitigation in livestock has to be substantial in the context of an increasing demand for animal protein in the future. Technical options are indeed available to reduce emissions along the production and distribution chain. Policy-makers and producers are, however, faced with a lack of information about the relative GHG emissions of animal food chains and emission hotspots within the chains, i.e. the production steps that cause the highest emissions. This is a constraint to the design of efficient public intervention as well as to the development of private sector response strategies.

So more insight is needed in the breakdown of the emissions in the wide range of livestock production systems all over the world. A research project has been started by the Food and Agriculture Organization of the United Nations (FAO) to make better and more detailed calculations on GHG emissions. This paper will illustrate the range in GHG emissions that occur within animal food chains.

It is obvious that there is a large variation between different livestock production systems. This will be discussed by comparing two extremes of the whole range of livestock production systems.

However, also within systems there are still large differences in GHG emissions. It is known from farm comparisons that there is a wide range in nutrient efficiency and profitability. An example will be discussed.

The previous comparison has been with one commodity type. There is also variation in GHG emissions between commodities. Some studies where commodities are compared will be discussed.

Comparisons always bear the risk of jumping to the conclusion that one is better than the other. Especially in the case of comparison between livestock production systems, attention should be given to interpretation. The comparison will be made to provide insight in the suitable mitigation options for every system. "One size fits all" does not work.

## GHG EMISSIONS IN CATTLE HUSBANDRY IN POOR AND OPTIMAL CONDITIONS

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A comparison has been made between agropastoralists in Sub-Saharan Africa and intensive dairy farming in the Netherlands.

Pastoralists in Sub-Saharan Africa have to deal with very poor growing conditions, mainly arid conditions and the related short growing season. Due to the difficult conditions, the profitability is low and no capital is available to condition the environment and increase production. Livestock supplies physical output as milk and meat, but also draught power, manure, savings, insurance and social status.

The intensive dairy husbandry in the Netherlands is in a region with favourable growing conditions and relies on high capital inputs of feed, fertilizer and energy. The intensive system is also supported by a high

level of infrastructure and services to improve the farmers management skills and technical performance. The milk and meat are the only output and are processed in industry with a high energy consumption.

These differences are reflected in the most important key parameters as shown in Table 2.

In the Life Cycle Assessment approach, the emissions of the complete production chain are involved and the emissions are mostly attributed on an economical basis to the output of the farm. Allocation of animal services has been calculated by Moll (2005). For the pastoralist system, it is estimated that the allocation to savings, insurance, status, manure and traction is 50 percent of the economical value.

The functional unit in these calculations is the kilogram of animal protein. The protein content of milk was set at 3.5 percent, while the protein content of meat is set at 19 percent, with a meat to live weight ratio of 0.45 to 1.

Very little information is known about the GHG emissions that relate to buildings, equipment and the complete infrastructure. For now, it has been chosen to add 100 and 50 percent of the calculated GHG emissions of milk and meat production for buildings, infrastructure, etc. and for after farm processing, respectively.

For comparison reasons, also the calves in the Dutch system are reared at the dairy farm.

The calculation shows that the differences between the two systems are very large. The emissions in Sub-Saharan Africa consist of large amounts of methane and nitrous oxide. Even with the estimated extra energy use for infrastructure and food processing, the differences remain large.

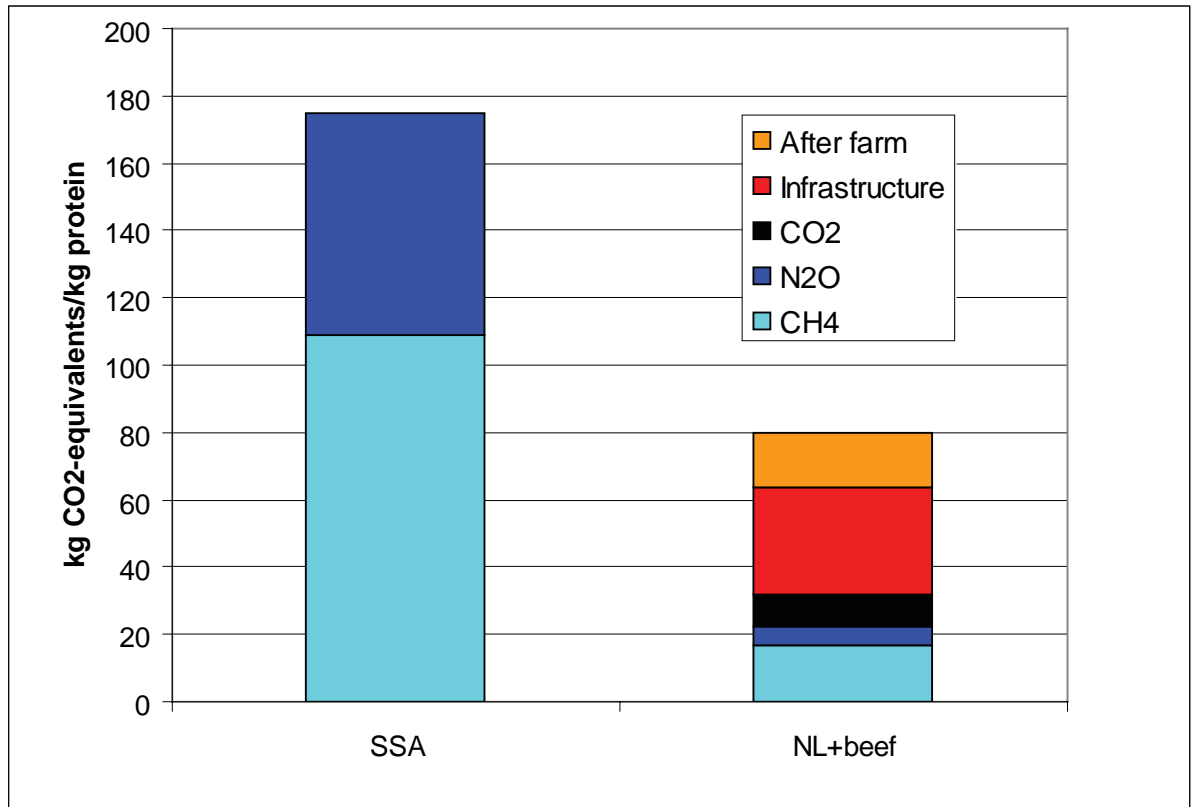
The main reasons for the large differences are found in the low productivity level of the herd, which in turn is caused by the poor growing conditions. This is reflected in the live weight of animals that is necessary to produce 1 kg of animal protein per year. For the Dutch situation this is 4 kg, while for the African situation 34 kg of live weight is necessary. Low feed quality, low fertility, high mortality rates and low growth rates are the main reasons.

The system in Sub-Saharan Africa is completely dependent on grassland and crop residues and is not a competitor for human food, whereas in the Dutch system, about 50 percent of the ration consists of maize silage and concentrates. The maize and a part of the concentrate components grow on arable land, which also could be used to grow human food.

**TABLE 2. The key parameters of the livestock production systems of Sub-Saharan Africa and the Netherlands**

Key parameters	Sub Saharan Africa	The Netherlands
Live weight (kg/cow)	250	650
Fertility (%)	58	95
Death rates calves (%)	23	2
Digestibility feed (%)	55	76
Milk/cow (kg/cow.year)	250	8 000
Fertilizer N use (kg/ha)	0	200
Concentrate (%)	0	25
Energy use (% of total emissions)	0	30
Additional		
Infrastructure (buildings, etc.)*	0	+100%
After farm processing*	0	+50%
* estimates		

FIGURE 1. The GHG emissions per kg of animal protein for livestock production systems in Sub-Saharan Africa and in the Netherlands.



The use per hectare of land is completely different in both systems, leading to environmental problems in the Netherlands with excessive emission of ammonia and leaching of nitrate and a severe loss of biodiversity.

## GHG EMISSIONS WITHIN LIVESTOCK PRODUCTION SYSTEMS AND BETWEEN COMMODITIES

A study by DeVries and DeBoer (2009) shows that there are also differences between commodities and within comparable livestock production systems (Figure 2).

It is already known from literature that meat production from pigs and poultry is much more efficient in terms of GHG emissions. On the other hand, pigs and poultry are mainly fed with feed crops, that compete with room for human nutrition, whereas the beef production is mainly based on the use of grass. Many grasslands in the OECD countries are relatively marginal areas where arable cropping is not possible.

FIGURE 2. The GHG emissions per kg of product for meat from pigs, poultry and cattle and for milk and eggs, based on livestock production systems in the Organisation for Economic Co-operation and Development (OECD) countries

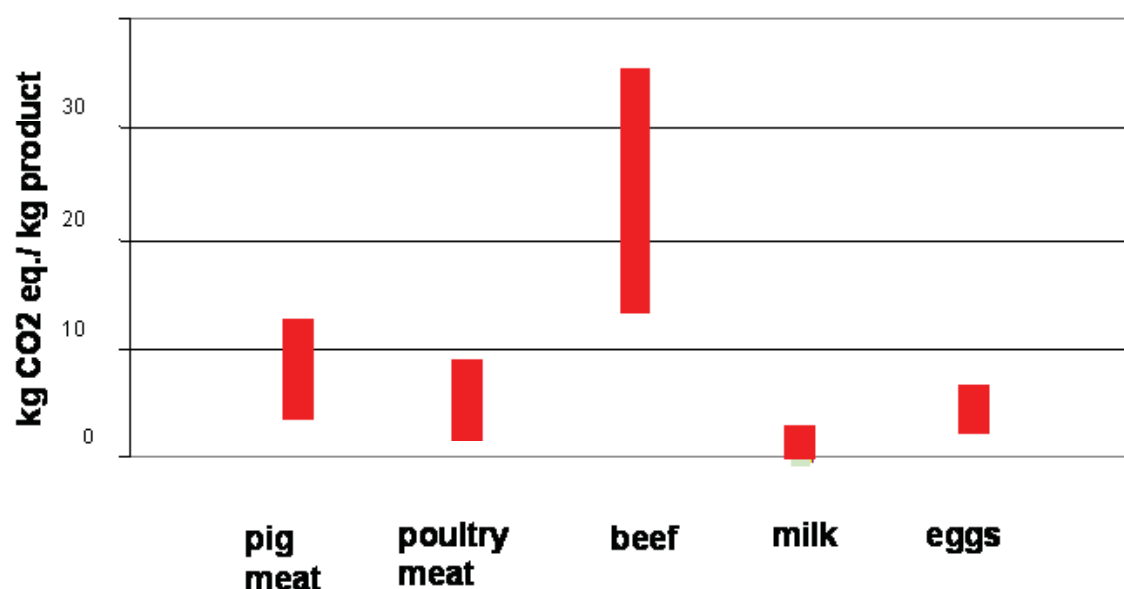


Figure 2 also shows that there is a variation in GHG emissions within the same commodity. A factor 2 can be found between the lowest and the highest GHG emissions. This indicates that there is a big opportunity for mitigation within intensive production systems.

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# *Scientific bases for definition of policies regarding greenhouse gas (GHG) emissions – the case of the Paraguayan livestock sector*

*(Roberto D. Sainz<sup>1</sup>, Luis Gustavo Barioni<sup>2</sup>, Geraldo Bueno Martha Jr.<sup>2</sup> and Frank M. Mitloehner<sup>1</sup>)*

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## BACKGROUND

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In 2005, the Intergovernmental Panel on Climate Change (IPCC) estimated that agriculture worldwide contributes 10 to 12 percent of global anthropogenic carbon dioxide (CO<sub>2</sub>) emissions, 40 percent of global methane (CH<sub>4</sub>) emissions, and 60 percent of global nitrous oxide (N<sub>2</sub>O) emissions. Agricultural processes and sources generating greenhouse gases (GHG) include burning of fossil fuels, deforestation, rice paddies, biomass burning, enteric fermentation of ruminants, fermentation of animal manure and application of nitrogenous fertilizers. Enteric fermentation by ruminants and the animals' manure produce both CH<sub>4</sub> and N<sub>2</sub>O emissions (Kaspar and Tiedje, 1981; Jarvis and Pain, 1994; IPCC 2007; Jungbluth, *et al.*, 2001; Phetteplace, *et al.*, 2001).

Livestock are considered a major source of global CH<sub>4</sub> and N<sub>2</sub>O emissions from enteric fermentation and their manure (IPCC, 2001). Contributions of CH<sub>4</sub> and CO<sub>2</sub> from cattle were determined to be primarily derived from enteric fermentation and respiration (Jungbluth, *et al.*, 2001), and to a lesser extent from manure (Shaw, *et al.*, 2007). Livestock respiration contributes significant amounts of CO<sub>2</sub>, approximately half of total CO<sub>2</sub> emissions from both humans and animals worldwide. Under the Kyoto Protocol, livestock contributions of CO<sub>2</sub> are not considered a net source because the plant matter being consumed previously sequestered atmospheric CO<sub>2</sub> (IPCC, 2007).

For CH<sub>4</sub>, many factors such as feed intake, animal size, growth rate, milk and meat production and particularly energy consumption, can affect emissions from cattle (Jungbluth, *et al.*, 2001). Most cattle operations house their animals in either dirt-floored corrals or on pasture, which have different biochemical pathways that result in varied GHG emission rates (USDA, 2004). Methane production from cattle is a complex process that involves anaerobic bacterial fermentation in the rumen and archaeal methanogenesis. During this process, rumen microbes convert ingested organic matter into energy for microbial growth, and into fermentation end-

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<sup>1</sup> University of California, Davis – CA – United States of America

<sup>2</sup> Embrapa Cerrados, Planaltina – DF – Brazil

products including volatile fatty acids, alcohols,  $H_2$  and  $CO_2$ . Methanogenic archaea are able to take some of these end products (i.e. formate, acetate, MeOH and  $CO_2$ ) and reduce them with  $H_2$  to produce  $CH_4$  and  $H_2O$ . Accumulated  $CH_4$  and other volatile gases that are produced in the rumen are eventually expelled through the mouth into the atmosphere via eructation.  $CH_4$  is a potent GHG with approximately 21 X the Global Warming Potential (GWP) of  $CO_2$ .

Nitrous oxide ( $N_2O$ ) contributes to stratospheric ozone depletion and is also a potent GHG with approximately 297 X the GWP of  $CO_2$ . Nitrous oxide is an intermediate product of denitrification, in which nitrate is converted to nitrogen gas. It may also be formed during nitrification if little oxygen is present or if other, non-optimal conditions exist (Monteny, *et al.*, 2001). Sources of  $N_2O$  emissions in cattle operations and grassland production systems come predominantly from microbial activity in soils and stored manure and to a lesser extent from the livestock themselves. Gaseous emissions of  $N_2O$  from soils result from denitrification processes reducing nitrate ( $NO_3$ ) to  $N_2O$  and can also result from nitrification oxidizing ammonium ( $NH_4$ ) to  $N_2O$ . When excess  $NO_3$  or  $NH_4$  are in the soil (i.e. from fertilizer application),  $N_2O$  emissions can be significant. Studies have shown  $N_2O$  emissions to increase in areas with higher applications of both mineral and manure fertilizers (van Groenigen, *et al.*, 2005). In addition, higher  $N_2O$  emissions have been noted at sites with long-term N applications suggesting that long-term accumulation of N in soils affects emissions.

The IPCC (2006) recommends the use of models to estimate GHG emissions from each country, region or industry, at three tiers. Tier 1 is the most basic, using population data (e.g. national herd) along with global emission factors. Tier 2 uses the same data, but applies more precise equations to estimate the intake and performance of each animal category, as well as diet digestibilities, to estimate the amounts of  $CH_4$  that are produced. Although it is more detailed, Tier 2 models still use global equations and coefficients. Tier 3 models use more detailed models, using local information and data, to improve the accuracy and precision of the estimates. Within Tier 3, are Life Cycle Analysis (LCA) models. LCA models represent mathematically the main processes involved in an activity, in order to account for all inputs and outputs of the system. Each process has its own inputs and outputs, enabling evaluation of the impacts of modifications of the system and its processes (EPA, 2006). One of the difficulties of conducting an LCA is the definition of system boundaries. A global LCA for GHG should begin with removal of carbon from air or soil, and end with its return to those pools. Such an analysis is beyond the scope of this study, which is limited to the impacts of enteric fermentation and manure.

## LIVESTOCK AND LAND USE IN PARAGUAY

Paraguay is located in the central region of South America, sharing borders with Bolivia (Plurinational State of) in the north and northwest, Brazil to the east, and Argentina to the south and southwest. It has a surface area of 406 752 km<sup>2</sup> and a human population of 5.8 million (MAG, 2006). There are two official languages: Spanish and Guaraní. The country is separated by the Paraguay river into two large physical regions: the western, subtropical Chaco Boreal region, with 246 925 km<sup>2</sup> (61 percent of the area), and less than 3 percent of the population; and the eastern tropical region, with 159 827 km<sup>2</sup> (39 percent of the area) and 97 percent of the population. More than half (57 percent) of the population lives in urban areas. Paraguay is divided politically into 17 *departamentos*, but their governments are accountable to the central government of the Republic. The climate is tropical to subtropical, with annual rainfall ranging from 400 mm (Western Region) to 1 700 mm

(Eastern Region) and being concentrated from October to March (MAG, 2006). Paraguayan novelist Augusto Roa Bastos referred to the country as “an island surrounded by land.” Although Paraguay is a landlocked country, 30 to 40 percent of the country is covered by wetlands.

Paraguay has about 20 million hectares of grazing land; about half is in native pastures, 15 to 20 percent in sown pastures, and the rest is bush land (Glatzle and Stosiek, 2001). In 1997 there were about 15.5 million hectares of dry xerophytic forest types in the Western Region, and 2.8 million hectares of humid semi-deciduous forest in the Eastern Region (IICA, 2009). By 2005, the Eastern Region was estimated to have only 0.9 million hectares of forest cover (SEAM, 2008). Overall, the rate of deforestation over the past 50 years has been estimated at around 179 000 ha/year (Carr and Bilsborrow, 2000; FAO, 2007). Although much of this land has been converted to pasture, expansion of soybean production in the 1990s accounts for a greater share of land use change (IICA, 2009).

Agriculture and forestry account for about 20 percent of gross domestic product (GDP) and 82 percent of total exports (IICA, 2009). Main crops (in decreasing land area) include soybeans, maize, cotton, cassava, wheat, beans, sugarcane, peanuts, sunflower, rice, tobacco, sesame, castor beans and stevia. Of these, soybeans represent 60 percent of the planted area. The livestock sector accounts for 6 percent of GDP and 11 percent of total exports (Figure 1; IICA, 2009). Paraguay has over 10 000 000 head of cattle, 400 000 sheep, 350 000 horses, 120 000 goats plus 1 800 000 pigs and about 15 000 000 poultry (DCEA, 2000; cited by Glatzle and Stosiek, 2001).

Most of the herds are small, with 82 percent of the herds being from 1 to 50 head and only 2 percent of the herds being larger than 1 000 head (Figure 2; SENACSA, 2009). Conversely, most of the cattle are in larger herds, with only 12 percent of the cattle in herds from 1 to 50 head and 51 percent of the cattle in herds larger than 1 000 head.

In the second semester of 2008, Paraguay vaccinated 10 694 703 cattle against foot-and-mouth disease (FMD, aftosa), of which 6 939 651 were in the Eastern Region and 3 955 052 in the Western Region (SENACSA, 2009). The herd was comprised of:

- 4 147 548 cows;
- 356 606 bulls;
- 1 453 572 heifers over 18 months of age;
- 1 616 728 steers over 18 months of age;
- remainder mainly young stock.

FIGURE 1. Contributions to agriculture and forestry GDP in 2007. Source: IICA (2008)

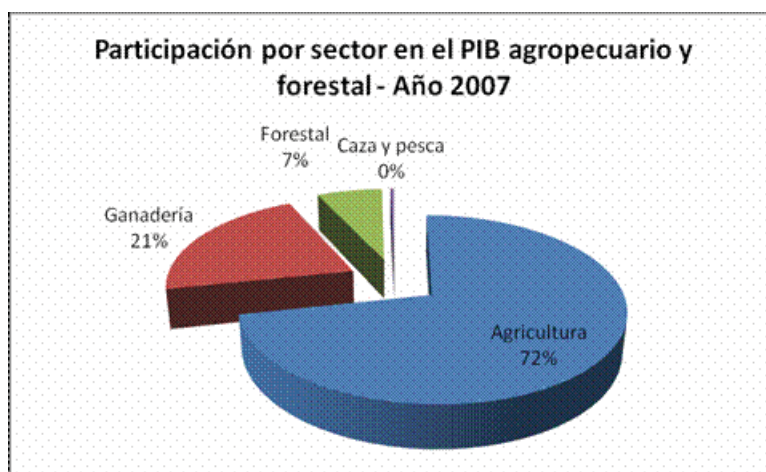
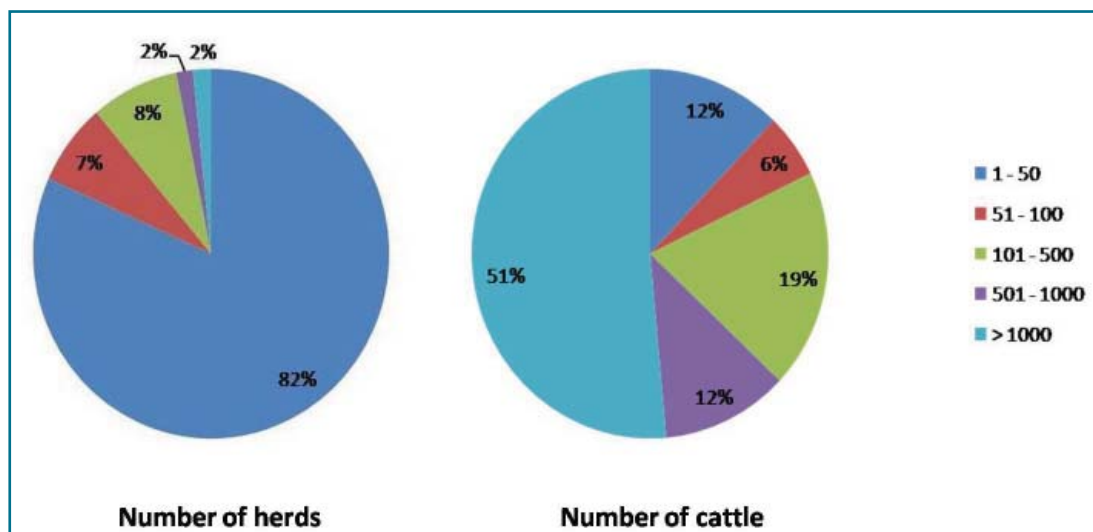


FIGURE 2. Distribution of beef cattle herd sizes in Paraguay, Source: SENACSA, 2009



There are no reliable data on performance indices, but the herd structure shown above indicates low levels of productivity on average. This is confirmed by official slaughter figures: 1 154 010 bovines in 2008, for an extraction rate (slaughter/total herd) of only 11 percent. Moreover, about 70 percent of the slaughtered animals were males, indicating that, in agreement with official figures, the beef cattle herd is undergoing expansion. Values of key indicators that are compatible with this herd structure and extraction rate are given in Table 1. In reality, these values vary continuously, but here for the sake of argument are presented values for low (70 percent of total) and high (30 percent of total) performance systems.

These numbers are in broad agreement with those given by Glatzle and Stosiek (2001), and by Corrales (2008). Both of these sources point out that these low averages are not uniformly distributed throughout Paraguay, but rather reflect a large number of smallholdings with very poor management, health status, nutrition and genetics, together with a small number of larger, more organized farms with much higher indices.

## OBJECTIVES

This study aims to evaluate the balance of GHGs ( $\text{CO}_2$ ,  $\text{CH}_4$ , and  $\text{N}_2\text{O}$ ) in the different beef production systems in Paraguay and the main mitigation strategies available.

## METHODOLOGY

A model of the beef production system was constructed according to Tier 2 recommendations of the IPCC (2006). The herd structure was used together with performance indices given in Table 1 to estimate net energy requirements and intakes ( $\text{NE}_m$ ,  $\text{NE}_l$  and  $\text{NE}_g$ ) for each animal category (NRC, 1987, 2000). Production of  $\text{CH}_4$  from enteric fermentation was modelled based on predicted dry matter intakes (DMI) and typical neutral detergent fibre

(NDF) and lignin contents of tropical forages, using equation (9c) from Ellis, *et al.* (2006):

$$\text{CH}_4 = 3.69 + (0.543 \times \text{DMI}) + (0.698 \times \text{NDF} \times \text{DMI}) - (3.26 \times \text{lignin} \times \text{DMI})$$

Besides enteric fermentation,  $\text{CH}_4$  and  $\text{N}_2\text{O}$  are produced from manure. For  $\text{CH}_4$ , the factor of 1 kg  $\text{CH}_4 \cdot \text{animal}^{-1} \cdot \text{year}^{-1}$  recommended by IPCC (2006) was used. For  $\text{N}_2\text{O}$  production by manure, excretion of N was calculated based on DMI, dietary crude protein (CP) and its digestibility (D), as well as endogenous N excretion (estimated from body weight, BW):

TABLE 1. Key performance indicators for average, low and high performance beef production systems in Paraguay

Index	Overall	Low performance system	High performance system
Birth rate, %	50	35	85
Weaning weight, kg	140	120	180
Cow replacement rate, %	10	5	20
Calf mortality, %	20	25	5
Adult mortality, %	8	10	2
Age at first calf, months	36 – 48	48	24 – 36
Age at slaughter, months	36 – 48	48	24 – 36

$$\text{N excretion} = \left[ (\text{DMI} \times \text{CP} \times (1 - D)) + \frac{0.0038 \times \text{BW}^{0.75}}{6} \right] \times 10^3$$

$\text{N}_2\text{O}$  production was estimated based on the observation that at pasture, 0.2 percent of excreted N is converted to  $\text{N}_2\text{O}$  (Loyon, *et al.*, 2008).

## RESULTS

The results of simulations for average, low and high performance beef production systems in Paraguay are presented in Table 2. Overall, the Paraguayan beef production system emits 624 218 tonnes of  $\text{CH}_4$  and 2 289 tonnes of  $\text{N}_2\text{O}$  each year, for a total of 13 818 199 tonnes of  $\text{CO}_2$  equivalents. By comparison, emissions of  $\text{CO}_2$  for electricity generation are low (due to substantial hydroelectric reserves), around 4.5 million tonnes (EIA, 2009). Similarly, the relatively small human population, with limited purchasing power, consumes little fossil fuel for transportation, so that emission of  $\text{CO}_2$  equivalents for transportation is only around 3 million tonnes. Therefore, beef cattle production may account for two-thirds of the anthropogenic GHG emissions of Paraguay. Even accounting for the livestock sector, yearly  $\text{CO}_2$  emissions per capita are about 3.8 tonnes/person (2.4 tonnes from beef production and 1.4 tonnes from energy and transportation). This is below the world average (4.5 tonnes), and far below those for Europe (8 tonnes) and North America (16 tonnes) (EIA, 2006). In fact, the entire beef industry of Paraguay produces about the same amount of GHG each year as the city of Washington, DC, and about 60 percent as much as Rome, Italy.

TABLE 2. Greenhouse gas emissions and productivity for average, low and high performance beef production systems in Paraguay

Index	Overall	Low performance systems	High performance systems
Total CH <sub>4</sub> emissions, tonnes-year-1	624 218	307 410	247 181
CH <sub>4</sub> emission, kg-animal-1-year-1	55.7	52.8	51.4
Total N <sub>2</sub> O emissions, tonnes-year-1	2 289	1 282	1 030
N <sub>2</sub> O emission, kg-animal-1-year-1	0.20	0.22	0.21
Total CO <sub>2</sub> equivalents, tonnes-year-1	13 818 199	6 852 948	5 510 162
CO <sub>2</sub> equivalents, tonnes-animal-1-year-1	1.23	1.18	1.15
Total carbon-equivalent, tonnes-year-1	3 768 600	1 868 986	1 502 771
Carbon-equivalent, tonnes-animal-1-year-1	0.34	0.32	0.31
Productivity, kg carcass equivalent-animal-1-year-1	23.5	14.5	63.5
CO <sub>2</sub> equivalent/carcass equivalent	52.5	81.3	18.0

The above-mentioned estimates of GHG production do not include changes in land use. Based on the estimated rate of deforestation (179 000 ha/year) and the carbon released by deforestation in the humid tropics (217 tonnes C/ha), Paraguay emitted 39 million tonnes of carbon (142 million tonnes of CO<sub>2</sub>) from deforestation alone each year through 2005 (FAO, 2007). Since the turn of the century, Paraguay has adopted a number of measures to protect its remaining forests, including the *Ley de Deforestación Cero* (Ley 2524 “De prohibición de las actividades de transformación y conservación de superficies con cobertura de bosques”) in 2004. Since then, deforestation was estimated to drop by 85 percent (WWF, 2009). If so, conversion of forests would still be contributing 21 million tonnes of CO<sub>2</sub> each year.

The GHG emission estimates presented here must be placed into context. Of the total 406 752 km<sup>2</sup> territory of Paraguay, at least 122 026 km<sup>2</sup> (30 percent) are wetlands. Based on an average CH<sub>4</sub> emission rate of 199 mg·m<sup>-2</sup>·d<sup>-1</sup> (Cao, *et al.*, 1996), these wetlands release 8.9 million tonnes of CH<sub>4</sub> into the atmosphere each year, or 186 million tonnes of CO<sub>2</sub> equivalents. Therefore, in Paraguay natural processes produce amounts of GHG that are an order of magnitude greater than anthropogenic sources.

Clearly, there is great potential to reduce GHG emissions by modification of beef cattle production systems. Given the importance and contribution of the livestock sector to the national economy, one may assume that this economic activity will continue as long as there is domestic and international demand for beef. Much can be

done to reduce the GHG footprint of the production system, mainly by improving performance indices (Tables 1 and 2). Some strategies to accomplish this include:

- improvement of forage quality;
- genetic improvement of the cattle herd;
- recovery of degraded pastures;
- adoption of integrated crop-livestock (including agrosilvopastoral) systems;
- expansion of the feedlot sector.

In their influential publication *Livestock's Long Shadow*, Steinfeld, *et al.* (2006) placed responsibility for deforestation on the livestock sector. It is certainly true that a great deal of forest land has given way to pastures and cropland in Paraguay and elsewhere. The drivers for conversion of land use, however, are economic rather than industry related. Any activity, such as cropping or even ranching, provides an income stream superior to leaving the forest intact. Outright prohibition of logging, if accompanied by strong enforcement, can also work, but only by shifting the cost of a public good onto the private sector (the landowner). Moreover, preserving a portion of rural properties from development, as has been done in the Western Region, raises issues of land tenure and invasion. Strong property rights are fundamental to continued economic development and alleviation of poverty. The real challenge is to develop mechanisms to provide a reasonable rate of return to the activity of forest preservation, perhaps through carbon credits or other forms of payment for environmental services. Other incentives to forest conservation might include stronger guarantees against invasion and loss of undeveloped land.

## CONCLUSIONS

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- The main factor contributing to GHG emissions by the beef industry is the transformation of native vegetation into pasture and crop land, not the production systems *per se*. This impact would occur from any kind of land use change.
- Mitigation measures to reduce GHG emissions should focus primarily on preventing deforestation and promoting afforestation, and only secondarily on the emissions by livestock and associated processes.
- Increased adoption of more intensive production systems (e.g. Integrated Crop-Livestock and feedlot finishing) could improve efficiency, reduce the demand for land, and prevent the emission by the Paraguayan beef industry.



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## *Policy measures for mitigation and adaptation – pasture management in dry and cold environments*

*(Rich Connant, Colorado State University)*

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Emissions from agriculture and land use change contribute nearly one-third of total global greenhouse gases (GHGs) due to human activities. In less industrialized countries, agriculture is proportionally an even larger GHG emitter. However, globally the land is a net sink for CO<sub>2</sub>, many of the past practices that have led to loss of soil organic carbon (as CO<sub>2</sub>) can be reversed, sequestering atmospheric CO<sub>2</sub> in the soil. Whereas grassland management practices that remove a very large proportion of forage or decrease forage production tend to lead to declines in soil carbon (C) stocks, practices that enhance production tend to increase soil C stocks.

A scientific synthesis published several years ago documented that improved grazing management, sowing more productive grass or leguminous species, and supplemental irrigation, all tended to lead to increases in soil C stocks. Global estimates of the technical potential, estimated as the difference between current soil C stocks and potential future soil C stocks, are quite large, rivalling those estimated for croplands globally. Also according to the Intergovernmental Panel on Climate Change (IPCC), much of this technical potential could be realized if the price of C was to reach USD 50/tonne CO<sub>2</sub>. Land in which the productive capacity of the system has declined due to overgrazing (about 10 percent of global grasslands), which is in the most dire need of improvement, may have the largest potential to sequester C in soil.

Agricultural carbon sequestration, including that in grasslands, was omitted from the Kyoto Protocol and the Clean Development Mechanism (CDM), despite the fact that improved grassland and natural resource management practices to mitigate climate change could be a win-win scenario. In most (but not all) cases, practices that lead to C sequestration in grasslands also lead to enhanced forage production and to other environmental co-benefits like increased soil structure and water holding capacity, increased soil fertility, and decreased soil erosion. For these reasons, it is widely expected that practices that sequester C in soil will also mitigate the negative impacts of climate change.

Numerous ongoing voluntary grassland projects intended to sequester C in soil have begun to expand the information necessary to base of C stock change estimate. To date projects have typically paid producers to adopt a practice that has been demonstrated to sequester C in soil (e.g. improved grazing management, sowing improved species, etc.) or to prevent loss of existing soil C stocks (i.e. as would happen if the land were to be converted to cropland). Monitoring, reporting and verification in grassland projects have tended to be based around verifying practices. For example, the Chicago Climate Exchange has paid producers in the United States of America to adopt an improved grazing management plan, on the expectation that when producers adopt those practices, C will be sequestered. Sequestration rates are *ex ante* estimates based on synthesis of

published research. One of the primary benefits of this type of system is the relatively low cost of verification in comparison with a programme that requires documentation of changes in soil C stocks. On the other hand, there is no additionality requirement for Chicago Climate Exchange Certified Emission Reduction credits (CERs). This means that a producer who long ago adopted conservation practices that have maximized C stocks, and who is likely no longer sequestering C, will be paid the same as a producer who is prompted to change his practices in order to earn a payment by sequestering C in soil. Such a system eliminates the perverse incentive of the long-time conservationist to revert to unsustainable practices in order to re-sequester C and it is adequate for those existing voluntary systems. However, this type of agreement is not in strict concord with current international agreements for forestry, which do require documentation of additionality.

Verification of terrestrial soil organic carbon (SOC) offsets could be achieved using a system that estimates management impacts on SOC using an ecosystem model, and generates estimates of uncertainty based on published observations. Current data- or model-based systems have taken a similar approach to create static systems based on ecosystem model output. If a dynamic system, comprised of a database that was updated as new measured terrestrial offset data became available, it could integrate the most current measurements with state-of-the-art knowledge about ecosystem function and enable the calculation of model uncertainty estimates using existing methods. An integrated system would thus have a firm basis in measurements, including the newest ones; but it would also include understanding of ecosystem processes built on an independent suite of observations. The diversity of ongoing pilot projects are currently not well coordinated to contribute to this or any other kind of monitoring, verification, reporting system, therefore, this is an opportunity to make a substantial technological improvement by coordinating existing efforts.

There are undeniable challenges involved in forecasting how much greenhouse gas mitigation could be achieved through changes in grassland management practices. Chief among these are: lack of information about the diverse practices, field-based measurement uncertainty, lack of data on full greenhouse gas accounting. Resolving these will require continued investments into research on what controls management-induced changes in soil C stocks and greenhouse gas fluxes in grasslands. Nevertheless, available information suggests that grassland stores a substantial amount of the world's soil C, management can reduce or enhance those soil C stocks, and that policies can be enacted that will preserve or enhance grassland soil C stocks.

# *Policy Measures for Mitigation and Adaptation in Cattle Production Systems in the Humid and Subhumid Tropics of Latin America*

*(Muhammad Ibrahim<sup>1</sup>, Leonardo Guerra<sup>2</sup>, Francisco Casasola<sup>3</sup>)*

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Conversion of native vegetation into different forms of land use has large implications for the energy, water and carbon exchange processes between soil, surface and atmosphere at local and regional levels. In tropical America there is an estimated 548 million ha of agricultural land and grasslands (including silvopastoral systems) constitute about 77 percent of this land (Amézquita, *et al.*, 2008a). A large percentage of established pastures are degraded because of inappropriate management (e.g. grass monoculture pastures) and this leads to a net loss of soil carbon stocks. In the humid tropics of Costa Rica, Veldkamp (1994) found a net loss of 2-18 percent of carbon stocks in the top 50 cm of forest equivalent soil after 25 years under pasture in lowland Costa Rica. However, the quality of management of tropical pastures is critical to the conclusions drawn about whether the soils under this land use represent a source or a sink of atmospheric carbon. Many studies have demonstrated that the implementation of well managed grass legume pastures and agroforestry systems (including silvopastoral systems) is associated with the maintenance and or increase of soil carbon stocks depending on climate, soil, vegetation and management factors (Neil, *et al.*, 1997, Ibrahim, *et al.*, 2007, Amézquita, *et al.*, 2008b). In the subhumid tropics soil carbon stocks measured in degraded pastures was 26.4 tonne/ha compared with in silvopastoral systems (dispersed trees in pastures, 119 tonne/ha) and in secondary forest (21 years forest, 206.8 tonne/ha), and these data indicate that well managed systems have the capacity of sequestering carbon while improving productivity and income of cattle farms (Ibrahim, *et al.*, 2007). In view of the vast area of grasslands and the impacts of improved pasture and silvopastoral systems in sequestering carbon and hence on mitigation of climate change, policy-makers have become interested in providing incentives to promote the adoption of these systems.

CATIE has worked with the FAO-FAO- Livestock Environment and Development Initiative (LEAD), World Bank, Center for Research on Sustainable Agricultural Production Systems/Centro para la Investigación en Sistemas Sostenibles de Producción Agropecuaria (CIPAV) of Colombia and Research and Development Institute affiliated to the Universidad Centroamericana/Instituto de Investigación y Desarrollo adscrito a la Universidad Centroamericana (NITLAPAN) of Nicaragua to implement a project funded by the Global Environment Facility (GEF) to develop methodologies and policies for payment of environmental services (PES) to promote the adoption of silvopastoral systems that will enhance carbon sequestration, and biodiversity conservation. The

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<sup>1</sup> Leader of Livestock and Environmental Management Programme, Livestock and Environmental Management Programme/Ganadería y Manejo del Medio Ambiente GAMMA (GAMMA), Agricultural Research and Higher Education Center/Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), email: mibrahim@catie.ac.cr

<sup>2</sup> Environmental Economist, Consultant of GAMMA

<sup>3</sup> Silvopastoral systems expert, GAMMA.

results of the project showed that PES resulted in a reduction in the area of degraded pastures and in an increase in the area with silvopastoral systems with low and high density trees (Table 1). The land use changes that farmers made resulted in an increase in carbon stocks of 71 712 CO<sub>2</sub> eq which amounts to an increment of 1.5 tonnes/ha/ yr (area 12 000 has). The benefits from enhanced carbon (C) sequestration were addressed in the context of significant emissions of methane and nitrous oxide from livestock production and the impact of changing management and land use. For example, many farmers adopted forages (e.g. *Leucaena*, *Cratylia*) that are of better quality than existing grass species and this was associated in an overall reduction in emissions of greenhouse gases when a life cycle analysis was conducted (Figure 1).

The adoption of silvopastoral systems is not only related to mitigation but also adaptation to climate change. For example, in Nicaragua, production and economic indicators were improved with the adoption of silvopastoral systems both poor and non-poor farmers benefited from PES (Table 2).

For mainstreaming adoption of silvopastoral systems, the project worked with local and national policy-makers to implement policies and develop incentive schemes for investing in silvopastoral systems. For example, before the project was initiated, National Forestry Financing Fund/Fondo Nacional de Financiamiento Forestal (Costa Rica) (FONAFIFO), which is the organization responsible for PES in Costa Rica, compensated farmers only for forest systems (primary forest, secondary forest and forest plantations). However, the project worked with FONAFIFO and the Agroforestry Commission of Costa Rica to develop and implement a regulation for PES for the adoption of agroforestry systems (AF, including silvopastoral systems) and currently FONAFIFO has contracts with farmers which compensates them for each tree planted in AF (USD 1.30/tree paid in five years). In Colombia, Colombian Federation of Cattle/Federación Colombiana de Ganaderos (FEDEGAN) which is the national livestock organization, was supported to develop a programme for sustainable cattle production based on the implementation of silvopastoral systems. FEDEGAN is currently developing a national project with the World bank, CIPAV, the Nature Conservancy/Conservación de la Naturaleza (TNC), CATIE and local organizations to mainstream PES in silvopastoral systems for conservation of biodiversity and mitigation and adaptation to climate change, and it has earmarked credits from government banks, to support the investments in silvopastoral systems. GEF funds were approved for developing the proposal and the project is expected to commence in 2010. The socio-economic studies showed that investment cost in silvopastoral systems (USD 700–1 500/ha) are higher than that of traditional pastures (grass pastures, USD 300–400/ha) and lack of capital is one of the main reasons why farmers have not been adopting silvopastoral systems/sistemas silvopastoriles (SPS). To overcome this barrier, the project worked with the Local Development Fund (FDL) of Nicaragua, to develop a credit package for investing in green practices (e.g. silvopastoral systems) that will contribute to mitigation of climate change and improvement in farm productivity. Over the last years, FDL has allocated credits to more than 1 000 cattle farmers in Nicaragua, and in Colombia a similar credit scheme is being developed to support cattle farmers. FDL plans to increase funding for this credit scheme over the next years and is in the process of negotiating funding from the Central American Bank for Integration (BCIE) in the framework of the Cambio project which is funded by GEF.

Within the Clean Development Mechanism (CDM), reforestation and afforestation projects are being included as eligible projects for the first commitment period of the Kyoto Protocol (2008–2012). Offering financial incentives to promote reforestation and afforestation projects in developing countries is a very positive step.



TABLE 1. Land use change of farms receiving Payment for Environmental Services (PES) in the pilot zones of Esparza, Costa Rica; Matiguas, Nicaragua; and el Quindío, Colombia, 2007.

Country	Costa Rica				Nicaragua				Colombia			
Year	2003	2005	2007	% Diff 2007- 2003	2003	2005	2007	% Diff 2007- 2003	2003	2005	2007	% Diff 2007- 2003
	Ha				ha				ha			
DP	548.9	183.3	123.7	-14.2	823.0	270.5	195.6	-20.4	83.6	16.0	9.1	-2.5
NP-T	243.6	4.3	3.1	-8.0	47.7	83.3	41.0	-0.2	730.8	251.6	239.5	-16.7
IP-T	57.3	22.7	16.2	-1.4	22.1	32.5	27.8	0.2	1 099.3	951.6	895.7	-6.9
NP+LDT	744.9	304.5	199.1	-18.2	322.7	385.2	317.3	-0.1	6.2	23.4	44.0	1.3
NP+HDT	113.1	174.2	146.6	1.1	373.6	444.5	497.1	4.1	0.0	34.9	34.3	1.2
IP+LDT	185.9	746.9	810.4	20.8	152.9	308.8	268.6	3.8	54.8	348.3	371.7	10.8
IP+HDT	48.8	474.5	606.5	18.6	158.5	382.8	532.2	12.2	2.2	187.0	239.8	8.1
FB	13.3	13.0	14.9	0.1	86.6	179.6	250.4	5.4	4.6	31.2	28.4	0.8
F+SV	903.4	929.6	929.2	0.9	751.8	798.7	775.5	0.9	639.0	650.2	667.1	1.0
Others	144.1	149.3	152.8	0.3	336.6	189.6	155.6	-5.9	326.6	452.8	417.5	3.1

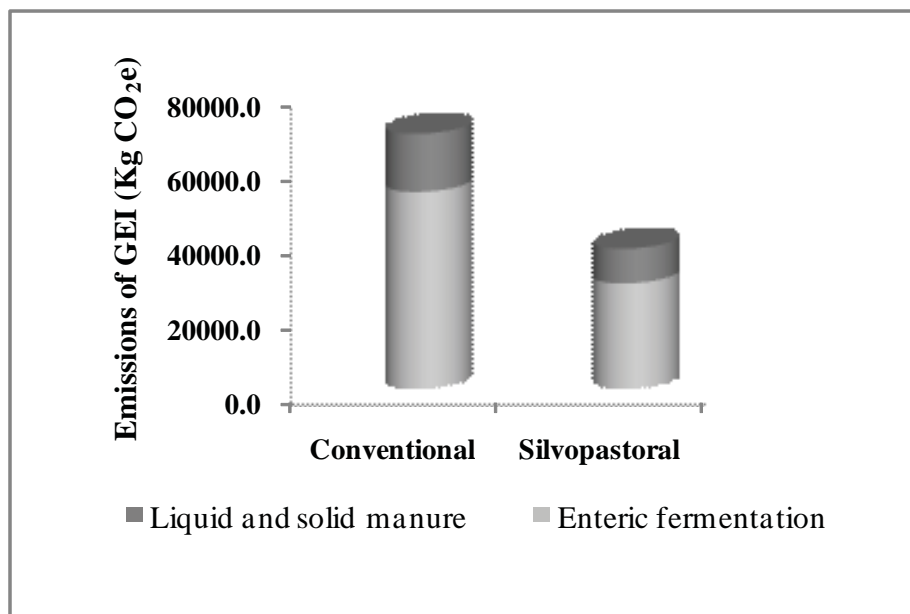
DP: Degraded Pasture; NP-T: Natural Pasture without Trees; IP-T: Improved Pasture without Trees; NP+LDT: Natural Pasture with Low Density Trees; NP+HDT: Natural Pasture with High Density Trees; IP+LDT: Improved Pasture with Low Density Trees; IP+HDT: Improved Pasture with High Density Trees; FB: Fodder Bank; F+SV: Forest and Secondary Vegetation.

TABLE 2. Socio-economic indicators with Payment for Environmental Services (PES) and different poverty levels.

Indicators	Poverty level	Base line (2003)	2006	% change
Milk production (kg ha <sup>-1</sup> year <sup>1</sup> )	Noon poor	617.4 + 94.5 a*	662.9 + 56.0 a	7.4
	Poor	657.8 + 84.7 a	864.3 + 75.2 b	31.7
	Very poor	637.4 + 58.8 a	878.3 + 54.7 b	37.8
Family income per capita (USD year <sup>-1</sup> )	Noon poor	3188.0 + 475.5	5005.7 + 555.0 a	57.0
	Poor	1258.0 + 166.4 b	2606.7 + 378.1 b	107.2
	Very poor	802.5 + 109.5 c	1371.4 + 163.0 c	70.9

\* Different letters indicate significant difference according to Duncan test (p <0.05).

FIGURE 1. Composition of emissions of greenhouse gases emissions/emisión de gases de efecto de invernadero (GEI) (Kg CO<sub>2</sub>e) in 2 livestock systems



However, the CDM does not include compensation for the adoption of good practices (e.g. silvopastoral systems) in grasslands ecosystems although these ecosystems occupy vast areas and have good potential for mitigation and adaptation to climate change. In the implementation of reduction of emissions from deforestation, forest degradation (REDD), it is expected that funds will be allocated in the agricultural sector, as there are many drivers in the agricultural sector related to deforestation. For example, establishment of silvopastoral will lead to more sustainable production reduced pastureland degradation, and expansion of cattle in the forest reserves.

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# *Methane Emissions from Livestock: Policy Issues and Analysis*

*Nigel Key, Food and Agriculture Organization of the United Nations (FAO) and the Economic Research Service (ERS) -United States Department of Agriculture (ERS-USDA)*

*Gregoire Tallard, FAO and Organisation for Economic Co-operation and Development (OECD)*

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Excluding greenhouse gas (GHG) emissions from land use change, methane emissions from enteric fermentation and manure management represent almost half of total GHG emissions from livestock production or about 6 percent of total anthropogenic GHG emissions (FAO, 2006, p.113). Methane emissions are likely to increase substantially in the coming decades as population growth and higher income increase demand for food, especially meat and dairy products. Between 2000 and 2020, global methane emissions from livestock production are estimated to increase about 30 percent (USEPA, 2006). Much of this increase will take place in Africa, Asia and Latin America.

Methane is a by-product of enteric fermentation – a digestive process in which carbohydrates are broken down by micro-organisms. The amount of methane released from enteric fermentation depends on the animal's digestive tract, age and weight; the quality and quantity of the feed consumed; and the energy expended by the animal. Methane is also produced when manure decomposes under anaerobic conditions that exist when manure is stored in large piles, holding tanks or lagoons. These conditions often exist when large numbers of animals are managed in a confined area (e.g. on dairy farms, beef feedlots and swine and poultry farms). The amount of methane produced during decomposition depends on the climate and how the manure is managed.

It is estimated that beef production accounts for about 62 percent of total livestock methane emissions, milk (19 percent), sheep meat (12 percent), pork (5 percent) and poultry (1 percent). Livestock in Asia and the Pacific produce 33 percent of total methane emissions, Latin America (23 percent), Europe (14 percent), Africa (14 percent), North America (11 percent) and Oceania (5 percent). It is estimated that between 2008 and 2013, 49 percent of the emissions growth will occur in Asia and the Pacific, 28 percent in Latin America, 17 percent in Africa, 3 percent in Europe, 2 percent in North America and 1 percent in Oceania.

Technical options for reducing methane emissions from enteric fermentation include altering feed composition and feeding practices, using additives or vaccines to reduce methane generated during digestion and improving feed-use efficiency. Mitigation options for manure involve the capture of methane with anaerobic digesters. Captured methane can be flared or used as a source of energy for electric generators, heat or lighting.

Mitigation policies can reduce GHG emissions by altering the inputs and technologies used in production or by changing the basket of goods produced and consumed. Incentive or market-based mechanisms to mitigate

GHG emissions include taxes on emissions, emissions trading (cap-and-trade), subsidies to reduce emissions (including offsets in an emissions trading scheme) and subsidies for abatement technologies. Implementing incentive-based schemes to reduce GHGs from livestock is challenging, in part, because of high costs associated with measuring and monitoring emissions, verifying compliance and administering and enforcing policy. Administrative costs are often high because emissions occur on a large number of relatively small operations and often vary over time. Some policy approaches, like carbon offsets in an emissions trading scheme (e.g. the Clean Development Mechanism [CDM]), can impose large fixed transaction costs on producers, which makes participation infeasible for small-scale operations.

Implementing incentive-based policies can face substantial political opposition if policies result in higher livestock product prices for consumers, lower profits and higher transaction costs for producers and increased administrative and budgetary costs for governments. Policies such as taxes, abatement subsidies and emissions trading schemes raise the marginal costs of domestic producers, which reduce producers' competitiveness in international markets. With international trade, the effectiveness of GHG mitigation policies can be severely diminished through "leakage", when production and consequently emissions, expand outside the regulated area.

Substantial reductions in global methane emissions from livestock require reductions in emissions from producers in non-Annex 1 countries. However, in contrast to Annex 1 countries (those with commitments under the Kyoto protocol), non-Annex 1 countries do not have obligations to reduce GHG emissions unless those reductions are supported by funding and technologies from developed countries. Hence, a key challenge is to design policies that are administratively and politically feasible in non-Annex 1 countries and provide incentives for these countries to participate.

## SECTORAL INCENTIVE-BASED POLICIES

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A policy approach that focuses on sectoral rather than individual farm emissions offers several advantages in terms of political and administrative feasibility. With a sectoral approach, emissions are measured and monitored at the sectoral-level; and taxes, subsidies or emissions trading target the sector as a whole, rather than individual producers. A sectoral approach can be enacted with lower administrative costs and producer transaction costs. Livestock methane emissions can be measured at the national sectoral level using the Intergovernmental Panel on Climate Change (IPCC) Tier 1 methods, which have minimal data requirements. Annex 1 countries currently report livestock methane emissions in the United Nations Framework Convention on Climate Change (UNFCCC) national inventory reports using Tier 2 methods. It is possible to design sectoral policies that avoid emissions leakage and provide incentives for participation by non-Annex 1.

A *sectoral carbon tax* on commodities based on average embodied emissions would induce consumers to switch from commodities with higher associated emissions (e.g. beef, sheep meat) to lower emissions (chicken, pork). If applied globally, such a tax would cause production to shift from regions with relatively high emissions (e.g. beef from Latin America) to regions with relatively low emissions (e.g. beef from the United States of America). If the tax were only applied to goods produced in some regions (e.g. Annex 1 countries), production

would tend to shift outside of the taxed region. To avoid emissions leakage, each country would need to tax both domestic and imported goods based on embodied emissions. However, laws governing international trade could preclude trade restrictions based on production methods.

Trade laws permit commodity taxes based on average embodied carbon emissions, as long as all “like” products are taxed equally. For example, Annex 1 countries could tax beef at a higher rate than other meats, as long as all beef, domestic and imported, is taxed at the same rate. Such a tax would avoid emissions leakage. In fact, to the extent that such a tax reduces imports into the taxed country, it would also lower emissions in non-taxed countries. However, such a tax would be less efficient than a globally applied emissions tax as it would not induce a shift in production from high-emission regions to low-emission regions.

Under a *sectoral emissions trading* scheme, each country would face a cap (or target) based on national emissions from its livestock sector. Each country could apply nationally appropriate mitigation strategies to reduce emissions. National governments would buy or sell emissions permits in a market depending on whether emissions are above or below the sectoral cap.

In one form of sectoral emissions trading, sometimes called a *sectoral crediting mechanism* (SCM) or “no-lose” target, non-Annex 1 countries earn tradable permits if livestock sector emissions are reduced below a defined target (Baron and Ellis, 2006). Participation is not binding and no penalties are incurred if actual emissions exceed the target. As there is no downside and potentially large gains for non-Annex 1 countries, such a framework could be expected to enjoy widespread support and participation. The main disadvantage with the SCM is it that it does not prevent carbon leakage if non-Annex 1 countries do not participate.

A “*high-cap*” emissions trading scheme is similar to an SCM except that non-Annex 1 countries that exceed their target (cap) would be required to purchase permits. To encourage non-Annex 1 countries to participate, emissions caps for non-Annex 1 countries would need to be sufficiently high. If caps for non-Annex 1 countries were set above their expected business-as-usual emission levels, non-Annex 1 countries should be unambiguously better off under the policy compared with the baseline.

It is not necessary for non-Annex 1 caps to be set below business-as-usual levels for there to be a reduction in emissions from the livestock sector. Even with high caps, countries would have an incentive to reduce emissions to earn revenues from permit sales. The global livestock sector could produce a net demand or net supply of marketable permits depending on where the caps are set and on the carbon price. Hence, a high-cap trading scheme would need to operate in conjunction with an emissions trading market, where producers or nations outside of the sector buy permits from or sell permits to the livestock sector.

The high-cap scheme addresses the problem of emissions leakage as all countries that increased emissions would have to purchase additional permits or sell fewer permits, a symmetric and equivalent incentive not to increase emissions.

A potential downside to either a high-cap or SCM scheme is that permit revenues flow to and from governments rather than individual producers. This requires governments to enact policies, such as a sectoral

emissions tax or standard, to induce emissions reductions from producers. Political opposition for either high-cap or SCM schemes might arise from the potentially large flow of permit revenues from Annex 1 to non-Annex 1 countries.

## MODELLING SECTORAL EMISSIONS POLICIES

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Recent FAO research provides insight into the implications of sectoral carbon tax and emissions trading policies. This research uses the OECD-FAO AGLINK-COSIMO model to estimate how production, consumption, trade and emissions change at the national level; to estimate the emissions leakage from Annex 1 countries under different scenarios; and to illustrate which policies would benefit non-Annex 1 countries.

The AGLINK-COSIMO model is a recursive-dynamic, partial equilibrium model of world agriculture that covers about 60 regions, 40 commodities and uses about 15 000 equations (OECD, 2007). The model generates medium-term forecasts and informs the annual OECD-FAO Agricultural Outlook.

For the policy simulations, the carbon tax or the value of carbon emissions permits required per unit of product is defined as the price of carbon (USD 30/tonne) times the total CO<sub>2</sub>-equivalent methane produced per unit of livestock product. For Annex 1 countries, the total methane is derived from the UNFCCC national reports. For non-Annex 1 countries, the total methane is estimated using the IPCC Tier 1 methodology.

The carbon tax based on methane emissions varies across commodities and countries because of variations in emissions per head, output per head and price per tonne of output. For example, dairy cattle in North America have higher methane emissions per head compared with Latin America. However, dairies in North America produce more milk per head. Hence, methane emissions per unit of milk is higher in Latin America as is the carbon tax as a share of price. As shown in Figure 1, the carbon tax rates are higher for beef and sheep and higher in Africa, Asia and Latin America compared with Europe, North America and Oceania.

A global carbon tax lowers the price farmers receive, which causes the supply to contract. This causes the price to increase for all commodities and to increase more for high-carbon products. Consumption adjusts to new prices: for high-carbon products consumption decreases, but for relatively cheap low-carbon products, consumption and production may increase. Global methane emissions unambiguously decline.

Figure 2 illustrates the estimated effect of a global tax initiated in 2008. The figure shows production in 2013 relative to the baseline for the major regions and commodities. Globally, beef production (and consumption) declines by about 5.7 percent and sheep meat production by 3.6 percent. In contrast, production of pork, poultry and milk increase marginally as consumers switch from the relatively highly taxed beef and sheep. The tax results in a 4.6 percent decline in global methane emissions, with declines attributed to each commodity and region in proportion to the decline in production.

Table 1 illustrates the effect of a carbon tax or trading scheme applied only in Annex 1 countries. This scenario is more feasible in the short run because Annex 1 countries have an existing administrative infrastructure for

monitoring and reporting methane emissions, have incentives for abatement (Kyoto protocol) and a functioning emissions trading scheme (European Union-Emission Trading Scheme [EU-ETS]). The Annex 1-only carbon tax (or trading) scheme results in a 5.4 percent decline in methane emissions in Annex 1 countries in 2013. However, the tax makes goods produced in Annex 1 countries more expensive, causing an increase in imports into Annex 1 and a decrease in exports from Annex 1. Consequently, production in non-Annex 1 countries increases and total emissions from non-Annex 1 countries increase by 1.5 percent. The net result is a 0.5 percent decline in global carbon emissions. About two-thirds of the Annex 1 emission reductions are offset by the increased emissions in the rest of the world.

Next, sectoral emissions permit trading between nations combined with a sectoral carbon tax policy are considered. For this scenario, the carbon tax and carbon permits are both USD 30/tonne CO<sub>2</sub>-equivalent emissions. This policy results in the same production, consumption, trade and emissions as with the emissions tax, regardless of where the caps are set. Emission permit sales and purchases depend on individual country caps.

Figure 3 illustrates the net carbon permit flows between regions in 2013 when the cap is set at 100 percent of 2008 emissions for all countries. Under this scenario, Africa, Asia and Latin America purchase permits because they increase their total production in 2013 *relative to 2008* even with the tax. Europe, North America and Oceania sell permits, because the tax causes production to decrease in these regions relative to 2008 levels. The livestock sector as a whole purchases approximately USD 3.2 billion of permits from outside of the sector.

If the cap were set at 104.5 percent of 2008 emissions for all countries then there would be no net purchases or sales of permits by the livestock sector. In this scenario, Asia is a net purchaser of permits; the rest of the world sells permits and the livestock sector is in a permit balance.

Figure 4 illustrates the net permit revenue flows if the cap were 84.5 percent of 2013 emissions for Annex 1 countries and 100 percent of 2013 emissions for non-Annex 1 countries. In this scenario, there are no net permit purchases or sales by the livestock sector. Europe, North America and Oceania purchase permits and Africa, Asia and Latin America sell permits. Note that because the cap on non-Annex 1 countries is set at baseline 2013 levels, Annex 1 countries are unambiguously better off.

## CONCLUSION

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Non-Annex 1 countries are a large and growing source of methane emissions from livestock, which makes their involvement in a global methane mitigation effort crucial. A global model of livestock production and trade demonstrated that incentive-based sectoral policies to reduce methane emissions would be much more effective if implemented at a global level. If a tax/trading scheme is enacted only in Annex 1 countries, it is estimated that two-thirds of Annex 1 emission reductions would be offset by increased emissions in non-Annex 1 countries.

Sectoral emissions trading, where emissions are monitored and reported at the national sectoral level and where emission permits are traded internationally, is a potentially feasible way to incorporate non-Annex 1

countries into a global climate framework. Sectoral trading, can addresses emissions leakage from Annex 1 countries and is administratively feasible for non-Annex 1 countries. Sufficiently high caps could provide incentives for non-Annex 1 countries to participate. Non-Annex 1 governments could use emissions revenues to compensate consumers for higher food prices, compensate producers for higher costs and to monitor emissions and reduce emissions.

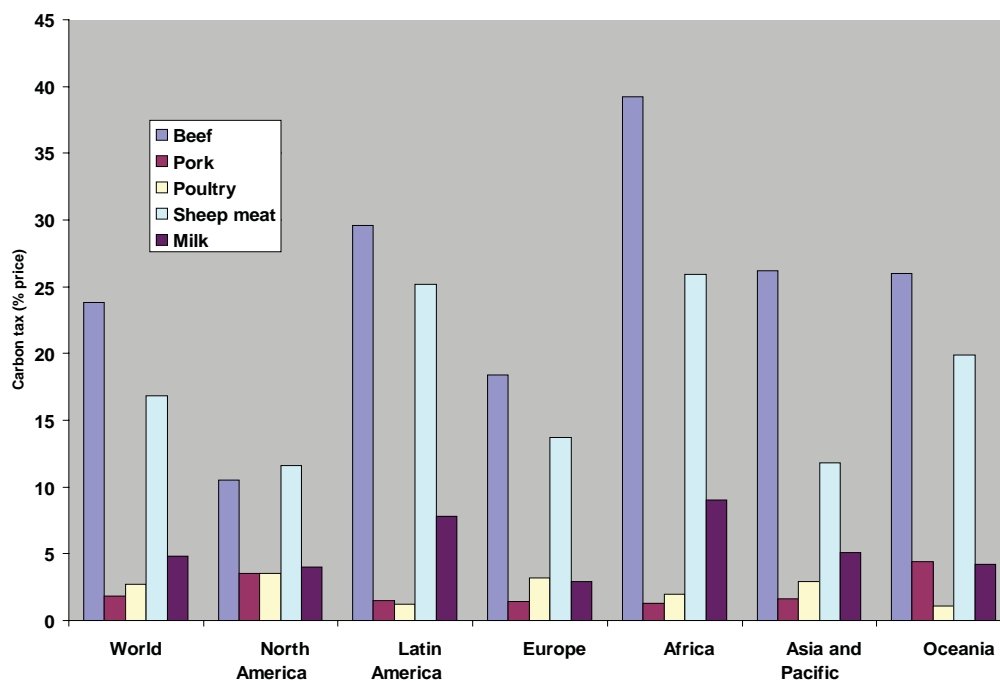
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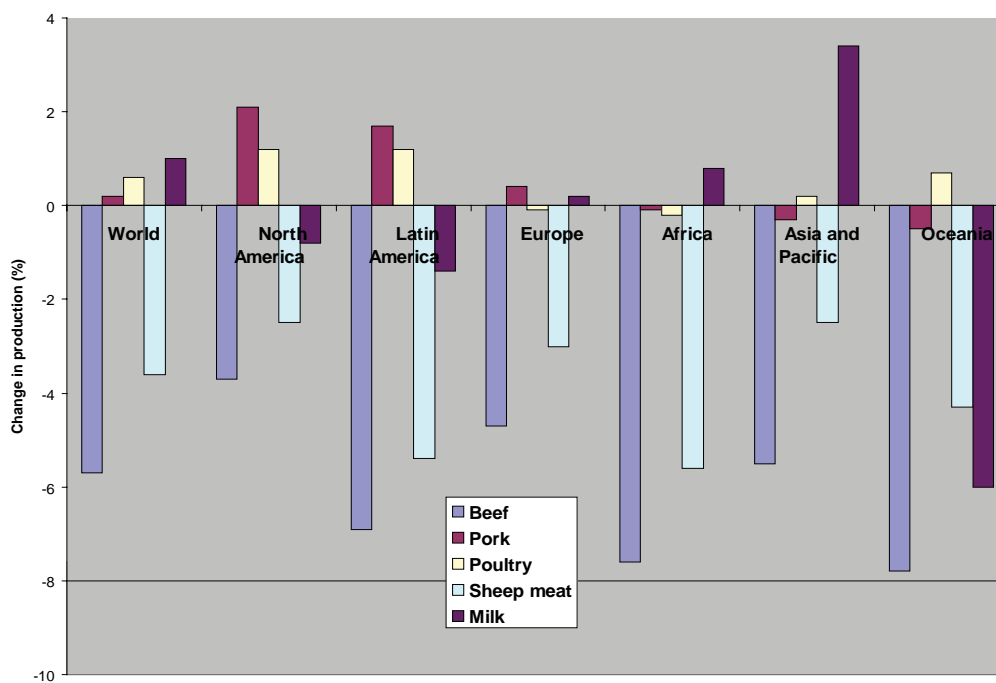


FIGURE 1. Carbon tax as a share of price (%)



Source: authors' estimates

FIGURE 2. Policy-induced change in production (%)



Source: authors' estimates.

TABLE 1. Methane slippage from Annex 1 Carbon tax, 2013

	Methane emissions (kilotonnes CO <sub>2</sub> -eq)			
	Base (no tax)	Tax (Annex 1 only)	Change	Change (%)
Annex 1 - Select Countries	700 127	662 293	-37 834	-5.4
Rest of World	1 702 822	1 728 646	25 824	1.5
World	2 402 949	2 390 938	-12 010	-0.5

Source: authors' estimates.

FIGURE 3. Emissions permit revenue (USD mil.), 2013 (Cap = 100 percent of 2008 emissions)

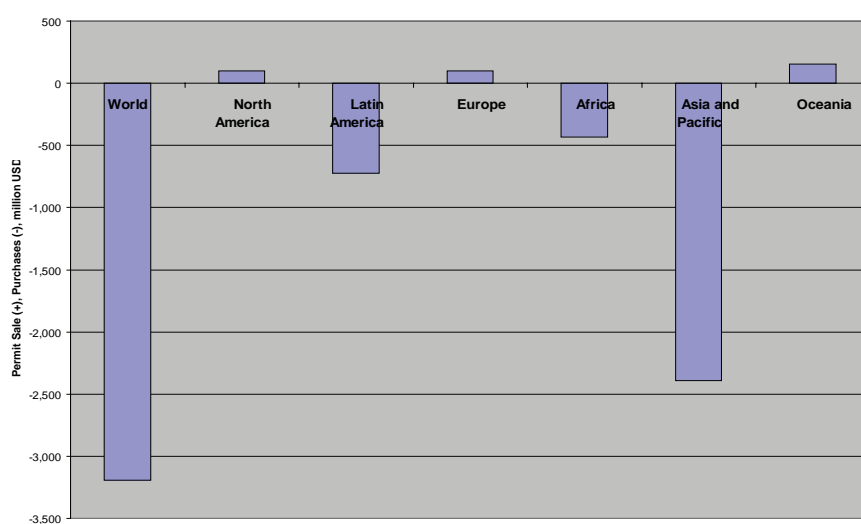
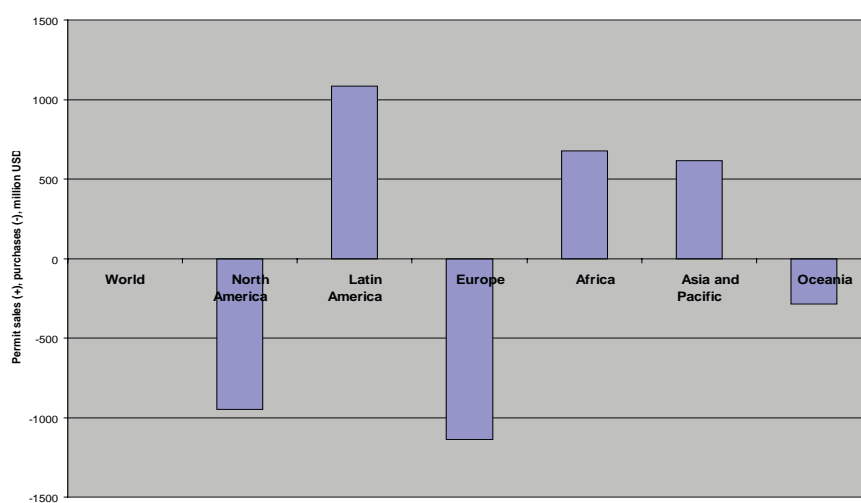


FIGURE 4. Emissions permit revenue (USD mil.), 2013 (Cap = Annex 1: 84.5 percent of 2013 emissions; Non-Annex 1: 100 percent 2013 emissions)



Source: authors' estimates.

# Agriculture and livestock in Carbon Markets

*(World Bank, Beatriz Nussbaumer, Agriculture and Rural Development Team, Buenos Aires Office)*

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The agricultural sector has a great mitigation potential particularly in the Latin America (LAC) region, associated with the deployment of improved agronomic and livestock management practices, as well as with measures to enhance carbon storage in soils or vegetative cover. Some of these measures have significant co-benefits, given that many of these are cost effective and emissions from cropland can be reduced by improving crop varieties; extending crop rotation; and reducing reliance on nitrogen fertilizers by using rotation with legume crops or improving the precision and efficiency of fertilizer applications. In certain climatic and soil conditions, conservation or zero tillage can be effective both at improving crop yields, restoring degraded soils and enhancing carbon storage in soils. Methane emissions from ruminant livestock, such as cattle and sheep, as well as swine, are a major source of agricultural emissions in the LAC region.

Measures to reduce emissions from livestock involve a change in feeding practices, use of dietary additives, selective breeding, and managing livestock with the objective of increasing productivity and minimizing emissions per unit of animal products. Another approach in the case of animals confined in a relatively small area, like swine and dairy, is to use biodigestors to process waste and capture the methane for later use.

This can either be flared (potentially generating carbon credits, as emissions from flaring are much less potent as greenhouse gases [GHGs] than is methane) or used to generate electricity for on-farm or local use. Projects to do this are currently underway in Mexico and Uruguay.

The potential for co-benefits as well as the effectiveness and cost of mitigation measures from this palette of agricultural practices vary by climatic zone and socioeconomic conditions. For example, in contrast to conventional tillage, zero tillage involves no ploughing of soils and incorporates the use of rotations with crop cover varieties and mulching (application of crop residues). The result is an increase in the storage (sequestration) of carbon in soils. Lower fuel requirements for ploughing operations that are no longer needed are another source of GHG reductions. However, application of nitrogen fertilizers to counteract nitrogen depletion that often occurs in the first few years after conversion from conventional to zero tillage may negate some of the reductions in GHG emissions (IPCC, 2007).

In summary, there are a number of opportunities for contributing to increasing agricultural production while reducing GHG emissions, the proposed practices need to be evaluated within specific regional and local settings, and there is no universally acceptable list of preferred interventions. Furthermore, competition for land among different uses means that many solutions are more cost efficient and more effective at achieving reductions when they are implemented as part of an integrated strategy that spans agricultural subsectors and forestry. As mitigation solutions are very context-specific in the agricultural sector, research efforts need to have a strong participatory dimension in order to ensure that they respond to the specific needs of small farmers.

### **The Kyoto Protocol, the Carbon Market and future challenges**

With the entry into force of the Kyoto Protocol on 16 February 2005, more than one hundred and forty countries agree to work together to fight global climate change. The thirty-six industrialized countries that ratified the Protocol, namely Canada, Japan, members of the European Union, as well economies in transition from Central and Eastern Europe, agree to put in place policies and measures to collectively reduce 5 percent of their emissions between 2008 to 2012 as measured against 1990 levels. To meet this binding commitment, industrialized countries have the option to reduce part of their emissions domestically, and they can also reduce emissions from developing countries (through the Clean Development Mechanism [CDM]), or from countries with economies in transition (through Joint Implementation or International Emissions Trading).

Emission reductions are typically measured in tonnes of carbon dioxide equivalent (tonne CO<sub>2</sub>e). Some examples of Clean Development Mechanism (CDM)/Joint Implementation (JI) projects are renewable energy projects that include wind, solar hydro, biomass and biofuels; methane reduction mostly from landfill gas flaring, energy efficiency including building efficiency, and biosequestration through afforestation and reforestation projects.

The money that flows to countries hosting GHG emission reduction activities under CDM/JI transactions is widely known as “carbon finance”. Carbon finance is basically a payment to a project entity (this can be any legal entity, public or private, NGO, etc.) for the emission reductions generated from that project, once the project is operational and typically at yearly basis, like a commercial transaction. The selling of emission reductions, or carbon finance, has been shown to increase the financial viability of projects, by adding an additional revenue stream in hard currency, which reduces the risks of commercial lending or grant finance. The carbon finance can also help overcoming barriers for project development and implementation, e.g. improving access to financial resources, enabling transfer of technologies and know-how. Thus, carbon finance provides a means of leveraging new private and public investment into projects in developing countries and economies in transition that reduce GHG emissions, thereby mitigating climate change while contributing to sustainable development. Examples of CDM projects from the agricultural sector will be presented during the session.

However, there are some restrictions to the current carbon finance structure that have been considered as obstacles to exploit the mitigation potential of many countries. In the case of LAC, it has been calculated that only about one third of its mitigation potential could be economically exploited unless carbon prices were increased (at over USD 20 per tonne CO<sub>2</sub>).

Although some obstacles to implementation are specific to the agricultural sector such as the permanence of GHG reductions (particularly for carbon sinks) and slow response of natural systems, the issue of the high transaction and monitoring costs is being revised as a result of the learning experience of CDM implementation. This is also linked to the difficulties in methodology development and the demonstration of additionality of the proposed RE projects. Moreover, the current evaluation of largely limited to stand-alone project-based initiatives has driven towards analysing a more programmatic structure to enable to scale-up the mitigation reduction projects.

In the case of LAC, from the perspective of long-term low-carbon (sustainable) economic growth, the region needs a mechanism for carbon finance that goes beyond the project-based approach of the CDM in

order to create incentives to significantly shift the carbon intensity of investments that will be made in the energy and transportation sectors and to take advantage of the many opportunities for increasing energy efficiency. As currently designed, the CDM cannot deliver LAC's potential to reduce its GHG emissions in a cost-effective way. A second issue is that, from the perspective of high-volume cost-effective mitigation and critical biodiversity protection, the new chapter of the regime must incorporate activities of reduction of emissions from deforestation, forest degradation (REDD). Worldwide, deforestation accounts for 20 percent of the total global emissions, being a great share from the developing countries, where deforestation accounts for one third of all emissions. The first commitment period of the Kyoto Protocol only recognized afforestation and reforestation projects in the CDM and did not include reduced emissions achieved by means of avoided deforestation or other types of forest management in developing countries. More recent international negotiations have moved towards recognizing decreases in deforestation and forest degradation from a pre-established baseline as a source of credits and/or compensation in a post-2012 regime.

Addressing these challenges the World Bank has designed two new carbon facilities, The Carbon Partnership Facility (CPF) and the Forest Carbon Partnership Facility (FCPF). Details of how these pilot instruments are conceived and applied will be presented during the corresponding session.

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