IV.14 Global Potentials for Greenhouse Gas Mitigation in Agriculture

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Improved management of agricultural lands and other terrestrial areas offers considerable potential to mitigate climate change. Currently, 83% of the world's land area is directly influenced by human interventions (Sanderson et al. 2002 cited in Kareiva et al. 2007), about half of the terrestrial earth's surface is extensively managed and 25% is intensively managed (UNEP 2005).

Agricultural lands, including arable land, permanent crops and pasture, occupy about 40% of the earth's land surface (FAO 2007), mostly under pasture and rangelands (∼70%), cropland (25%) and permanent crops (<3%). Estimates were that by rather early this century, all land would be under some degree of management (Vitousek 1994). How these lands are managed will impact directly on the potential for mitigation of climate change.

In terms of forcing agents for climate change, the Pew Centre (2006) reports that anthropogenic factors were relatively unimportant during the first few decades of the twentieth century (compared to changes in solar energy and volcanic activity), but anthropogenic greenhouse gasses (GHGs) assumed dominance during the last half of the century.

The Stern Review (Stern 2007) reports that current levels of GHGs in the atmosphere are approximately 430 ppm carbon dioxide equivalent (CO_2 e), and rising at more than 2 ppm each year. The Review emphasizes that risks of the worst impacts of climate change can be substantially reduced if greenhouse gas levels in the atmosphere can be stabilized between 450 and 550 ppm CO_2 e, but stabilization in this range requires that emissions be reduced by at least 25% below current levels by 2050. At the Bali conference there was repeated asking for 50% reduction by 2050 (e.g. Anderson and Bows 2008). More recent estimations from large social climate movements for a safe atmosphere even go as low as 350 ppm but Anderson and Bows (2008) indicate that by taking the trends between 2000 and 2008 into account,

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even an optimistic interpretation suggests that stabilization much below 650 ppm is improbable.

Between 1970 and 2004, global emissions of GHGs increased by 70%, from close to 29–49 Gt CO_2 e. CO_2 emissions increased by about 80% and represented 77% of total anthropogenic GHG emissions. During this period, emissions from the energy supply sector increased by 145%, transport 120%, industry 65%, land use change, and forestry, 40%, and agriculture by 27% (IPCC 2007).

Agriculture and land use change are normally considered as non-energy emissions, and collectively these accounted for about 35% of total emissions (compared to industry, transport, power generation, etc.). China, India, Brazil, and the USA are clearly the largest polluters of non-CO_2 GHGs. Although the emissions from agriculture are relatively small, the mitigation of climate change requires that all sectors reduce their emissions to the atmosphere.

In addition to emission reductions, climate change can be mitigated by enhancing carbon sinks and promoting carbon sequestration, particularly in terrestrial and oceanic systems. Agriculture, along with forestry and land use change, can make significant contributions by removing carbon from the atmosphere through soil organic carbon sequestration (see Box IV.14), and by providing biomass for energy sources. The opportunity for improved sequestration arises because of the already degraded organic carbon status of most cultivated soils. Lackner (2003) estimated the global storage capacity of soil organic carbon at roughly 100 Gt C, slightly greater than the potential for carbon storage in woody biomass, and less than the potential for carbon storage in the ocean.

Box IV.14 (Contributed by R. Lal)

This Box deals with the potential for carbon sequestration in terrestrial systems. Increases in atmospheric concentration of CO_2 began 8,000 years ago, and that of CH_4 5,000 years ago (Ruddiman 2003, 2005). This corresponds with the conversion of grasslands, deforestation, soil cultivation, spread of rice paddies, and domestication of livestock involved with settled agriculture. He estimated pre-industrial emission (prior to 1750) of CO_2 from terrestrial ecosystems at $\sim$ 320 Pg, whereas post-industrial emission (1750–2000) is estimated at 270 Pg from fossil fuel combustion, and 136 Pg from land use change (IPCC 2000). Thus, emissions from terrestrial ecosystems have accumulated about 456 Pg or 114 ppm of CO_2 (1 ppm of atmospheric $CO_2 = 4$ Pg of CO_2 emission) since the onset of settled agriculture. This has resulted in temperature increases since 1950 of about 0.16°C/decade with a cumulative increase in temperature of 0.6 ± 0.2°C during the twentieth century (IPCC 2007).

Considering the historic carbon emissions from the atmosphere (114 ppm), and assuming that 40–50% of these can be re-sequestered, this amounts to off-setting atmospheric concentration by about 50 ppm over the next 50 years. Potentially, this is a huge contribution to mitigating climate change. Carbon sequestration in world soils and terrestrial ecosystems, compared with geologic and oceanic sequestration, is a natural and cost-effective win–win strategy, and a bridge to the future until low-C economies are developed and adopted.

There are already a large number of technical options for carbon sequestration in soils and terrestrial ecosystems. These include restoration of degraded and desertified soils through afforestation and reforestation, adoption of best management practices on cropland and grasslands, establishment of biofuel plantations (such as warm season grasses and short rotation woody perennials), and agroforestry. Each of these strategies has a potential carbon sink capacity of about 1 Pg C year^{-1} for the next 50 years (Pacala and Socolow 2004).

Soil carbon sequestration and an enhanced soil organic carbon pool have numerous ancillary benefits including: (i) increase in soil aggregation and improvement in soil tilth; (ii) decrease in risks of soil erosion by water and wind; (iii) increase in plant available water storage capacity; (iv) improvement in plant nutrient retention and availability; (v) increase in food/energy supply for soil organisms; (vi) biodegradation and denaturing of pollutants; (vii) purification of water; (viii) decrease in non-point source pollution; (ix) increase in biodiversity and (x) improved efficiency of fertilizer and irrigation waters. Thus, while mitigating climate change and improving the environment, soil carbon sequestration is also essential to advancing global food security. Lal (2006) estimated that an increase in the soil organic carbon pool by 1 Mg C ha^{-1} year^{-1} in degraded and desertified soils can lead to an increase in food production in developing countries by an additional 30–50 million tons year^{-1}, which is adequate to fill the food gap in Sub-Saharan Africa and elsewhere in the developing world (Shapouri and Rosen 2006).

Currently, soils in developing countries, particularly Sub-Saharan Africa and South Asia, are the most depleted of carbon and nutrient reserves, and thus have a large potential for carbon sequestration. However, and despite the higher potential and greater need, the challenge of soil organic carbon sequestration in these soils is also much greater than those in soils of temperate regions (Lal 2000, 2007).

"Mitigation potential", the extent of GHG reductions that may be possible for a given price of carbon can be described in several terms. "*Market potential*" is the mitigation potential which might occur considering current and forecasted markets, policies, programs, and existing barriers. "*Economic potential*" takes into account social costs, benefits, and discount rates, assuming that market efficiency is improved through improved policies and programs, and barriers are removed.

"*Technical potential*" is a theoretical potential assuming adoption of all technical options and no economic or policy barriers.

The technical potential for mitigation options in agriculture by 2030, considering all gasses, was estimated at 4.5–6.0 Gt CO_2 e (Caldeira et al. 2004; Smith et al. 2008). The economic potential, of course, is considerably lower. Mitigation potential should not be confused with "adaptation to climate change", which is the process of building resilience and minimizing the costs of climate change, assuming that climate change is inevitable (Stern 2007). Both processes are important and must be considered in developing strategies to deal with climate change.

The evidence is increasingly clear that global climate change is already occurring, and that strong mitigation measures are needed now to avoid serious impacts on the global economies. The Stern Review (Stern 2007) concludes that the concentration of GHGs in the atmosphere could reach double its pre-industrial level as early as 2035, in which case global average temperature rise may be 2 °C and perhaps as high as 5 °C. This rise in global temperatures is equivalent to the change in average temperatures from the last ice age to today.

Among the many indicators assembled by the Pew Centre (2006), they report that the six oceans that straddle the equator have been warming simultaneously for at least the past 40 years, and that the oceans have been warming from the surface downward. They also report on the clear patterns of global deterioration of ice cover, both for sea ice and land based glaciers, indicative of global warming. These and many other changes cannot be explained by regional differences, but require external forcing. The benefits of early action on mitigation far outweigh the continued costs of inaction.

The agriculture sector was once a major contributor to GHG emissions, but it has been superseded by the power and transportation sectors. However, all sectors have a role to play and all must be mobilized in the collective efforts to mitigate global climate change. Significantly, agriculture has an important role because of the large land areas involved, and because there are already many available technologies and opportunities in agriculture to contribute to the global mitigation effort, many of which can be implemented with minimal or no cost.

Although deforestation is often treated as an issue in forestland management, it is also an important link with land use change and the conversion of forested land to agriculture. Annual emissions from land use change during the 1990s, considering the collective impacts of CO_2, CH_4 (methane), and N_2O (nitrogen dioxide), accounted for about 20–25 % of the total anthropogenic emissions of GHGs (Houghton 2005). FAO (2005) estimates that about 15.4 million hectares of tropical forests were lost each year during the 1980s, 10.1 million hectares were lost annually from 1990 to 2000, and 10.4 million hectares were lost annually from 2000 to 2005.

Agricultural expansion was by far the leading cause at a global scale, whether through forest conversion for permanent crops, cattle ranching, shifting cultivation or colonization agriculture. The most prominent underlying causes of deforestation and degradation are economic factors, weak institutions and inadequate national policies, and other remote influences such as wood extraction, and road and infrastructure extension, that drive proximate causes of agricultural expansion.

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