

Soil carbon management

for sustainable food system

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The importance of soil organic carbon (SOC) in food, nutrition and climate security is undeniable. Increasing SOC stocks helps in mitigating the increasing atmospheric carbon dioxide (CO₂) concentration; besides improving the soil quality attributes such as stability of aggregates, soil fertility, and nutrient cycling etc. Use of manure, judicious fertilizer application, reduce/no tillage, utilization of crop residues, integrated nutrient management, application of biochar, use of cover crops, switch from single cropping to intercropping, introducing pulse crops in cropping systems, eliminating summer fallow periods are more or less effective for increasing C sequestration. Several government policies and programmes are being initiated to promote soil health and achieving sustainable development goals (SDGs), G20 commitments, land degradation neutrality, net zero emission and sustainable food systems.

Keywords: Crop residues, Land degradation, Soil carbon stock, Soil health

A sustainable food system is one that provides food and nutritional security for all ensuring the economic, social and environmental bases to generate food security and nutrition for future generation. Even sustainable agriculture and food security remain top priorities in the G20 agenda. The G20 members are committed to promoting sustainable agriculture, which has a significant role in achieving a wide range of sustainable development goals (SDGs), including food and nutrition security. The G20 economies are central players in the global food production and supply chain system as G20 nations produce nearly 80% of the world's cereals and account for a similar percentage of world agricultural exports.

Soil is directly/indirectly linked with SDGs and food systems. Sustainable management of soil health is critical for advancing several SDGs, especially those related to alleviating poverty, ending hunger, improving health, clean water, economic growth, climate action as well as achieving the sustainable food systems. Implementation of "4 per Thousand" initiative proposed at the Paris Climate Summit in 2015 highlights the importance of sequestering C in soil at the aspirational rate of 0.4%/year to 40 cm soil depth. However, globally one-third of planet's soils are degraded and soils have lost about 25–75% soil organic carbon (SOC), which is otherwise vital for sustainable soil quality and food production systems. On the other hand, agricultural

activities around the world contribute about ~25% to the annual emissions of greenhouse gases (GHGs).

Importance of carbon sequestration

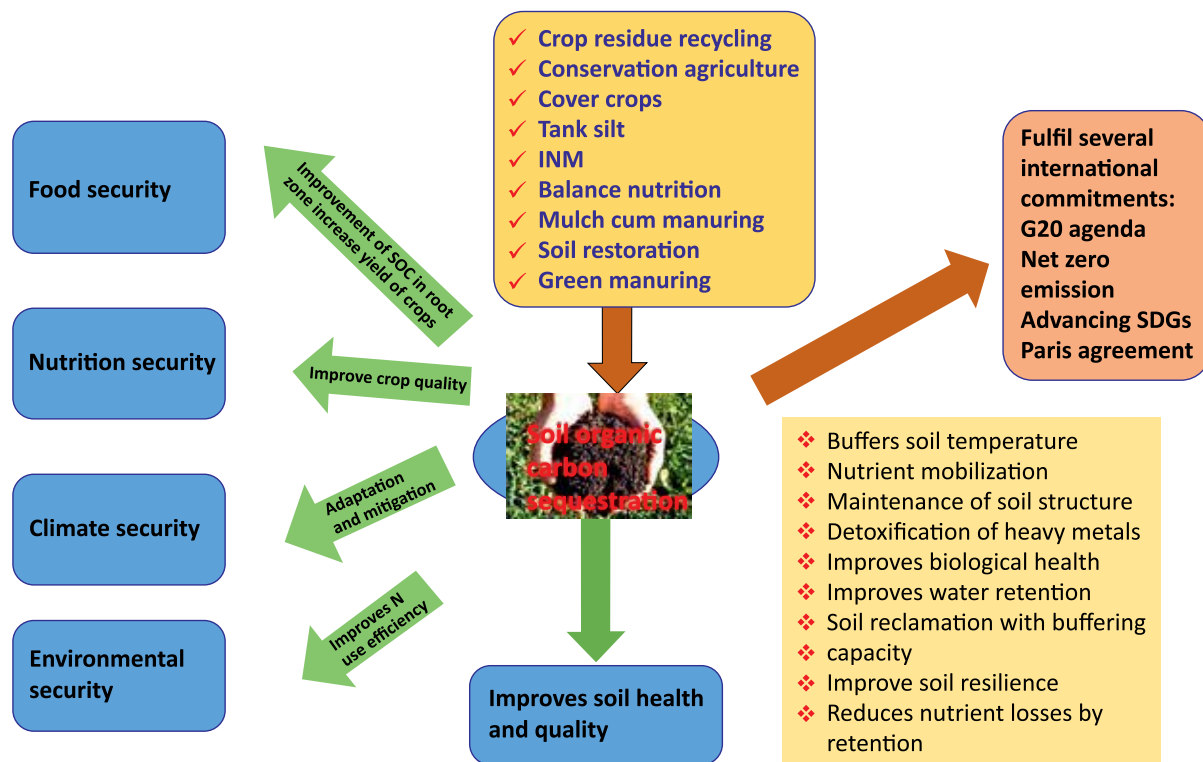
SOC is decreasing due to changes in land use such as the conversion of natural systems to food or bioenergy production systems. The losses of SOC have impacted crop productivity and other ecosystem services adversely. The degradation of one third of the world's soils has already released up to 78 gigatonnes (Gt) of carbon into the atmosphere, so further damage to soil carbon stocks through poor soil management would hamper efforts to contain a rise in global temperatures. As the climate changes, it is likely that more carbon will be lost to the atmosphere than be sequestered into the soil if business-as-usual agricultural practices continue, resulting in a soil carbon-climate feedback loop that could further accelerate climate change. Agricultural soil carbon sequestration has been considered as an important approach to mitigate GHG emission and global climate change. It is estimated that enhancing SOC sequestration by adopting improved agricultural and land management practices alone can remove 0.79 to 1.54 Gt C/yr from the atmosphere. Increased SOC sequestration on agricultural lands could enhance crop productivity while providing other agro-ecosystem benefits through their positive effects on soil water

storage, nutrient cycling and erosion control. Several reports say that crop yields can be increased by 20–70 kg/ha for wheat, 10–50 kg/ha for rice, and 30–300 kg/ha for maize with every 1 t/ha increase in SOC pool in the root zone through enhanced soil quality. Thus, we need a sustainable soil management (SSM) practices to improve soil carbon, soil health, crop productivity, reverse land degradation and enhance ecosystem services. Overall, increasing soil organic matter content can both improve soil fertility and reduce the impact of drought, improving adaptive capacity and making agriculture less vulnerable to climate change, while also sequestering carbon. Increased levels of soil carbon in farms improve soil fertility, hence improve food security, increase economic returns from carbon revenues, and create business development opportunities for farmers to diversify income-generating activities. Increasing SOC increased soil aggregation and aggregate stability, improve porosity and soil water retention. Increased macro and meso pores also increase soil water infiltration and decrease runoff. Managing soils in a sustainable way and rehabilitating degraded agricultural soils and grasslands can therefore help mitigate the impacts of the climate crisis and improve food security and nutrition. Sustainable management of SOC specifically in rainfed areas is critical to sustain the food security and soil fertility without impairing the environmental quality. Therefore, it is a need of the hour for the humankind to realize the mistakes done since decades and transform the current agriculture system to sustainable production system using present innovative technologies in order to ensure the global food security and environmental safety. India's Long-Term Low-

Carbon Development strategy articulates India's vision and action plan for achieving its NDC goals and the target of net zero emissions by 2070. Quantity, quality, and dynamics/turnover of SOC are critical for soil health. Maintenance of SOC pool at above the threshold/critical level is essential for soil structure and aggregation, water retention, nutrient retention and use efficiency, rhizospheric processes which influence elemental transformations and creation of disease-suppressive soils and gaseous emissions. Thus, management of soil health involves management of SOC pool. The SOC pool can be enhanced by technological options that create a positive C budget. Important among these are conservation agriculture (CA), integrated and diverse cropping/farming systems, use of organic amendments and those options that restore soil/ecosystem functions. Among numerous soil properties, it is pertinent to identify the site specific indicators of soil health. Thus, key soil properties (e.g. physical, chemical, biological, ecological) must be identified to develop an appropriate soil health index. Soil biological properties are among the most dynamic characteristics, which have a rapid response to land use, land use change and soil/crop/animal management.

Low cost technologies for enhancing SOC

Crop residue recycling: Soil organic matter (SOM) can be efficiently improved by the incorporation of crop residues such as stubbles, stem, leaves, husks, etc. which also play a decisive role in improving soil quality and sequestering SOC as well as addressing several environmental issues. Residue incorporation changes the labile pool of SOC. Retention of sun hemp residues on soil surface significantly enhanced the SOC by 0.92%



Multiple ecosystem services related to increased soil organic carbon storage

compared to no residue incorporation. Alternatively, crop residues can also be used to make a biochar (by-product of the pyrolysis: bio-waste is heated at 400–600°C temperature in absence of oxygen). Agricultural wastes such as poultry litter, waste wood, manure, plant material, bagasse etc. are used in making biochar, which then becomes a great source of carbon.

In India, about 500 Mt of crop residues is produced every year as per the report of the Ministry of New and Renewable Energy. Domestic sector consumes a big share and also an industrial sector. Apart from those, a huge portion of residues is left in the field. In some places, it is also burnt in the field itself. On-site burning of crop residues produces huge amount of greenhouse gases (GHGs) i.e., majorly methane (CH_4) and nitrous oxide (N_2O) that harms the soil quality by depleting SOC and environment.

Conservation agriculture: Continuous cultivation of agricultural lands using similar tillage implements adversely affect the crop productivity specifically in semi-arid regions. Conservation agriculture (CA) involved 3 basic principles i.e. minimum soil disturbance, diversified cropping systems and crop residue retention may hold the key to address the C losses. Also, CA has been widely identified as an effective practice to increase soil aggregation and C sequestration compared to conventional tillage (CT). Many studies revealed that CA system has significantly enhanced the overall concentration of total organic carbon (TOC) at the upper two soil depth (0–5 and 5–10 cm).

Cover crops: Cover crops are well known for atmospheric-nitrogen (N_2) fixation that improves N recycling in the soil-plant system. Integrating cover crop into crop rotations highly benefits the soil by enhancing the soil C sequestration and organic matter. Incorporation of the roots and stubbles of leguminous cover crops grown for short periods helps in maintaining the high levels of SOM in some soils. Incorporation of short duration legume cover crops at the stage of flowering would enhance the soil organic matter that ultimately improves the nutrient cycling besides protecting the soil from erosion. Additionally,



Cover crops with horsegram

soil biological factors such as arbuscular mycorrhizal fungi (AMF) and microbial population and their activity would be efficiently promoted by cover crop, which have a large effect on soil aggregation.

Integrated nutrient management: Integrated nutrient management (INM), whereby both organic manures/amendments and inorganic chemical fertilizers are combined used is an efficient technique for attaining sustainability in crop production. INM is one of the best strategies that would help in restoring the depleted SOC while improving the degraded soils and crop yields.

Tank silt: Tank silt is a top soil eroded with high intensive rains which contains fine soil particles (silt + clay) and organic materials that accumulated in farm or village tanks. It is a rich source of nutrients and SOC. Carbon and nutrient content of tank silt ranged as: organic carbon (%) from 0.4–2.0; mineral nitrogen (mg/kg) from 200–1400; available P (mg/kg) from 8.0–35.2; K (mg/kg) from 400–600; S (mg/kg) from 12–50; Zn (mg/kg) from 0.7–2.2; B (mg/kg) from 0.3 ₹ 1.0. Being rich in SOC and other nutrients, its application particularly in rainfed agriculture can enhance water holding capacity (WHC). Tank silt application improved the organic carbon in the red soil from 0.30 to 0.38%.

Balanced nutrition: Balanced fertilization/nutrition is the supplement of plant nutrients in the right proportion, in the right method and at the right time for a specific crop and agro-climatic situation, which improve soil health and nutrient use efficiency. Government of India



Zero till pigeonpea and cotton in red soil



Residue mulching



Mulching in ginger with *Schima wallichii*

launched Soil Health Card (SHC) in 2015 to ensure the farmland's nutrient status and decide the recommended dose of fertilizers to reduce the burden on agriculture soils. Implementation of site specific nutrient management (SSNM) package (tested the individual fields for nutrient deficiencies and recommended the particular nutrient requirement of the crop) in 8 clusters of Telangana and Andhra Pradesh resulted in increased yield by 25% in major rainfed crops in comparison with farmers' practices. Combining these techniques with carbon biomass addition in the form of manures, crop residues, or with any other organic amendments would be effective in enhancing the SOC status of the soils.

Soil restoration: Loss of SOC pool driven by erosion, acidification, salinization, elemental imbalance etc. through physicochemical, biological and ecological degradation leading to decline in soil quality. This can only be minimized through the adoption of recommended management practices. Enhancing the SOC pool above the critical level (10 to 15 g/kg) is highly required to set-in-motion the restorative trends. India joined the global commitment "Bonn Challenge" and pledge a total of 21 Mha to be restored by 2030 (13 Mha by 2020 and an additional 8 Mha by 2030). This mainly focuses on restoring land productivity and ecosystem services of 26 million hectares of most degraded and vulnerable land by adopting a landscape restoration approach.

Mulch cum manuring: Mulching has been considered as an effective practice for conserving soil health specifically under rainfed condition. In rainfed regions, soil moisture protection and reducing the C losses is a great challenge. Crop residues of rainfed crops such as cotton, castor, pigeon pea, maize, etc., left on the surface, can be utilized as a mulch-cum-manure, that contributes to improve crop productivity and soil fertility. Decomposition of mulches leads to addition of nutrients and organic carbon to the soil. Mulches reduce evaporation losses, insulate soil against extreme heat and cold by moderating soil temperature, reduce soil compaction and control the wind and, water erosion.

Green manuring: Incorporation of green manure biomass into the soil help in the accumulation of organic matter and recycling of plant available nutrients. Especially leguminous green manures recognized to be a promising nutrient source that improve soil nutrient accumulation. Because of its lowest C: N ratio than cereal crops, it promotes a faster mineralization of nitrogen which significantly increases enzymatic activities (urease and dehydrogenase) in the soil. Green manuring/green leaf manuring improves soil biological health and enhances soil moisture storage, which helps in coping with intermittent droughts.

Growing short duration legume crops such as horsegram, greengram, cowpea etc., and incorporating into the soil at flowering stage would add huge amount



Green manuring with sunhemp



Green manuring in rice

of organic matter to the soil that helps in increasing crop yields. Green manure crops such as greengram, cowpea, and *sesbania* used for *in situ* manuring for 5 consecutive years helped in enhancing SOC stocks significantly compared to non-green manured soils. Forest Tree crops such as *Gliricidia* sps., *Pongamia pinnata*, *Cassia fistula*, *Calotropis gigantea*, *Delonix regia*, and *Azadirachta indica* etc., can be utilized for green leaf manuring.

Composting: Composts are bulky in nature; for example, farmyard manure, vermicompost, kitchen waste composts, sheep manure, poultry litter, bio-enriched composts, market waste compost, and night soils (urban composts). Organic manures substantially increase the SOC content that proliferates the soil microbial activity ultimately results in retaining soil moisture and nutrients besides imparting drought tolerance during dry spells.

Programmes and policies

Government of India has initiated several policies and programmes for promoting the buildup of SOC,



Composting

which facilitated the farmers to improve their land fertility status through some innovative technologies. National Mission for Sustainable Agriculture (NMSA), Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), Soil Health Card (SHC), National Policy for Management of Crop Residue (NPMCR), Customized Fertilizers, National Biogas and Manure Management Programme (NBMMP), neem Coated Urea Scheme, Rehabilitation of Degraded Lands Targets and Land Degradation Neutrality, Nano Fertilizers, India's commitment for Net Zero Emissions are some of the steps for improving soil health.

SUMMARY

“If we feed the soil, it will feed us,” and only productive soil can support a prosperous people. Thus, maintaining soil health is essential to human health, ecosystem functions and nature conservancy. However, impact of soil health goes beyond human health, it also has a profound impact on atmosphere, biosphere and the hydrosphere. The environmental consequence of soil health is also determined by the SOC pool, its dynamics and the turnover time, and that of climate change by both SOC and soil inorganic carbon dynamics. Creating awareness among farmers regarding the soil fertility depletion, its correction and the importance of SOC in crop production, development of rehabilitation policy programmes at micro-level to promote soil management practices that are a net sink for atmospheric C and encouragement of integrated and holistic land management practices are required to sustain SOC sequestration rates.

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- Management System for Post-Graduate Education (MSPGE) enabling academic and e-learning modules while also being a repository of academic records
- E-Samvad, an online interface of the Council to answer citizens queries.
- KRISHI –A knowledge repository portal of digital information pertaining to research experiments, outputs, publications, etc.
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