IV.15 Strategies and Economies for Greenhouse Gas Mitigation in Agriculture

Julian Dumanski, Raymond L. Desjardins, Rattan Lal, Pedro Luiz De Freitas, Pierre Gerber, Henning Steinfeld, Louis Verchot, Gerald E. Schuman, Justin D. Derner, and Mark Rosegrant

Agriculture can make significant contributions to climate change mitigation by (a) increasing soil organic carbon (SOC) sinks, (b) reducing GHG emissions, and (c) off-setting fossil fuel by promoting biofuels. The latter has the potential to counterbalance fossil fuel emissions to some degree, but the overall impact is still uncertain compared to emissions of non-CO_2 GHGs, which are likely to increase as production systems intensify. Agricultural lands also remove CH_4 from the atmosphere by oxidation, though less than forestlands (Tate et al. 2006; Verchot et al. 2000), but this effect is small compared to other GHG fluxes (Smith and Conen 2004).

The main GHGs from agriculture are CO_2, CH_4, and N_2O, and collectively these account for 10–20% of the annual increase in radiative forcing, and up to one third when land use change is included (IPCC 2007). Agriculture accounts for between 59 and 63% of the world's non-CO_2 GHG emissions, including 84% of the global N_2O emissions and 54% of the global CH_4 emissions (USEPA 2006). Of these, N_2O emissions from soils are the most important, followed by CH_4 from enteric fermentation. Methane from rice cultivation is the third largest source. Deforestation is another major source of GHG emissions (about 7.6 Pg CO_2 e year^{-1}). Direct emissions from fossil fuel account for about 10% from this sector (Verchot 2007).

Non-CO_2 GHG emissions from agriculture are expected to increase significantly in the future, with soil emissions of N_2O (75%) and CH_4 from enteric fermentation (70%) being the largest sources. Enteric fermentation and emissions from manure are expected to increase significantly, and become about 50% greater than in 1990 (USEPA 2006). These emissions are driven by production pressures, which in turn are driven by global processes such as world population density, globalization, urbanization, increased purchasing power of the middle classes, etc (Dumanski 2008). Increased consumption of meat products as societies become more affluent is an important driver for emissions from enteric fermentation. All of these are expected to increase in the future, particularly in tropical countries.

J. Dumanski (✉)
Retired from Agriculture and Agri-Food Canada and World Bank, Ottawa, ON, Canada
e-mail: jdumanski@rogers.com

K. Stigter (ed.), *Applied Agrometeorology*, DOI 10.1007/978-3-540-74698-0_115,

Attention has recently focused on the role of agriculture to supply biomass for the production of ethanol and biodiesel. These are renewable energy sources with the potential to reduce emissions from fossil fuels, but there are concerns regarding the carbon efficiency of the process as well as possible negative impacts on soil erosion if residues are used for biofuels.

The Stern Review (Stern 2007) estimates that global mitigation of GHG emissions can be achieved with as little as 1% of global GDP if action is taken immediately. This, however, requires strong policy signals, including pricing of carbon (implemented through tax, trading or regulation), support for innovation and low-carbon technologies, and removal of barriers to energy efficiency. Although emphasis has to be on reductions in the power sector and transport, cuts in non-energy emissions, such as those resulting from deforestation and from agricultural and industrial processes, are also essential. While not as large as the potential from the power sector and transportation, the total potential savings from various agricultural and land use change activities are still substantial, and they can be achieved at a competitive cost.

Mitigation of GHGs in agriculture involves emission reductions, as well as carbon sequestration. Details on management aspects are in Box IV.15. Verchot (2007) estimates that some emission reductions can be achieved with no increase of implementation costs. Globally, approximately 7% of the net emissions from agriculture can be mitigated at a net benefit or at no cost, including approximately 15% from croplands, approximately 3% from rice cultivation, and 6% from animal production.

Box IV.15

Recently, there have been significant improvements in farm management practices with a resulting increase in the carbon efficiency of agricultural production. Notably, while N_2O and CH_4 emissions have increased because of increasing levels of food production, the GHG emissions per unit of production have decreased. In Canada, for example, GHG emissions per kilogram of beef cattle live weight are estimated to have decreased from 13.9 to 10.4 kg CO_2e from 1991 to 2006 (Vergé et al. 2008). During the same period, the GHG emission intensities for pork and poultry have decreased by 29 and 16% respectively (Vergé et al. 2009a, b).

Mitigation of climate change in agriculture requires adoption of integrated farming systems, since these capture the synergism of multiple practices and have the potential to reverse the decline and actually increase the soil organic carbon (SOC) pool. Practices such as zero tillage (ZT) have the combined effect of soil carbon sequestration while concurrently reducing fossil fuel use and improving biodiversity. Other mitigation measures include agronomic practices such as improved crop varieties, improved crop rotations, and improved fertilizer management. Better residue management and water management in rice can yield significant reductions of CH_4 emissions. For livestock, there are a wide range of practices associated with grazing land management, improved feeding, and manure management that can reduce emissions and increase carbon sequestration. The collective impact of these practices is to reduce GHG emissions and sequester carbon in the soil.

The IPCC (2000) identified three land use systems with significant global potentials for climate change mitigation, agroforestry, improved grassland management, and restoration of severely degraded lands. Verchot (2007) evaluated these options, and identified agroforestry and grassland management as the best options. Agroforestry involves the integration of trees into farming systems and agricultural landscapes, including the conversion of slash and burn to agroforests after deforestation, as well as conversion from low-productivity croplands to sequential agroforestry. Agroforestry has such a high potential because it is the land use category with the second highest carbon density after forests, and because there are large area suitable for such land use systems.

Improved grassland management, despite the low carbon densities in this land use system, has a high potential because of the large land areas suitable for these improvements (3.4 billion hectares). Improved carbon sequestration in grasslands can be achieved through introduction of more productive grass species and legumes, improved livestock management, proper stocking and improved nutrient management. About 60% of the grazing lands suitable for improved carbon sequestration are in developing countries (Verchot 2007). These land use systems are also effective in helping small scale farmers adapt to climate change, because they reduce their vulnerability to inter-annual weather variability and changing climatic conditions. Rehabilitation of degraded land and wetland restoration are very expensive, and globally they have limited potential for climate change mitigation, although they may have significant local benefits.

The mitigation potentials increase somewhat with an increase in the price of carbon. Approximately 20% of agricultural emissions can be mitigated as carbon prices approach \$30/t CO_2e (Verchot 2007). Beyond this point, the returns on investment decrease rapidly, suggesting that there are fewer opportunities for greater reductions at higher carbon prices. The greatest potentials for negative and low-cost reductions are in the Russian Federation, non-OECD countries, Australia/New Zealand, and the United States, with only moderate potential in most other countries.

Achieving significant carbon mitigation in developing countries will require tapping carbon offsets from agriculture and land use change. With as much as 13 Gt of CO_2 per year at prices of US\$10–20 per tons, this represents potential financial flows of US\$130–260 billion annually, comparable to annual official development assistance of US\$100 billion, and foreign direct investment in developing countries of US\$150 billion (Mark Rosegrant/IFPRI, personal communication).

Evidence for the conclusions in this paper can be found in Chap. IV.16, "Supporting evidence for greenhouse gas mitigation in agriculture". The opportunities for enhanced carbon sequestration in soils arise because of the degraded carbon stocks in most cultivated soils. However, the sequestration potentials vary according to soil type and ecosystems. Soil carbon sequestration will continue only to the point where a new carbon equilibrium is reached. In all probability, this new level will be lower than the original carbon stock, and to a large extent it will be highly controlled by specific land management practices and inputs, operating within specific soil types and local environments. Although soil carbon sequestration has considerable potential to mitigate climate change, increases in SOC are often associated with increases in N_2O emissions, which act to counterbalance the sequestration benefits. Soils with higher SOC generally have higher N_2O emissions (Grant et al. 2004).

Spatial and temporal variability associated with the biophysical environment and variation in farm management systems remain major problems for monitoring, evaluation, and certification of soil carbon sequestration. The agricultural sector consists of many millions of small and large scale entrepreneurs (individual decision makers), each of which use specific management strategies to optimize their enterprises on their specific land holdings. Although there are common threads among these multitudes, the dual constraints of spatial variability due to varying land areas and those of varying management practices generates significant difficulties in monitoring the progress of mitigation.

Generally, progress has been made in estimating soil carbon sequestration, but the estimation of the non-CO_2 GHGs like N_2O and CH_4 remains problematic. In terms of mitigation potentials, this is particularly important since carbon and nitrogen move in coupled biogeochemical cycles in nature, and increased soil carbon sequestration often results in increased N_2O emissions, thus negating somewhat the mitigation benefits.

Soil carbon sequestration has a higher mitigation potential than emission reductions in agriculture, although both are important. These are best achieved under management systems with higher carbon density, as well as improved soil conservation. Also, enhanced soil carbon pools provide numerous agronomic and environmental benefits, and stabilize global nutrient cycles, with the resultant long-term enhancement of the resilience of agricultural systems to climate change. There are lingering uncertainties on the permanence of the sequestered carbon and on the potentials for leakage, but permanence can be assured by promoting land management philosophies such as sustainable land management that enhance economic viability while also sequestering carbon. It can also be assured through agronomic practices that "inject" more carbon at depth, using more deep rooting cultivars.

On a global scale, grassland management, agroforestry, integrated ZT technologies (Conservation Agriculture), and reduced GHG emissions from animal production have emerged as the strategies with the highest potentials for GHG mitigation in agriculture. These arise because of the large land areas suitable for these land uses, the high carbon density in agroforestry systems, and the increased carbon sequestration capacity under ZT systems. Important emission reductions can also be achieved through improved fertilizer and soil nitrogen management. Also, crops and crop residues can be used as source material for ethanol and bio-diesel, to reduce the use of fossil fuels. However, the social issues and equity issues involved with bioenergy still have to be worked out. Use of agricultural land for biomass production for energy can have implications for food security as well as positive and negative environmental impacts.

The lack of an effective carbon price is currently one of the most significant detriments to collective global action. There are some strong trends in the expansion of global carbon trading, and some initiatives to promote carbon taxes. These are positive, since ultimately they will promote a realistic price on carbon. However, some key constraints still need to be overcome, namely how to mobilize the large and highly diverse global farm populations. And how to certify sequestered carbon and GHG emission reductions, given the high variability inherent in agricultural production environments?

In addition, the rules of access to the benefits of carbon trading need to be streamlined, particularly for avoiding deforestation and stimulating soil carbon sequestration, as well as reducing the transaction costs for large and small initiatives which collectively will result in mitigation of climate change. There are no magic bullets, but the collective impacts of many similar initiatives, by small and large scale farmers, can produce significant results in mitigating climate change, while simultaneously enhancing the resilience of the agricultural sector to adapt to the climate change that is already occurring.

References

Dumanski J (2008) Commentary: The changing face of soil and water conservation. Keynote Presentation from the XVII Meeting of the Brazilian Society for Management and Conservation of Soil and Water, Rio de Janeiro, August

Grant B, Smith W, Desjardins RL, Lemke R, Li C (2004) Estimated N_2O and CO_2 emissions as influenced by agricultural practices in Canada. Clim Change 65:315–332

IPCC (2000) Land-use, land-use change and forestry. Special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, 375pp. http://www.ipcc.ch/ipccreports/sres/land_use/index.htm

IPCC (2007) Climate change: the physical science base. Cambridge University Press, Cambridge. http://www.ipcc.ch/ipccreports/ar4-wg1.htm

Smith KA, Conen F (2004) Impacts of land management on fluxes of trace greenhouse gases. Soil Use Manag 20:255–263

Stern N (2007) The economics of climate change. Cambridge University Press, Cambridge, 667pp. http://webarchive.nationalarchives.gov.uk/+/http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm

Tate KR, Ross DJ, Scott NA, Rodda NJ, Townsend JA, Arnold GC (2006) Postharvest patterns of carbon dioxide production, methane uptake and nitrous oxide production in a Pinus radiata D. Don plantation. For Ecol Manag 228:40–50

USEPA (2006) Global mitigation of non-CO_2 greenhouse gases. US Environmental Protection Agency (USEPA), Washington. http://www.iiasa.ac.at/Research/ECS/IEW2006/docs/2006PPT_Fawcett.pdf

Verchot LV (2007) Opportunities for climate change mitigation in agriculture. A report to the UNFCCC Secretariat. Financial and Technical Support Programme. unfccc.int/files/cooperation_and_support/financial_mechanism/application/pdf/verchot.pdf

Verchot LV, Davidson EA, Cattânio JH, Ackerman IL (2000) Land-use change and biogeochemical controls of methane fluxes in soils of eastern Amazonia. Ecosystem 3:41–56

Vergé XPC, Dyer JA, Desjardins RL, Worth D (2008) Greenhouse gas emissions from the Canadian beef industry. Agric Syst 98:126–134

Vergé XPC, Dyer JA, Desjardins RL, Worth D (2009a) Greenhouse gas emissions from the Canadian pork industry. Livest Sci 121:92–101

Vergé XPC, Dyer JA, Desjardins RL, Worth D (2009b) Long-term trends in greenhouse gas emissions from the Canadian poultry industry. J Appl Poultry Res, 18:210–222