Terrestrial Carbon Sequestration

Activities in forestry and agriculture can reduce and divert the atmospheric buildup of the three most important GHGs directly emitted by human actions: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Adoption of recommended management practices can enhance soil carbon, and improve soil quality and productivity. The opportunities to enhance soil carbon include: increasing the soil organic carbon concentration, improving water and nutrient use efficiencies, and improving biomass productivity. Terrestrial sequestration is considered a near term approach to reducing GHGs because it can be implemented today. Moreover, soils provide a significant reservoir for organic carbon, storing twice as much as the atmosphere and three times as much as plants.

Many U.S. cropland soils have lost as much as 50% of their original organic carbon due to the effects of land clearing and tillage. It is estimated that U.S. cropland and grazing lands alone have the potential to store 150-380 million metric tons of carbon per year or 9.4-23.8% of total U.S. emissions. Some management practices that sequester carbon are: reducing tillage intensity, diversifying crop rotations, reducing summer fallow, planting higher residue crops, such as corn, grain sorghum and wheat, planting winter cover crops, selecting varieties and hybrids that store more carbon, reducing soil inputs, converting marginal agricultural land to grassland or forest, restoring wetlands, and using vegetation buffers and conservation measures that reduce soil erosion.

Grazing lands, comprised of pasture and rangelands, represent the largest, most diverse single-land resource in the United States and in the world. Grazing land comprises more than half of the land surface in the world and 55% of the total land in the United States. As with croplands, the magnitude of the carbon input to the soil in grazing lands depends on several management approaches such as residue management, improving the use of fertilizers, application of organic manure, planting improved species, improved forage quality, regular use of prescribed burns to increase forage productivity, reducing overgrazing and improving grazing practices. Soils under grazing management have more soil organic than those under cropping. This can be attributed to the lower frequency and intensity of soil disturbance.

Forests cover about one-third of the United States, totaling about 750 million acres. The growth of forests and their management offers one of the most promising sources of carbon sequestration in the biosphere. The concept of offsetting carbon dioxide emissions by sequestering the CO_2 in forests is not new. IPCC reviews concluded that globally, changes in forest management could induce future carbon sequestration adequate to offset an additional 15-20% of CO_2 emissions. Reforestation and afforestation present many opportunities to sequester carbon. Among these opportunities are increasing in situ tree growth, increasing the area planted to forests, increasing use and permanence of forest products, and decreasing the loss of current forests.

Terrestrial carbon sequestration also provides the opportunity to trade carbon credits and reduce emissions voluntarily. Carbon sequestered by one party could offset emissions produced by another. The U.S. Department of Agriculture (USDA) and the U.S. Department of Energy are currently developing accounting rules for sequestration projects and improving the voluntary GHG registry (1605b) and crediting system. Furthermore, USDA is giving consideration to management practices that store carbon and reduce GHGs in setting priorities and implementing conservation programs. Private sector groups such as the National Carbon Offset Coalition and the Chicago Climate Exchange, Big Sky Partnership members, have initiated pilot market-based systems to trade CO_2.

Opportunities For Soil Carbon Sequestration in Croplands

***Increase the soil organic carbon concentration or density*:**
The soil organic carbon concentration can be enhanced by applying large quantities of biomass to the soil and improving water and nutrient use efficiencies. Agricultural practices that return biomass to the soil include mulch farming, conservation tillage, use of composts and farmyard manure. Crop rotation, agroforestry systems, and application of bio-solids to the soil also increase soil organic carbon. The degree of soil disturbance through tillage operations adversely impacts soil aggregation, exacerbates residue decomposition, and reduces the ultimate retention of carbon in the soil. In this context, no-till agriculture, among the most significant technological innovations of the last thirty years, allows farmers to grow crops economically while reducing erosion and improving both quantity and quality of soil organic material. Conversion of plow till to no till, in combination with growing cover crops and applying farmyard manure or compost, has a large potential to sequester carbon in cropland soils.

***Improve biomass productivity*:**
Soil and vegetation management practices could be adopted as a way of enhancing biomass productivity and returning more biomass, both above and belowground, to the soil. Deep-rooted cover crops and forages enhance the organic carbon pool in the subsoil. Careful application of fertilizers and other inputs via integrated nutrient management (INM) and precision farming or soil-specific management are critical to soil carbon sequestration.

***Restore degraded soils of ecosystems*:**
A clear opportunity also exists in restoring degraded soils of ecosystems. This is an important strategy to resequester part of the soil organic carbon that has been depleted by land misuse and soil mismanagement. There are a number of techniques that could be used for restoring degraded soils and ecosystems. Important among these are establishing vegetation cover for erosion control, conservation tillage, mulch farming, establishing winter cover crops, and eliminating summer fallow. Increasing soil fertility and replenishing depleted nutrients through well-advised application of fertilizers, integrated nutrient management, and biological nitrogen fixation, manuring and recycling of nutrients through application of bio-solids are among the numerous options.

Opportunities for Soil Carbon Sequestration in Grazing Lands

Opportunities in grazing lands:
These opportunities include growing species with high biomass productivity and deep root systems, controlled/rotational grazing with low stocking rates, and the management of soil fertility and fire frequency. The restoration of degraded soils such as those that are eroded or mined are important strategies for enhancing biomass production and sequestering soil carbon. It should be noted that fire management is important because controlled burning can improve biomass production and excessive intense fires can acerbate losses and adversely affect productivity.

Opportunities for Soil Carbon Sequestration in Forests and Trees

The most successful tactics for sequestering and retaining increasing amounts of carbon from the atmosphere in forests vary widely with the types of trees. Favorable opportunities for management actions follow:

Increase in situ tree growth:
Opportunities include the common forest management techniques aimed at increasing wood production. Forest thinning and selective harvesting permits the remaining trees to grow much larger and forests of large trees store more carbon than forests of small trees. In addition, thinning removes "ladder fuels" which permit small, smoldering ground fires to climb into the forest canopy and become intense stand destroying fires, which release carbon already stored.

Increase area planted to forests:
This set of opportunities involves increasing the incentives to shift current non-forest land uses to forests, and rapid reestablishment of forests following harvests. The amount of wastelands and marginal agricultural lands increases in the United States

every year, as new techniques produce greater crop yields, and as the focus shifts to the best croplands. The planting of forests of rapidly growing species, such as aspen, for either carbon storage or for harvest as biofuels can sequester up to 4.5 Mg of carbon/hectare/year on these lands. In many cases, planting along riparian areas can reduce erosion and flooding while cultivating a fast growing biomass tree crop. Another approach to this problem is to grow trees at the same location as crops are being grown, that is, the practice of agro forestry. Obviously, the utility of all these afforestation efforts to carbon sequestration can be significant as well as profitable.

Increase use and permanence of forest products:

These strategies are centered on encouraging greater use of forest products, in the expectation that some of the uses will more permanently store carbon. All will be followed by forest replanting to continue taking up atmospheric carbon. The substitution of forest products for aluminum, steel, concrete and brick has the added advantage of reducing the fossil fuel use expended in production of these latter raw materials. This indirect effect on carbon sequestration can be greater than the effect of the carbon stored directly in the wood products.

Decrease losses of current forests:

The 20th century in the United States is characterized by growth of forests on lands freed from agricultural uses, and a lesser decrease of forests as they are replaced by urban and suburban uses. One means to reduce the loss of forests is to increase the rotation period of forests, such that forests harvested every 30 years are retained for 40 or even 50 years.

Other opportunities:

Techniques to reduce the impact on carbon stocks of forest harvests, by "low impact forestry" need to be adopted. These techniques range from selective harvests that leave large trees and a large portion of the forest community behind, to minimize disturbance to the soil and the remaining vegetation. Another approach aims at reducing losses to common forest disturbances such as wildfire and pest infestations