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Role of soil carbon in mitigating Global Green House Gas (GHG) emission

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Global warming is the biggest threat to our environment, facing humanity with implications for food production, natural ecosystems, health etc. The primary greenhouse gases are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The mean global level of greenhouse gases in the atmosphere is increasing to a level that can generate serious climate changes in air temperature and destructive weather cycles. The average surface temperature of the earth is likely to increase by 2 to 11.5°F by the end of the 21st century, relative to 1980-1990, with a best estimate of 3.2 to 7.2°F. Agriculture accounts for about 14 per cent or 6.8 Gigatonnes of CO_2 of the world's greenhouse gas emissions. Connected to agriculture is a land use change such as deforestation that stands for another 17 per cent CO_2 of the world's greenhouse gas emissions. The annual greenhouse gas emissions from agriculture are expected to increase in coming decades due to increased demand for food and shifts in diet. According to one estimate developing countries accounted for only 37% of cumulative CO_2 emissions from industrial sources and land-use change during the period 1900 to 1999 whereas industrialized countries accounted for 63%. However, in recent years, developing countries, largely China and India have contributed the biggest increase in emissions, while those from the developed countries are growing slowly. The International Energy Agency (IEA) projects that more than two-thirds of the world energy will come from developing countries between 2003 and 2030. Since agriculture is a major contributor to the problem of climate change, it must also be a part of the solution. Long-term experiments indicated that carbon losses due to oxidation and erosion can be reversed with soil management practices that minimize soil disturbance and optimize plant yield through fertilization. When we use appropriate land management practices can result in a significant increase in the rate of carbon into the soil. Conservation agriculture, organic production, cover cropping and crop rotations can drastically increase the amount of carbon stored in soils.

GHG in agriculture:

The primary sources of greenhouse gases in agriculture are the production of nitrogen based fertilizers; the combustion of fossil fuels and waste management. Agriculture accounts for approximately 14% of total global anthropogenic emissions and is responsible for about 47% and 58% of total anthropogenic emissions of methane (CH_4) and nitrous oxide (N_2O), respectively. Each year, agriculture emits 10 to 12 per cent of the total estimated GHG emissions. Besides CH_4 from enteric fermentation (32%), N_2O emissions from soils due to fertilization constitute the largest sources (38%) from agriculture. Studies indicated that agricultural chemicals RMPs involve 0.86 kg C/kg N, 0.17 kg C/kg P_2O_5, 0.12 kg C/kg K_2O, 0.36 kg C/kg lime, 4.7 kg C/kg of herbicides, 5.2 kg C/kg of fungicides, 4.9 kg C/kg of insecticides, and 150 kg C/ha for pumping groundwater for irrigation. Agricultural soils represent a very large, and growing, global source of nitrous oxide. A major direct source of nitrous oxide from agricultural soils is that of synthetic fertilizer use. Crop production and livestock release GHG emissions into the air such as methane (CH_4) from cattle and wetlands, especially rice paddies, nitrous oxide (N_2O) from the use of fertilizers and carbon (CO_2) from deforestation and soil degradation. Ruminant animals are the largest contributor of methane. It is also produced from anaerobic (without oxygen) organic matter decomposition in wet soil. Animal manure also emits methane when decomposition occurs without oxygen. There are two primary sources of GHG emissions in agriculture: fossil energy used for the manufacture and use of production inputs, and emissions from soil that is affected by crop rotation and soil management. The U.S. agricultural production sector is a net emitter of greenhouse gas emissions (Fig. 1). The U.S. agricultural production sector contributes more greenhouse gas emissions from methane (CH_4) and nitrous oxide (N_2O) than from carbon dioxide (CO_2).Agricultural soil management is the single greatest contributor to greenhouse gas emissions from the U.S agricultural production.

Need of the day:

"Soil, and specifically sound soil management, is essential in our continued quest to increase the production of food, feed, fiber, and fuel while maintaining and improving the environment, and mitigating the effects of climate change. Being the essence of all terrestrial life and ecosystem services, we cannot take the soils for

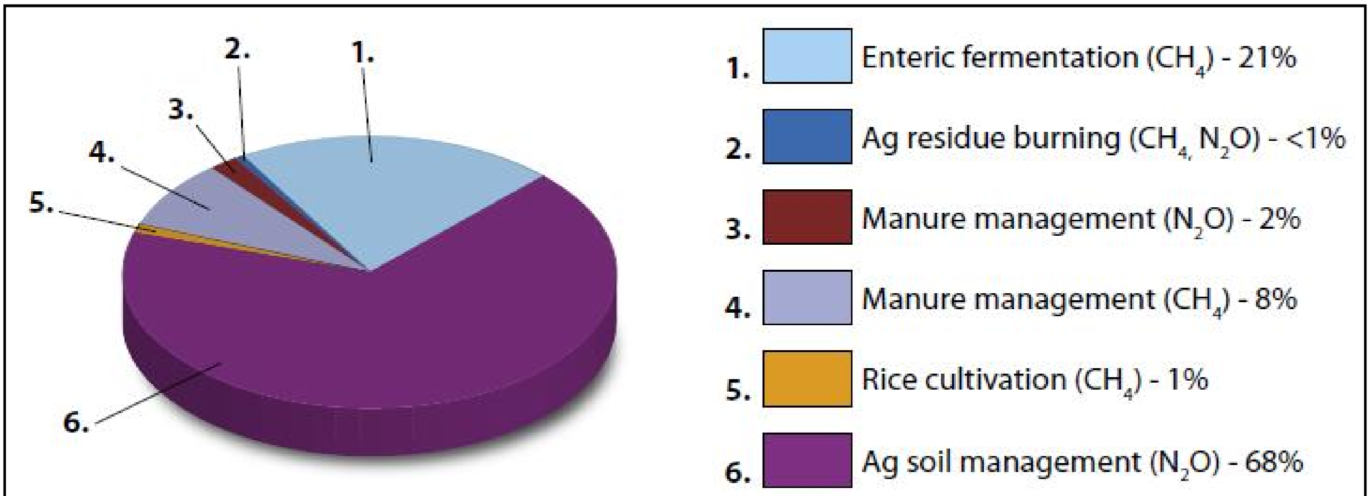

Fig. 1 : Agricultural greenhouse gas emission (Average 2001-2005, Source EPA 2007)

granted. Soil is the basis of survival for present and future generations" (Rattan Lal, The Ohio State University). Soil is a principal component of the global carbon (C) cycle where key interactions between biotic and abiotic components take place to regulate the flow of materials to and from the pedosphere, atmosphere and hydrosphere. Carbon dioxide is removed from the atmosphere and converted to organic carbon through the process of photosynthesis (Fig. 2). As organic carbon decomposes, it is converted back to carbon dioxide through the process of respiration. Soils contain about three times more C than vegetation and twice as much as that present in the atmosphere. Soils contain much more C (1500 Pg of C to 1 m depth and 2500 Pg of C to 2 m; 1 Pg = 1 × 10 g) than is contained in vegetation (650 Pg of C) and twice as much C as the atmosphere (750 Pg of C). Carbon in the form of organic matter is a key element to healthy soil. It is estimated that each tonne of soil organic matter releases 3.667 tonnes of CO_2, which is lost into the atmosphere. Similarly, the build-up of each tonne of soil organic matter removes 3.667 tonnes of CO_2 from the atmosphere. Soil organic matter of which Carbon is a major part holds a great proportion of nutrients, cations and trace elements that are of importance to plant growth. It prevents nutrient leaching and is integral to the organic acids that make minerals available to plants. It also buffers soil from strong changes in pH. Organic matter constitutes 1-8% of the weight most soils and nearly all the dry weight of organic soils such as peats. Because of the great weight of soils to the plant rooting depth at which carbon accumulates, the soils of the world store about 1600 Pg of carbon. This represents a carbon storage capacity that is twice that in

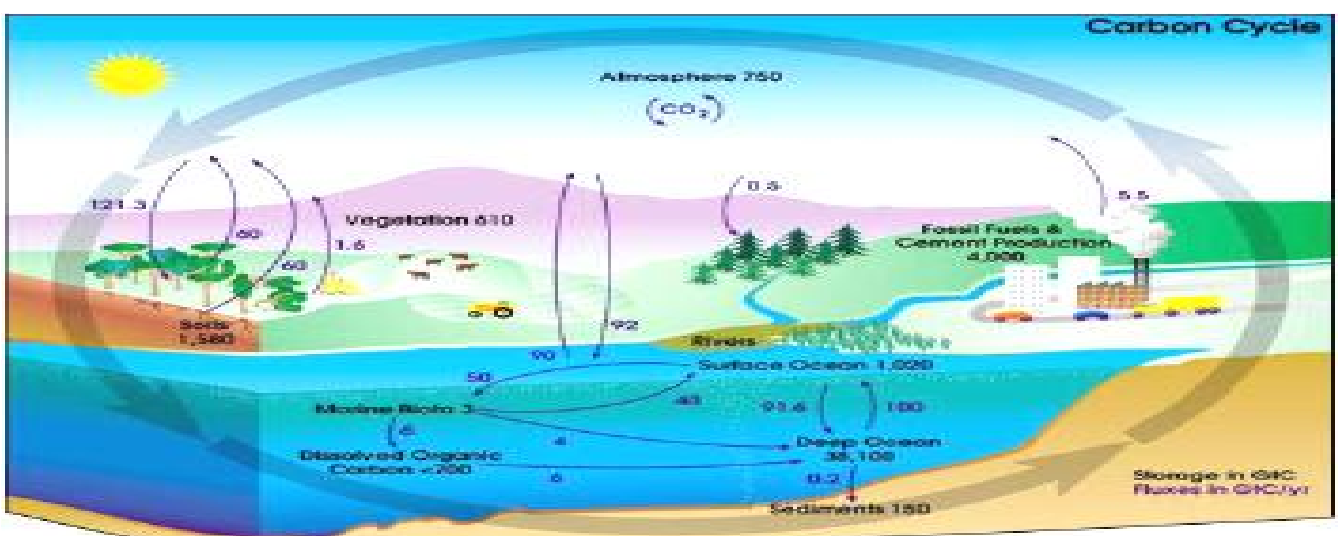

Fig. 2 : Carbon cycle

the atmosphere. In many parts of agricultural soil organic matter content is decreasing at an alarming rate which is categorized as poor soil. Grasslands contain approximately one fifth of the world's global carbon reserves; many of the world's grasslands have been degraded by overgrazing. The content of organic carbon in soils in most cases constitutes less than 5% of the mass of soil material and is generally concentrated mainly in the upper 20 to 40 cm (the so-called topsoil).Soils are the fundamental foundation of our food security, global economy and environmental quality. Soil quality is largely governed by soil organic matter (SOM) content, which is a dynamic pool and responds effectively to changes in soil management, primarily tillage and carbon inputs resulting from biomass production. Maintaining soil quality and soil health can reduce problems of land degradation, decreasing soil fertility and rapidly declining productivity In view of the rapidly expanding global population and, therefore, the pressure on the finite amount of land available for agricultural production, we must learn and communicate the importance of protecting our soils and natural resources. When used inappropriately, agricultural practices can cause serious soil losses. Excessive tillage often leads to unintended consequences of water, wind and tillage erosion. If the degradation of agricultural soils continues unchecked, the world may face serious problems in feeding a growing population. Soil loss through erosion, however, is only one consequence of the way agricultural soils are treated in mechanized agriculture. The loss of rain water that cannot infiltrate in the soils to replenish the ground water reserves might be the more serious long-term result of excessive tillage. Consequently, the way soil is cultivated must be drastically changed. Soil erosion and water loss are controlled not only by mechanical means but also by a living and stable soil structure that depends on the soil carbon pool and its quality.

Factors affecting organic carbon in soil:

– Soil management – e.g. cultivation enhances breakdown.

– Plant species/crop selection – continuous pasture builds organic carbon quicker than other rotations.

– Residue management – residue is a source of organic material and removing it means less inputs.

– Soil and nutrient losses – erosion events remove topsoil which contains the bulk of a soil's organic matter. This can take years of good management to replace.

– Plant production restraints (e.g. soil constraints, disease, poor management) - affect plant root growth, available water and nutrient absorption, restricting plant growth and biomass above and below the soil surface, reducing organic inputs.

– Climatic conditions, such as rainfall and temperature, are rate determining factors for organic matter decomposition.

– Agricultural practices and plant inputs influence both the quantity and quality of soil organic carbon, which directly impacts on soil productivity, soil resilience and soil sustainability

Approach for change:

Agriculture can help mitigate climate change by either reducing GHG emissions or by sequestering CO_2 from the atmosphere in the soil. The application of improved agricultural techniques reduces soil erosion and converts carbon losses into gains (Table 1). Practices such as stubble burning reduce the quantity of organic plant litter entering the soil. Ploughing, by aerating the soil, speeds up the rate of decomposition due to increased oxygen levels. Soil factors such as moisture and temperature also play a significant role. Overall, management practices that increase the input of organic matter to the soil and decrease the rate of decomposition are said to increase carbon sequestration. The essence of true soil conservation is

Table 1 : Agricultural practices for enhancing productivity and increasing the amount of carbon in soils

Traditional practices	Recommended
Plough till	Conservation till/ no till
Residue removal/ burning	Residue return as mulch
Summer fallow	Growing cover crop
Low off-farm input	Judicious use of fertilizers and integrated nutrient management
Regular fertilizer use	Soil- site specific management
No water control Fence-to fence cultivation	Water management/ conservation, irrigation, water table management
Fence-to fence cultivation	Conservation of marginal lands to nature conservation
Monoculture	Improved farming systems with several crop rotations
Land use along poverty lines and political boundaries	Integrated watershed management
Draining wetland	Restoring wetlands

carbon management. According to the IPCC, agriculture is responsible for 20 per cent of global emissions of greenhouse gases. This includes historical loss of carbon from cultivated land. If the degradation of agricultural soils continues unchecked, the world may face serious problems in feeding a growing population. Conservation agriculture includes a minimum 30% soil cover after planting to reduce soil erosion implies conformity with all three of its pillars: (i) minimum soil disturbance, (ii) diverse crop rotations and/or cover crops and (iii) continuous plant residue cover. Storing carbon in soils reduces atmospheric levels of carbon. The amount of carbon released from soils depends directly on the volume of soil disturbed during tillage operations. Therefore, the less soil is disturbed, the better the conservation of soil carbon. No-till (NT), zero till (ZT) and direct seeding (DS) are often used interchangeably to denote minimum soil disturbance and are associated with many environmental benefits. Conversely, intensive tillage with ploughing and powered tools like rotary cultivators leads to uncontrollable carbon loss in soils and to a degradation of soil fauna and biodiversity. Therefore, intensive agriculture that avoids inversion tillage and emphasizes carbon management with conservation agriculture has potential to offset some CO_2 emissions and may be a small but significant player in sequestering carbon and mitigating GHG emissions. Conservation agriculture also includes the integration of crop and livestock production and controlled traffic. These complimentary practices might be required to reduce energy inputs and avoid soil compaction. Emissions of other relevant greenhouse gases, such as methane, N_2O and NOx, can be reduced as well under conservation agricultural systems that avoid compaction, provide adequate water, manage nutrients and other inputs, and reduce fossil fuel use.

Conservation tillage and soil quality:

Soil quality refers to the package of chemical. Physical and biological factors which influence the soil tilth and ultimately crop yield. Conservation tillage (CT) systems are known to improve soil quality and have many advantages over conventional tillage system which are listed below:

– Presence of crop residue on the soil surface leads to a moderating effect on soil temperature, so the soil warms up slowly in the spring. The lower temperature reduces soil microbial activity and hence less organic matter loss by oxidation.

– The conservation of moisture can be very important in the regions of reduced rainfall, on soils low in water holding capacity and in years with below average rainfall. The mulch reduces evaporation and thus increases water retention in the soil.

– Conservation tillage result in less compaction of soil as compare to the conventional tillage that helps in better root penetration and free movement of air and water.

– Long-term implementation of conservation tillage practices also increase organic matter levels in the soil. Lower soil temperature and increased soil moisture and maximum root distribution by conservation tillage will facilitate greater biological activity in rhizosphere and thus enhanced nutrient availability in plants in assimilatory form.

– Conservation tillage helps to increase aggregate stability with increased organic matter content which resist surface crusting thus ameliorate a major constraint in dryland farming.

– It increases microbial activity which accelerates mineralization of nutrients. Hence enhanced availability of nutrients for plants uptake and better fertility status of the soil.

– Conservation tillage can reduce erosion by maintaining a greater trash cover which physically protect the soil, increase infiltration rate and decrease the speed of surface runoff.

– A major source of water loss in dryland is water use by weeds. Conventional tillage practice depletes soil moisture through evaporation and destroys crop residue. Whereas judicious application of herbicides in conjugation with conservation tillage can effectively control weeds and in addition conserves moisture and maintains crop residue cover

Benefits of conservation tillage:

– Intensive soil tillage accelerates organic matter mineralized contributing to the green house affect and accentuates global warming.

– Less leaching of soil nutrients or chemicals into the groundwater

– Less pollution of the water

– Less soil erosion

– Less fuel consumption in agriculture.

– Residue cover protects the soil physically, increases the infiltration and decreased the speed of volume of surface runoff.

– Reduced incidence and intensity of desertification

– Increased biodiversity both in the soil and the above-ground agricultural environment for nutrient

– Cycling

– Lower levels of soil erosion and sediments in rivers, dams and irrigation systems

– Greater carbon sequestration and retention in soils resulting in reduced emissions of GHGs.

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