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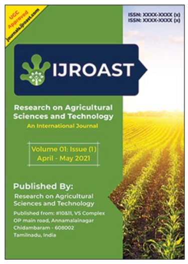

Effect of different agronomic management practices to increase carbon sequestration in rice based cropping system

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The dramatic increase in atmospheric CO_2 concentrations and the loss of soil organic carbon (SOC) have sparked interest in using soil as a carbon sink [1]. Soil carbon has been lost due to poor soil and crop management techniques. Around 1417 Pg of soil carbon is stored in the first metre of soil depth around the world, while 456 Pg is stored in above-ground vegetation and decaying organic matter. Healthy soils will aid in the fight against global warming since soils with high organic matter have a higher CO_2 sequestration potential. Agriculture accounts for roughly 25-30% of total global GHG emissions in the form of CO_2, NO_2, and CH_4. Rice-wheat, an intense and dominant cropping system that covers 24 million hectares of tilth worldwide, contributes greatly to global warming potential. Adapting suitable tillage procedures, using quiet crop rotations to build soil organic matter, and adding organic fertilisers are all examples of agronomic management methods that can help with soil carbon sequestration [2]. As a result, the goal of this study is to identify the most effective management techniques for C sequestration in the rice-wheat cropping system by increasing SOC.

Introduction

Carbon is ne of the universe's most important elements, and it can be found almost everywhere on the planet: in the air, the ocean, the soil, and the rock. The majority of active carbon in the environment is found in soil. Plants absorb carbon from the air and convert it to plant structure, some of which ends up as plant residue in the soil [3]. With proper management, soil may sequester carbon from the atmosphere. The utilisation fullness soil as a carbon sink and drawdown solution appears to be vital, based on global assessments of historic carbon stocks and projections of rising emissions. Because agricultural production systems cover more than a third of the world's arable land, finding techniques to prolong soil carbon in agricultural production systems will be a critical component of utilising the soil as a sink. Soil carbon has been lost due to poor soil and crop management techniques [4]. The use of diverse agronomic management strategies is beneficial to carbon sequestration. Integrated nutrient management systems, for example, have gained relevance not only in increasing agricultural yields but also in maintaining soil health and increasing carbon sequestration [5]. Carbon sequestration is the process of storing atmospheric CO2 in the soil for a lengthy period of time in order to prevent it from being released into the atmosphere. Carbon sequestration in agricultural soils may be a complicated process influenced by environmental conditions as well as farming practises. Heating could be a factor in global climate change, which is anticipated to have major consequences for the world. Such an occurrence occurs in close proximity to gas emissions. Carbon sequestration may be the most promising strategy for reducing GHS emissions while preserving carbon in soil strata's permanent pools. Carbon is a crucial element in soil quality because it controls nutrient recycling, soil structure, water availability, and other key soil qualities. Maintaining SOC is critical for cycling plant nutrients and enhancing the physical, chemical, and biological aspects of the soil. Because of its link to crop productivity, SOC is a critical indicator of soil quality. A decrease in SOC reduces the structural stability of the soil. Restoration of SOC on arable lands could also act as a CO_2 sink in the atmosphere. In general, fertilising with both organic and inorganic fertilisers raises SOC levels. Rice is a basic food for about half of the world's population, in most South Asian countries that cater to food demands, rice-based cropping

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systems are the most common agricultural production systems. The introduction of high-yielding varieties and, as a result, the adoption of improved cultural practises has deteriorated the soil structure in order to increase crop output. Yield decreases or stagnation are thought to be caused by deterioration of soil qualities, as well as poor crop and nutrient management and unfavourable changes in meteorological conditions. Many Indian soils have a soil organic carbon (SOC) level of less than 10 g kg^{-1}, which can be ascribed to excessive tillage, fertiliser imbalances, little or no crop waste return to the soil, and soil degradation. There are approximately 192 million hectares in the world. And it is currently farmed on approximately 192 million hectares globally. SOC is a crucial soil property that is sometimes referred to as the "backbone" of soil quality. Adoption of the INM strategy for rice production employing particular on-farm resources could improve soil quality and aid in the sequestration of different fractions of SOC. Incorporating pulses into a rice-based cropping system enhanced the productivity of the following crop while also increasing carbon storage, according to the report. a million hectares around the world.

HOW IS CARBON SEQUESTERED IN SOILS?

Because the amount of the stable pool is usually constant, soil carbon is effectively accelerated inside the labile and sluggish pools by increasing the net balance of carbon entering the soil each year compared to what is lost. In four ways, agricultural managers can have a significant impact on this dynamic:

• Improving the physical safety of soil carbon in aggregates by reducing soil disturbance (i.e. tillage).
• Increasing the amount and fineness of soil plant and animal inputs.
• Increasing the diversity and richness of soil microbes.
• Maintaining a year-round dwelling plant cowl on soils.

Using these methods can result in a rapid increase in soil carbon, which can be very effective in lowering CO_2 levels in the atmosphere. The scope and long-term viability of soil-based carbon sequestration are now being researched and debated. The following parts go over some of the hotly debated topics in further detail.

Agronomic practices helpful in SOC sequestration

Tillage

Tillage is defined as the physical disturbance of upper soil layers for the purpose of preparing the soil bed, incorporating fertilisers, agricultural leftovers, and weed control. Tillage methods differ around the world depending on the soil, climate, crop management, and technological availability. The relationship between tillage, soil structure, and soil organic matter dynamics is critical for agricultural soils' ability to sequester carbon. The impacts of tillage on soil carbon dynamics are complex and vary. Human cultivation has resulted in significant losses in natural SOC, with estimates ranging from 60 (temperate regions) to 75 percent of the original SOC. No tillage improves the soundness and number of soil aggregates, whereas conventional tillage degrades soil structure and accelerates soil organic matter decomposition. Soil carbon levels have dropped from 30 to 50 percent globally to as low as 20 percent as a result of traditional tillage methods. Ploughing is the primary cause of SOC oxidation and CO_2 emissions into the atmosphere. Compared to conventional tillage, conservation tillage techniques preserve more crop residues on the soil surface and have a higher SOC content in the surface layer. Conservation tillage is expected to trap 25 Gt C globally over the next 50 years, which could help with atmospheric carbon stabilisation. All of this suggests that using conservation tillage practises can assist reduce CO2 emissions into the atmosphere while also supporting carbon storage in the soil.

Crop rotation

Crop rotations, climates, soils, and crop-related management methods all have an impact on carbon sequestration. SOM is depleted in intensive cropping systems, but balanced fertilisation with NPK, application of organic amendments, and similarly application of crop residues can increase carbon sequestration levels to 5-10 Mg ha^{-1} per year because these amendments contain 10.7-18 percent carbon, which may even be beneficial in carbon sequestration. Different legume crops, such as peas, lentils, alfalfa, chickpea, sesbania, and others, can serve as nitrogen substitutes. Crop rotations, particularly the use of legume cover crops, which contain carbon molecules that are presumably more resistant to microbial degradation, can help to stabilise soil carbon. Cropping systems as a means of reducing CO_2 emissions from agriculture Cover cropping, ratoon cropping, and companion cropping are all examples of cropping systems that can help with carbon sequestration. Row intercropping, strip intercropping, mixed cropping, and relay intercropping are all examples of intercropping that can boost income and soil fertility. With economic concerns in mind, selecting appropriate crop rotations in accordance with soil and environmental conditions can aid with carbon sequestration, which not only improves soil fertility but also reduces CO_2 emissions into the atmosphere and increase farmer's income.

Residues management

Crop residues are the vegetative remains of crop plants that are left to perish in agricultural fields after the crop has been harvested. Crop leftovers are produced in large quantities around the world, and if 15% of that amount is applied to the soil, it can boost the C content of the soil, because one tonne of grain residue, for example, comprises 12-20 kilogramme N, 1-4 kg P, 7-30 kg K, 4-8 kg Ca, and 2-4 kg Mg. Crop residues play a critical role in the control of SOC and the improvement of soil quality. Mulching improves soil moisture, lowers soil erosion, and reduces carbon loss from the soil and crop leftovers, which are absorbed into the soil to strengthen the soil organic matter. As a result of enhanced carbon inputs and reduced soil disturbance, an instantaneous seedling mulch-based cropping strategy enhances soil organic matter. Within the upper 0-5 cm of soil depth, mulch can improve soil organic matter (SOM) and carbon sequestration. It enhances the physical and chemical features of soils, and it has the potential to boost carbon sequestration in agricultural soils by 8-16 Mg ha^{-1} each year.

Mulch and crop leftovers can promote soil microbial activity, reduce heat stress, aid in water storage, and improve soil organic carbon.

Use of improved crop varieties

Soil organic carbon can be boosted by selecting improved cultivars of various crops that improve both above and below ground biomass. Crops with extensive root systems have the ability to increase SOC levels in soils. Soil carbon storage can match anthropogenic emissions for the next 40 years through improving root growth in agricultural crops. All of this suggests that using superior crop types with deeper root systems and higher yields can boost both yields and soil fertility.

Nutrient management

Increased crop output and improved SOC sequestration require better nutrient management strategies. Organic nutrient addition can accumulate 18-62 percent more SOC than chemical fertiliser addition of nitrogen, phosphorus, and potassium (NPK). When compared to control plots, SOC concentration within the 0-60 cm profile was greater during FYM application followed by NPK application. Organic and inorganic fertiliser blends can help increase SOC accumulation and crop yield. When comparing farmer's practises of no manure and fertiliser application to chicken litter and^{-1} cattle manure application, high SOC content was discovered. Similarly, when manure or straw was added together with NP fertiliser, SOC content increased by 0.30 Mg ha^{-1} yr^{-1}. [6] According to a 19-year study, using NPK and organic amendments might improve SOC by 24 percent. Under inorganic and organic fertiliser applications, soil C sequestration rates range from 0.08 to 0.98 t ha^{-1} yr. However, the amount of SOC accumulated as a result of improved fertiliser management varied depending on the soil type, climate, and beginning fertility status. [7] It will be determined that the proper application of fertilisers based on soil conditions will aid in maximum carbon sequestration, maximum crop yield, and reductions in various GHG emissions.

INM practice on carbon sequestration

Among the different agronomic practices to increase carbon sequestration in cropping system, INM Practice (application of inorganic fertilizer and organic manures in combination) seems to be a viable option to increase crop yield while improving soil carbon accumulation.

Effects of Different INM Practices on Soil Carbon Fractions

The decline in production rates is due to dwindling carbon reserves in soils. Fertilization procedures induced the carbon sequestration pools and dynamics. The results showed that using organic manures in combination with NPK fertilisers considerably enhanced TOC and other carbon fractions, whereas using NPK fertilisers alone had little effect on TOC. Long-term tests have revealed that optimum inorganic fertiliser application has either increased or maintained SOC over time, with no significant effects on TOC in NPK-only soils. Because of the addition of plant residue to the soil, the total organic carbon level increased. The greatest TOC values were found in the RS + NPK plots, implying that using rice straw in conjunction with chemical fertilisers results in a larger accumulation of organic matter than using chemical fertiliser alone. As a result of combining inorganic fertilisers with radially decomposable organic manures, more labile carbon is produced, which can be used as a source of energy and nutrients.

Carbon sequestration and crop yield under different INM practices

According to the findings, treatments using solely inorganic fertilisers or a combination of inorganic fertilisers and organic manures could promote C sequestration in soils. However, the type of carbon fraction stored (passive or labile) and hence the pace of sequestration in soils will most likely be determined by the type and quality of organic manure used. As a result, in organic manure plots with more resistant compounds like Rice Straw, both TOC and PPC fractions increase, whereas application of Vermicompost and FYM with chemical fertilisers builds up more labile carbon fractions, which can be attributed to the presence of higher proportions of recalcitrant organic compounds in these compounds. It's a "win–win" method that can boost rice yields while also enhancing labile carbon fractions, which are significant soil quality indicators. In addition, FYM in combination with inorganic fertilisers could be employed to achieve large yields in the near term. In the short run, rice straw + NPK produces yields of 3-4 t ha^{-1} while enhancing soil TOC and passive carbon pools. The presence of easily decomposable organic molecules in VC and FYM led in the rapid release of various labile forms of C and nutrients, which increased crop output.

Benefits of soil carbon sequestration

- ✓ It has the potential to aid in the reduction of CO2 emissions.
- ✓ It has the potential to minimise certain GHG emissions.
- ✓ It may be beneficial in lowering atmospheric temperatures.
- ✓ It aids in the preservation of a healthy biotic environment.
- ✓ It cuts down on nutritional losses.
- ✓ It has the potential to boost soil health and productivity.
- ✓ It has the potential to improve water conservation.
- ✓ It has the ability to promote and maintain root growth.
- ✓ It has the potential to minimise soil erosion.

Challenges and opportunities in sustaining soil organic carbon in rice-based production system

South Asia contains the world's largest population of food insecure people, and rice and wheat cultivation are at the heart of the region's food security. The greatest barrier to achieving food security and agricultural sustainability is the depletion of soil's intrinsic potential to sustain crop output. Lowland rice-based farming systems are thought to be the most stable and SOC-preserving. Reduced- and no-tillage management, crop residue addition, and improved nutrient management strategies have all been shown to improve SOC and crop yields in studies. However, there isn't enough material to draw a firm conclusion. The rice-wheat combination, which is the region's most common farming system, has produced the most research. There hasn't been a comparison of the relative responses of different rice-based rotations to improve SOC under different management strategies. The reactions of diverse tillage, crop residue, and nutrient management strategies were further complicated by alternate drying and wetting in several rice-based systems. Similarly, our understanding of the ratio, storage, and loss of SOC in rice-based production systems is limited by a knowledge deficit in disentangling the soil C pools under varied agro environments and management approaches. Furthermore, producers alter cropping patterns to meet market demand while paying less attention to the environmental benefits. Because no-tillage and other conservation measures require several years to collect SOC within the profile, the benefits acquired are soon lost following agriculture. In South Asia, global climate change and growing climate unpredictability have brought new hurdles for sustainable food production. In general, and in rice-based agriculture systems in particular, there is a scarcity of data on carbon sinks and climate feedback in South Asia. The availability of nutrients from crop leftovers can influence when and how much fertiliser is needed to maximise crop yields. It also has an impact on the amount and quality of SOC sequestered inside the system. It's normally difficult to figure out how alternate drying and wetting affect crop residue breakdown, nutrient dynamics, and SOC sequestration. New research opportunities in South Asia are created by the successful integration of developing technologies in agro ecosystems under rice-based production systems.

Conclusion

CO_2 levels are rising at a rate of 2.3 parts per million each year, contributing to global warming and pollution. Carbon sequestration on agricultural areas is possible through a variety of soil management practises, and will be significant if widely implemented. Agriculture that is sustainable is critical to humanity's survival. Carbon sequestration in soil is a possible approach for reducing or mitigating the effects of global warming. Adoption of diverse management strategies is frequently beneficial in terms of carbon sequestration. Rice-based production systems in South Asia have exhausted a significant amount of SOC, posing a threat to the region's agricultural viability. Reduced and no-tillage, crop residue addition, FYM inclusion, and integrated nutrient management are examples of conservation management strategies that have boosted SOC accumulation and improved agricultural system sustainability. According to the findings of the study, nutrient management is the best management approach for extending production and enhancing carbon sequestration in rice-based cropping systems.

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