AGRICULTURAL SOILS: TOOL FOR STABILIZING ATMOSPHERIC CO_2

SANGEETA LENKA[1*], NARENDRA KUMAR LENKA[1], VASSANDA COUMAR[1], SONALIKA SAHOO[2], JK SAHA[1]

[1]ICAR - Indian Institute of Soil Science, Bhopal, Madhya Pradesh
[2]ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur, Maharashtra
*Corresponding author, E-mail: sangeeta_2@rediffmail.com

Soils are the largest reservoir of bio-geochemically active terrestrial carbon pool on earth and are critical for stabilizing atmospheric CO2 concentration. It is a global concern to decrease the atmospheric concentration of greenhouse gases (GHGs) and enhance the soil organic carbon storage in the soils. It is evident that atmospheric carbon dioxide (CO2) concentration increased drastically from 280 ppm during the preindustrial era to about 410 ppm at present. Soil organic carbon is also an important index of soil quality because of its relationship to crop productivity (Lenka et al., 2017a). Therefore, it is important to understand and predict the fate of soil organic carbon (SOC) in the context of global climate change. The edaphic pool (soil) stores three times more carbon (C) than the atmospheric or terrestrial vegetation pool. Further, soil C storage is one of the most important ecosystem processes as it plays a critical role in supporting key ecosystem services such as climate regulation, soil fertility, and food production. According to India's 2nd National Communication to the UNFCC, the rise in annual mean surface air temperature by the end of the century ranges from 3.5 °C to 4.3 °C. The increase in temperature and consequently evapotranspiration will have a profound influence on the net primary productivity and SOC storage across India. This calls for a better understanding of the effects of changes in climatic variables and management practices on SOC sequestration and stabilization.

PRINCIPLE OF STABILIZING ATMOSPHERIC CO2 IN AGRICULTURAL SOILS

Managing agricultural lands helps stabilize atmospheric CO2 in two ways, first by reducing emissions and second by sequestering emissions. Sequestering carbon in soil is a critical element in mitigating climate change. Carbon Sequestration is defined as the removal and storage of carbon from the atmosphere in carbon sinks (such as oceans, forests or soils) through physical or biological processes, such as photosynthesis. The soil carbon pool alone is 3.3 times the size of the atmospheric pool and 4.5 times the size of the terrestrial biotic pool (Lal, 2004). The SOC levels result from the interactions of several ecosystem processes, of which photosynthesis, respiration, and decomposition are the key.

Photosynthesis is the fixation of atmospheric CO_2 into plant biomass. SOC input rates are primarily determined by the root biomass of a plant, but also include litter deposited from plant shoots. Soil C results both directly from growth and death of plant roots, as well as indirectly from the transfer of carbon-enriched compounds from roots to soil microbes. For example, many plants form symbiotic associations between their roots and specialized fungi in the soil known as mycorrhizae; the roots provide the fungi energy in the form of carbon while the fungi provide the plant with often-limiting nutrients such as phosphorus.

Decomposition of biomass by soil microbes results in carbon loss as CO_2 from the soil due to microbial respiration, while a small proportion of the original carbon is retained in the soil through the formation of humus, a product that often gives carbon-rich soils their characteristic dark color. These various forms of SOC differ in their recalcitrance, or resistance to decomposition. Humus is highly recalcitrant, and this resistance to decomposition leads to a long residence time in soil. Plant debris is less recalcitrant, resulting in a much shorter residence time in soil. Other ecosystem processes that can lead to carbon loss include soil erosion and leaching of dissolved carbon into groundwater. When carbon inputs and outputs are in balance with one another, there is no net change in SOC levels. When carbon inputs from photosynthesis exceed carbon losses, SOC levels increase over time.

STRATEGIES FOR SEQUESTRATION OF CARBON IN AGRICULTURAL SOILS

Several strategies have been advocated for stabilizing atmospheric abundance of CO_2. The three main strategies to lower down the CO_2 emissions include reducing the global energy use, developing low or no-carbon fuel, and sequestering CO_2 through natural and engineering techniques. Because of historic losses of C from soils, estimated to be 41 to 55 Gt, the soils now offer an opportunity for carbon storage. Some of the factors that influence the C sequestration are: climate (Emmett et al., 2004), the type of vegetation it supports, the nature of parent material, the depth of solum, soil drainage, the edaphic environment, soil organic matter content and its decomposability and land management practices.

Carbon sequestration in terrestrial ecosystems has two distinct but related components: sequestration in biomass (primarily trees comprising both the above ground and below ground components) and soil. A fraction of the biomass returned to the soil is converted into stable humic substances and related organo-mineral complexes with a long residence time. The effectiveness of soil C sequestration depends on the quantity and quality of biomass returned to the soil. In cropland soils, a principal source of biomass is the crop residues. Improved management of agro-ecosystems can significantly enhance C sequestration in soils (Kundu et al., 2007). Management practices or technologies that increase carbon input to the soil and reduce C loss or both, lead to net carbon sequestration in soils (Figure 1).

Increased C input in agro-ecosystems can be achieved in a number of ways such as selection of high biomass producing crops, residue recycling or residue retention by low tillage intensity, application of organic materials (e.g. animal manure, compost, sludge, green manure etc.), adoption of agroforestry systems, intensification of agriculture through improved nutrient and water management practices, reducing summer or winter fallow, changing from monoculture to rotation cropping, and switching from annual crops to perennial vegetation. Soil carbon loss could be decreased by adopting conservation agriculture and minimizing soil disturbance, checking erosion through reduced tillage intensity, and using low quality organic inputs.

Intensive agriculture with improved nutrient and water management results in enhanced C sequestration due to higher crop productivity and greater return of crop residues, root biomass and root exudates to soil (Lenka et al., 2017b). The increased SOC not only mitigates CO_2 emission but also enhances soil productivity. It is, however, argued that SOC sequestration is a big challenge in soils of the tropics and the sub-tropics, where climate is harsh and the resource-poor farmers cannot afford the input of organic manure and crop residues. The rate of C mineralization is high in the tropics because of high temperature and the humification efficiency is low.

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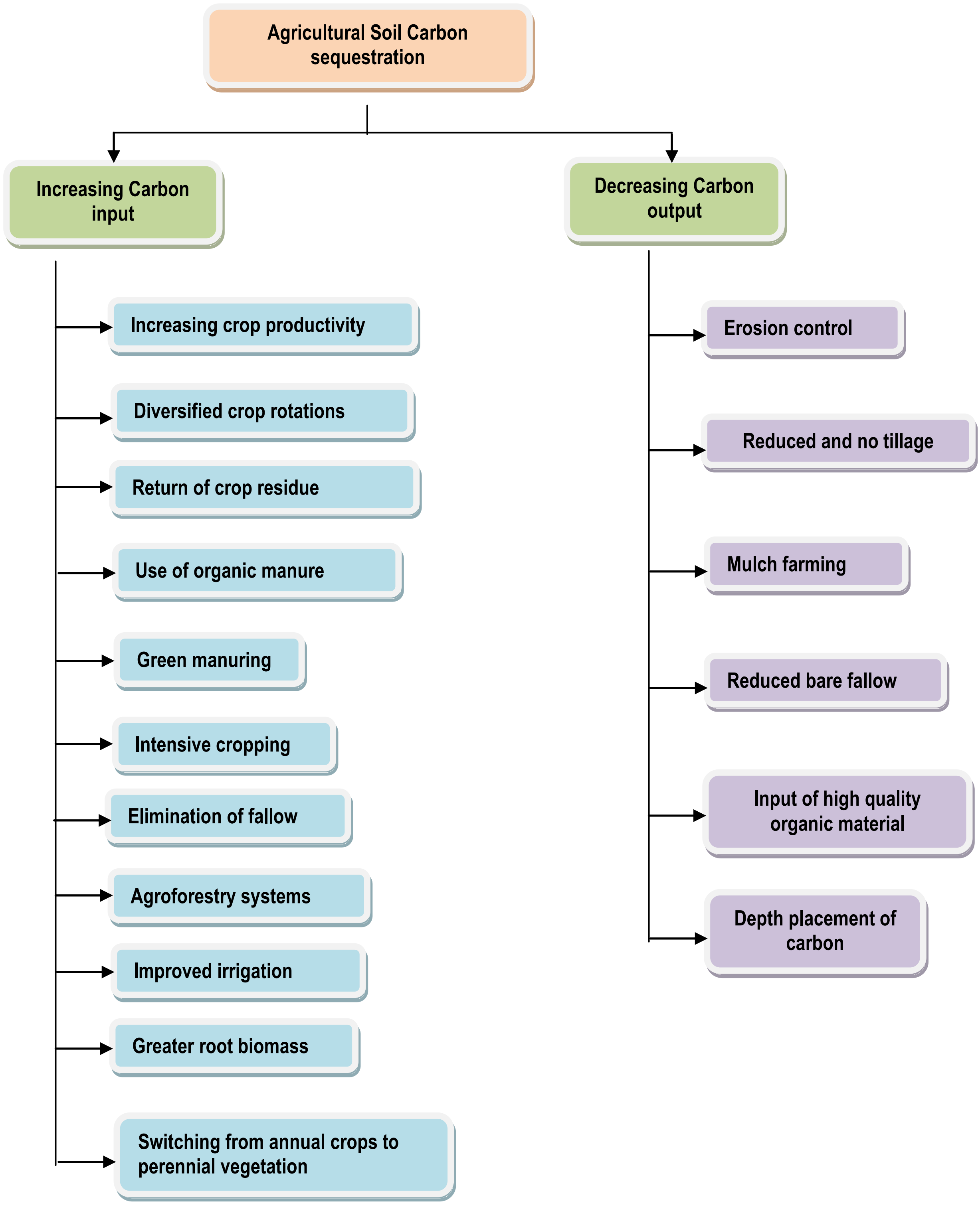

Figure 1. Schematic representation of strategies for C sequestration in agricultural soils