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Assessment of Green Manuring Crops for Improving Soil Carbon Stocks: A Review

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Abstract

Green manuring is a simple and sustainable farming practice that helps improve soil fertility and increase soil organic carbon (SOC). Soil organic carbon is important for maintaining soil health, improving soil structure, increasing water-holding capacity, and supporting better crop growth. When green manure crops are grown and incorporated into the soil, they add organic matter that increases carbon storage in the soil. Green manuring also encourages the growth of beneficial soil microorganisms, improves soil aggregation, and reduces soil erosion. As a result, more carbon is stored in the soil and less is released into the atmosphere. Studies conducted in different parts of the world and in India have shown that green manure crops can effectively increase soil carbon levels and improve soil quality. Among the commonly used crops, Dhaincha (*Sesbania aculeata*), Sunhemp (*Crotalaria juncea*), and Greengram (*Vigna radiata*) are particularly effective in enhancing soil carbon storage. Therefore, green manuring is an environmentally friendly practice that not only improves crop productivity and soil health but also helps reduce the impacts of climate change by storing carbon in the soil.

Keywords: Green manuring, Soil organic carbon, Carbon sequestration, Soil health, Climate-smart agriculture, Cover crops

Introduction

Soil Carbon Sequestration through Green Manuring

Soil organic carbon (SOC) is an important part of soil that helps maintain soil fertility, improves soil structure, increases water-holding capacity, and supports nutrient cycling. It also plays a significant role in reducing climate change by storing carbon in the soil. As concerns about global warming increase, enhancing carbon storage in agricultural soils has become an important strategy for reducing atmospheric carbon dioxide (CO₂). Green manuring is one of the most effective and eco-friendly methods for increasing soil organic carbon. It involves growing crops specifically for incorporation into the soil while they are still green. These crops add organic matter to the soil, improve nutrient availability, stimulate beneficial microbial activity, and reduce soil degradation. Studies conducted in India and around the world have shown that green manuring can increase soil carbon storage, improve soil health, and enhance crop productivity.

Green manure crops are generally grouped into three categories: leguminous green manure crops, non-leguminous green manure crops, and green leaf manure crops. Leguminous crops such as dhaincha (*Sesbania aculeata*), sunhemp (*Crotalaria juncea*), greengram (*Vigna radiata*), blackgram (*Vigna mungo*), and cowpea (*Vigna unguiculata*) are widely used because they can fix atmospheric nitrogen through their association with *Rhizobium* bacteria. These crops enrich the soil with nitrogen and add large amounts of biomass, which increases soil organic matter and carbon content. Their incorporation improves soil structure, microbial activity, and overall soil fertility.

Non-leguminous green manure crops, including mustard, karanj (*Pongamia pinnata*), sorghum, and maize, mainly contribute organic matter to the soil. Although they do not fix nitrogen, they improve soil aeration, moisture retention, and soil structure while suppressing weed growth. The decomposition of their biomass adds carbon to the soil and supports long-term soil productivity.

Green leaf manuring involves incorporating leaves and tender branches collected from trees and shrubs such as *Gliricidia sepium*, *Pongamia pinnata* (Karanj), *Leucaena leucocephala* (Subabul), and *Sesbania grandiflora* (Agathi). These materials decompose quickly after incorporation, releasing nutrients and organic compounds into the soil. Green leaf manures improve nutrient recycling, increase soil organic carbon, stimulate microbial activity, and enhance soil fertility. Due to their rapid decomposition and easy availability, they are an effective source of organic matter for maintaining soil health and promoting sustainable agricultural production.

Mechanisms of Soil Carbon Stock Enhancement through Green Manuring: Green manuring contributes to soil carbon sequestration through several interconnected mechanisms.

Biomass Incorporation: Green manure crops add a large amount of plant material, such as leaves, stems, and roots, to the soil. When these plant parts decompose, they increase soil organic matter and add carbon to the soil. Root exudates

also provide food for soil microorganisms, helping to build up soil carbon.

Enhancement of Microbial Activity: Soil microorganisms break down green manure residues and convert them into stable forms of soil organic carbon. During this process, organic matter is transformed into humus, which can remain in the soil for a long time. This increases microbial biomass and helps store more carbon in the soil.

Improvement of Soil Aggregation

Green manuring helps soil particles stick together and form stable aggregates. Microorganisms and fungal hyphae produce substances that bind soil particles together. These aggregates protect organic matter from rapid decomposition, helping carbon remain stored in the soil for a longer period.

Reduction of Soil Erosion

Green manure crops cover the soil surface and develop strong root systems that reduce runoff and soil loss. This protection prevents the removal of carbon-rich topsoil and helps maintain soil structure. As a result, more carbon is retained in the soil and soil health is improved.

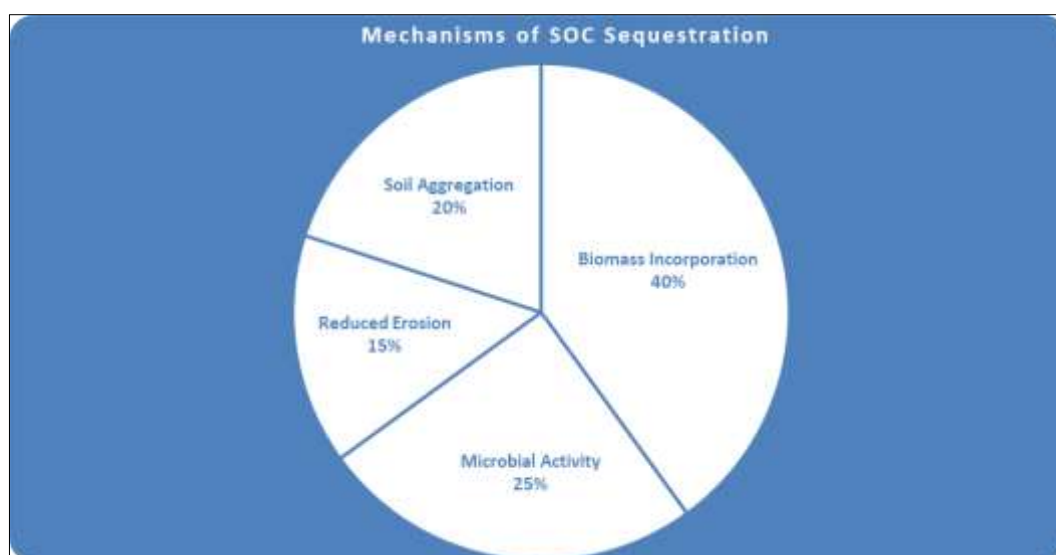


Fig 1: Mechanism of SOC Sequestration

Global Evidence on Carbon Sequestration through Green Manuring

Numerous studies worldwide have demonstrated the effectiveness of green manuring in enhancing soil carbon stocks.

Research conducted across different regions of the world has consistently demonstrated the positive impact of green manuring on soil carbon sequestration and overall soil health. A study published in *Soil & Tillage Research* (2022) in the Eastern Himalayan region of India reported that the combined application of green manuring and crop residue management significantly increased soil organic carbon stocks, improved soil aggregate stability, and enhanced overall cropping system productivity. The incorporation of organic residues contributed to better soil structure and long-term soil fertility, thereby supporting sustainable agricultural production.

Similarly, a global meta-analysis published in the *Journal of Cleaner Production* (2026) revealed that the incorporation of green manure crops substantially increased soil organic

carbon (SOC) stocks across diverse agroecosystems. The study further demonstrated that green manuring reduced the agricultural carbon footprint by enhancing carbon sequestration in soils and improving nutrient-use efficiency. These benefits contribute to the long-term sustainability and environmental resilience of farming systems worldwide.

Furthermore, a mechanistic review published through *ScienceDirect* (2026) emphasized the importance of diversified planting systems, cover crop integration, and green manure incorporation in enhancing soil carbon sequestration. The review explained that these practices promote carbon accumulation through biological processes such as increased biomass production and microbial activity, as well as physical mechanisms including improved soil aggregation and protection of organic matter within soil aggregates. Together, these mechanisms contribute to the stabilization and long-term storage of carbon in agricultural soils.

Indian Evidence on Green Manuring and Soil Carbon Stock

India has generated substantial evidence regarding the effectiveness of green manuring under diverse agro-climatic conditions.

Long-Term Fertilization Study (ICAR-IARI, New Delhi, 2021)

Long-term agricultural experiments conducted by the Indian Agricultural Research Institute (ICAR-IARI) in New Delhi

revealed significant increases in critical soil parameters through targeted green manuring. The application of these crops led to a measurable expansion in mineralizable carbon pools and enhanced aggregate-associated carbon throughout the soil profile. Ultimately, these structural changes resulted in a substantial rise in total soil organic carbon (SOC) stocks. Among the evaluated species, green manure crops such as *Sesbania* (dhaincha) and sunhemp (*Crotalaria juncea*) proved particularly effective at accumulating and stabilizing these carbon fractions over extended periods.

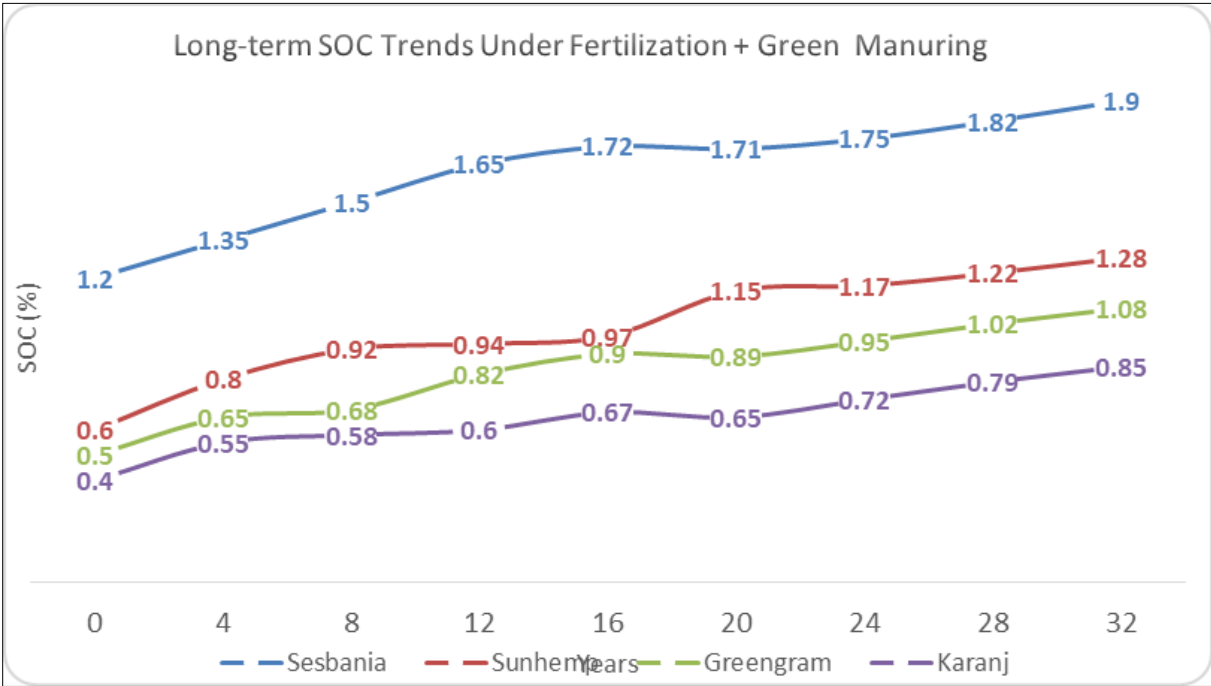


Fig 2: Long-term Soil Organic Carbon (SOC) Trends Under Fertilization + Green Manuring

Climate-Resilient Agriculture Study (ICAR-IARI, Pusa, Bihar, 2024)

A 2024 field assessment evaluating climate-resilient farming practices at ICAR-IARI in Pusa, Bihar, demonstrated that integrating green manuring into local crop rotations yields multi-faceted environmental benefits. The practices consistently improved overall crop productivity while boosting core soil health indicators, such as microbial biomass and nutrient availability. Furthermore, the inclusion of green manures markedly enhanced the climate resilience of regional farming systems, allowing crops to sustain steady growth even under severe environmental stress conditions like drought and shifting precipitation patterns.

Rice–Greengram Cropping System (ICAR-NRRI, Cuttack, 2023)

Research led by the National Rice Research Institute (ICAR-NRRI) in Cuttack highlighted the distinct structural and environmental advantages of utilizing a rice–greengram (*Vigna radiata*) cropping system. This sustainable rotation recorded a high Soil Quality Index (SQI) score of 2.26, reflecting major improvements across a variety of soil physical and biological properties. By maintaining active root systems and regular biomass return, the rice–greengram system enhanced the field's overall carbon sequestration potential, establishing an efficient pathway for long-term carbon storage in lowland agricultural soils

Comparative Performance of Green Manuring Crops in Carbon Sequestration

Table 1: Carbon Sequestration Potential of Major Green Manuring Crops in India

Crop (Scientific Name)	Common Use	Soil Type	Carbon Sequestration Effect	Quantitative Impact
<i>Sesbania aculeata</i> (Dhaincha)	Rice-based systems	Inceptisols	High biomass incorporation and SOC improvement	SOC increase of 0.35–0.40 Mg C ha ⁻¹ yr ⁻¹
<i>Crotalaria juncea</i> (Sunhemp)	Rainfed systems	Vertisols	Improved macro-aggregate stability	SOC increase of 0.28–0.32 Mg C ha ⁻¹ yr ⁻¹
<i>Vigna radiata</i> (Greengram)	Rice–greengram systems	Mollisols	Improved soil quality index	SOC increase of 0.30 Mg C ha ⁻¹ yr ⁻¹
<i>Pongamia pinnata</i> (Karanj)	Agroforestry systems	Alfisols	Increased mineralizable carbon pools	SOC increase of 0.25 Mg C ha ⁻¹ yr ⁻¹

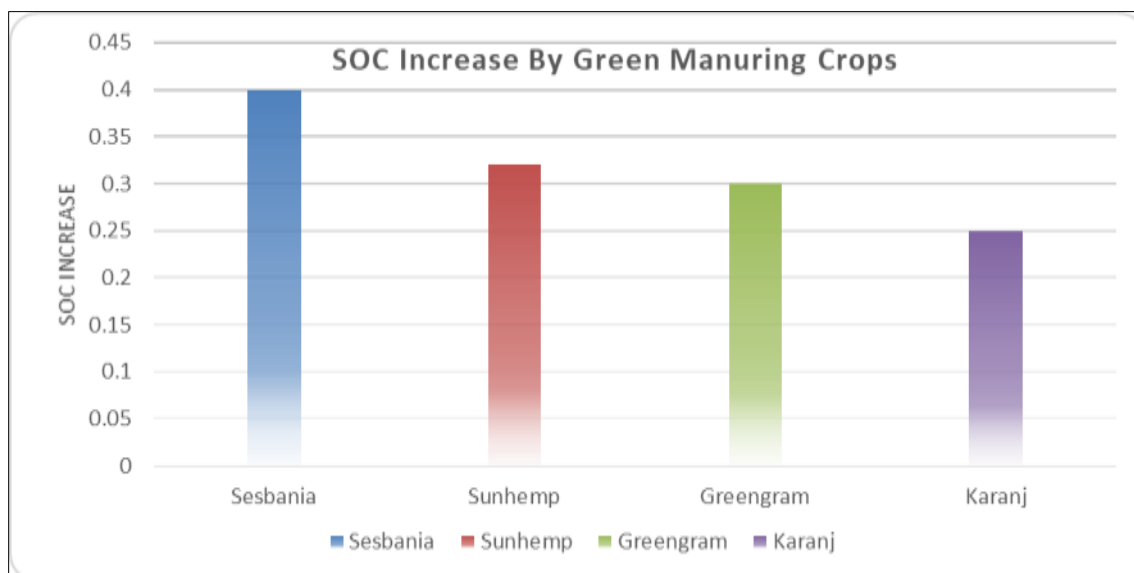


Fig 3: "SOC Increase By Green Manuring Crops"

Challenges and Limitations

Despite its benefits, green manuring faces several constraints:

- Need for location-specific crop selection
- Competition for land and water resources
- Short-term yield trade-offs
- Limited awareness among farmers
- Inadequate long-term monitoring of carbon sequestration
- Lack of standardized carbon measurement protocols

Policy Implications

To maximize the benefits of green manuring, the following policy interventions are recommended:

1. Integration with the National Mission for Sustainable Agriculture (NMSA).
2. Inclusion of green manuring practices in the Soil Health Card Scheme.
3. Carbon-credit incentives for farmers adopting green manuring.
4. Promotion through agricultural extension services.
5. Support for long-term carbon monitoring and research.

Future Research Needs

Future studies should focus on:

- Long-term quantification of SOC sequestration rates.
- Crop-specific carbon sequestration efficiencies.
- Interactions between green manuring and conservation agriculture.
- Carbon stabilization mechanisms in different soil types.
- Economic assessment of green manuring practices.
- Development of region-specific recommendations.

Conclusion

Green manuring is an eco-friendly farming practice that helps improve soil fertility and increase the amount of carbon stored in the soil. When green manure crops are grown and mixed into the soil, they add organic matter, which improves soil health and increases soil organic carbon (SOC). These crops also encourage the growth of beneficial microorganisms, improve soil structure, and reduce soil erosion. As a result, more carbon is stored in the soil and

soil productivity is improved. Studies from India and other countries have shown that green manuring is an effective way to increase soil carbon levels and support sustainable agriculture. Crops such as Dhaincha (*Sesbania aculeata*) and Sunhemp (*Crotalaria juncea*) are especially useful because they produce large amounts of biomass and improve soil fertility. Therefore, green manuring is a simple and effective practice for improving soil health, increasing crop production, and helping to reduce the effects of climate change.

References

1. Green manuring and crop residue management: effect on soil organic carbon stock, aggregation, and system productivity in the foothills of Eastern Himalaya (India). *Soil Tillage Res.* 2022.
2. Green manure reduces global agricultural carbon footprint by enhancing soil organic carbon stocks: evidence from global meta-analysis and machine learning assessment. *J Clean Prod.* 2026.
3. Mechanisms underlying soil carbon sequestration and enhancement strategies via diversified planting and green manure integration. *Sci Direct Rev.* 2026.
4. ICAR–Indian Agricultural Research Institute. Long-term effect of fertilization and manuring on soil aggregate carbon mineralization. New Delhi: ICAR–Indian Agricultural Research Institute; 2021.
5. ICAR–IARI Regional Station, Pusa. Green manuring for optimal yield and soil health management under changing climate. Pusa, Bihar: ICAR–IARI Regional Station; 2024.
6. ICAR–National Rice Research Institute. Soil quality as affected by resource conserving technologies in rice–green gram cropping system in Eastern India. Cuttack: ICAR–National Rice Research Institute; 2023.