Agriculture and Climate Change: An Agenda for Negotiation in Copenhagen

The Potential for Soil Carbon Sequestration

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Of the five principal global carbon pools, the ocean pool is the largest at 38.4 trillion metric tons (mt) in the surface layer, followed by the fossil fuels (4.13 trillion mt), soils (2.5 trillion mt to a depth of one meter), biotic (620 billion mt), and atmospheric pools (800 billion mt). If the fluxes among terrestrial pools are combined, annual total carbon flows across the pools average around 60 billion mt, with managed ecosystems (croplands, grazing lands, and plantations) accounting for 57 percent of that total. Thus, land managers have custody of more annual carbon flows than any other group.

What is carbon sequestration?

Carbon concentration in the atmosphere is increasing at the rate of about 4 billion mt (2 parts per million) per year, with transfer primarily from the fossil fuel, biotic, and soil pools. This increase is a double jeopardy. One, the loss of carbon from the terrestrial pools reduces the ecosystem services and goods that these systems provide. In particular, decline in soil quality adversely affects use efficiency of inputs, decreases agronomic yields, and exacerbates food insecurity. Two, increase in atmospheric pools accentuates global warming with the attendant impact on pole-ward shifts of ecosystems and the increase in frequency and intensity of extreme events including droughts, melting glaciers and Arctic ice sheet, rising sea level, and loss of biodiversity. One solution to this problem is to transfer atmospheric CO_2 into other long-lived pools (such as the soil and biotic pools); this is called carbon sequestration. Increasing carbon pools in the soil beyond a threshold level (about 1.2 percent in the surface layer) is essential to enhancing soil quality, increasing agronomic productivity, and improving quality of natural waters. The strategy of carbon sequestration in soils and biota is cost effective, safe, and has numerous co-benefits over leaving carbon in the atmosphere or sequestering it in geologic and oceanic strata. Biotic, or plant-based, sequestration is based on a natural process whereby CO_2 is photosynthesized into organic substances and stored for the long term in plant products and soil organic matter. The natural rate of photosynthesis in the global biosphere is about 120 billion mt of carbon per year. Fossil fuel combustion emits about 8 billion mt of carbon annually, and deforestation and land-use conversion emit another 1.6 billion to 2 billion mt of carbon per year, for a total of 9.6 to 10.8 billion mt of carbon emissions per year. Thus, if roughly 8 percent of the carbon being photosynthesized by the biosphere is retained within the soil and biotic pools, the global carbon budget would be balanced.

The technical potential for soil carbon sequestration

Soil organic carbon has been depleted through (1) the long-term use of extractive farming practices and (2) the conversion of natural ecosystems (such as forest lands, prairie lands, and steppes) into croplands and grazing lands. Such a conversion depletes the soil organic carbon pool by increasing the rate of conversion of soil organic matter to CO_2, thereby reducing the input of biomass carbon and accentuating losses by erosion. Most agricultural soils have lost 30 to 40 mt of carbon per hectare, and their current reserves of soil organic carbon are much lower than their potential capacity.

Soil carbon sequestration involves adding the maximum amount of carbon possible to the soil. The technical potential for this process is higher in degraded/desertified soils and soils that have been managed with extractive farming practices than it is in good-quality soils managed according to recommended management practices (RMPs). Thus, converting degraded/desertified soils into restorative land and adopting RMPs can increase the soil carbon pool. While no single technology is appropriate for all soils, climates, or cropping and farming systems, the goal is to identify site-specific technologies that create a positive soil carbon budget. The rate of soil carbon sequestration through the adoption of RMPs on degraded soils ranges from 100 kilograms per hectare (kg/ha) per year in warm and dry regions to 1,500 kg/ha per year in cool and temperate regions. A recent estimate of the technical potential of soil organic carbon sequestration through adoption of RMPs for world cropland soils (1.5 billion hectares) is 0.4 billion to 1.2 billion mt of carbon per year.

Examples of soil and crop management technologies that increase soil carbon sequestration include

- no-till (NT) farming with residue mulch and cover cropping;
- integrated nutrient management (INM), which balances nutrient application with judicious use of organic manures and inorganic fertilizers;
- various crop rotations (including agroforestry);
- use of soil amendments (such as zeolites, biochar, or compost); and
- improved pastures with recommended stocking rates and controlled fire as a rejuvenate method.

Another good strategy for soil carbon sequestration is the restoration of degraded/desertified soils (about 2 billion hectares), which can be achieved through afforestation and reforestation. The technical potential of soil carbon sequestration through restoration of degraded/desertified soils is 0.6 billion to 1 billion mt of carbon per year. The establishment of energy plantations can also improve ecosystem carbon pools. It is estimated that afforestation and establishment of energy plantations can offset 25 billion mt of carbon between 2000 and 2050.

The technical potential of carbon sequestration in world soils may be 2 billion to 3 billion mt per year for the next 50 years. Thus, the potential of carbon sequestration in soils and vegetation together is equivalent to a draw-down of about 50 parts per million of atmospheric CO_2 by 2100.

Soil carbon in peatlands

One particularly important and unique soil carbon pool is in peatlands. Peat is formed when plant material in marshy areas is kept from decaying by acidic conditions. Draining and burning peatlands is a significant source of CO_2 emissions. Restoration of wetlands and avoiding cultivation of peatland can convert these soils from a large source to a vast carbon sink. Drained and cultivated peat lands decompose and subside at the rate of 1 to 2 centimeters per year. The rate of soil carbon sequestration in restored peatlands may be greater than 1 mt of carbon per hectare per year. This rate of sequestration is above the emission avoidance rate through inundation of wetlands because of the decomposition of cultivated peat. About 400 million hectares of peatlands in the world can sequester 0.4 billion mt of carbon per year.

The economic potential for soil carbon sequestration

One way to think of soil carbon is as a commodity. It can be produced and, if carbon markets exist, traded like any other farm produce. Additional income can be an important incentive for the resource-poor farmers in developing countries to invest in soil restoration and adopt RMPs. The economic potential may be as much as 60 percent of the technical potential, or 1.2 to 2.0 billion mt of carbon per year. Furthermore, measuring and monitoring protocols of change in carbon pools at the landscape, farm, and regional scales are available to facilitate carbon trading.

The greatest potential for sequestration is in the soils of those regions that have lost the most soil carbon. These are the regions where soils are severely degraded and have been used with extractive farming practices for a long time. Among developing countries, these regions include Sub-Saharan Africa, South and Central Asia, the Caribbean, Central America, and the Andean regions. Most soils have a technical or maximum sink capacity of 20 to 50 mt of carbon per hectare that can be sequestered over a 20-to-50-year period.

Soil carbon sequestration can enhance productivity and resilience

Increases in soil organic material have important productivity and resilience benefits. These benefits include improvement in soil quality, increase in use efficiency of inputs, reduction in soil erosion and sedimentation, decrease in nonpoint source pollution, and lower rates of anoxia or hypoxia (dead water) in coastal ecosystems. Global food security cannot be achieved without restoring the quality of degraded soils, for which soil carbon sequestration is an essential prerequisite.

Soil carbon sequestration is a win–win strategy. It mitigates climate change by offsetting anthropogenic emissions; improves the environment, especially the quality of natural waters; enhances soil quality; improves agronomic productivity; and advances food security. It is a low-hanging fruit and a bridge to the future, until carbon-neutral fuel sources and low-carbon economy take effect.

Suggested negotiating outcomes:

Carbon sequestration in soils and plants is the only strategy that can remove carbon from the atmosphere and, over time, reduce atmospheric concentration of CO_2. Initiatives to support reduced emissions from deforestation (REDD) are well underway. Funds for soil carbon mitigation should also be made available. Support should be provided for

- crop mixes to include more plants that are perennial or have deep-root systems in order to increase the amount of carbon stored in the soil;
- cultivation systems that leave residues and reduce tillage, especially deep tillage, in order to encourage the buildup of soil carbon;
- shifting land use from annual crops to perennial crops, pasture, and agroforestry in order to increase both above- and below-ground carbon stocks; and
- activities that restore degraded and desertified soils and ecosystems, especially those affected by accelerated erosion, salinization, and nutrient depletion.

Carbon offset payments should be allowed for carbon sequestered in soils where low-cost monitoring is available. Funds for the development of these monitoring systems should be part of any outcome.

Paying resource-poor farmers and smallholders in developing countries for soil carbon sequestration would contribute to GHG mitigation, provide much needed resources to support development and adaption of improved crop technologies, and reduce rural poverty. ■

For Further Reading: R. Lal. "Challenges and Opportunities in Soil Organic Matter Research," ***European Journal of Soil Science*** **60 (2009): 158–160; R. Lal, "Enhancing Crop Yield in Developing Countries through Restoration of Soil Organic Carbon Pool in Agricultural Lands,"** ***Land Degradation and Development*** **17 (2006): 197–209; R. Lal, "Soil Carbon Sequestration Impacts on Global Climate Change and Food Security,"** ***Science*** **304 (2004): 1623–1627.**

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