



Awareness programmes & soil testing in India among farmers

Trilok Nath Rai¹, Kedar Nath Rai², Sanjeev Kumar Rai³, Rajeev Kumar Rai⁴, Jyoti Rai⁵

¹ Subject Matter Specialist, Department of Soil Science and Agricultural Chemistry, Krishi Vigyan Kendra (ICAR-CSSRI), Dhikunni, Sandila, Hardoi, Uttar Pradesh, India

² Associate Professor and Head, Department of Soil Science & Agricultural Chemistry, Kamla Nehru Institute of Physical and Social Sciences, Sultanpur, Uttar Pradesh, India

³ Department of Soil Science & Agricultural Chemistry, Kamla Nehru Institute of Physical and Social Sciences, Sultanpur, Uttar Pradesh, India

⁴ Department of Nursing, Institute of Nursing & Paramedical Sciences Sultanpur, Uttar Pradesh, India

⁵ A.P.S., University, Rewa, Madhya Pradesh, India

Abstract

Field experiments were conducted in the district Sultanpur, U.P., from May 2019 to March 2021 to study the effect of conservation agriculture (CA) practices on carbon stock, carbon sequestration and soil biological properties. Rice - okra- green manure cropping system with conservation practice were compared with rice - okra cropping system without conservation practices keeping the same layout for two years. Conservation agriculture practices had significant influence on carbon stock, carbon sequestration and soil biological properties. After six cropping sequence, conservation practices such as direct sowing rice in flat bed + green manuring- okra+ crop residue mulch-cowpea had the maximum soil carbon sequestration of 9.52 Mg ha⁻¹ and 6.03 Mg ha⁻¹, at 15 and 30 cm soil depth, followed by direct seeding rice in flat bed + brown manuring- okra+ crop residue mulch-cowpea (10.17, 6.07 Mg ha⁻¹). The treatments without conservation agriculture practices, such as direct seeding rice in flat beds - okra-fallow, had a negative sequestration value. The highest microbial biomass carbon 134.83 µg g⁻¹ was recorded in direct seeding rice in flat bed + brown manuring - okra + crop residue mulch-cowpea. Dehydrogenase activity was found to be significantly highest in direct seeding rice in flat bed + brown manuring - okra + crop residue mulch-cowpea (57.17 µg TPF g⁻¹ soil day⁻¹) and it was on par with direct seeding rice in flat bed + green manuring - okra + crop residue mulch-cowpea (T4) (57.17 µg TPF g⁻¹ soil day⁻¹).

Keywords: Awareness on soil testing, conservation agriculture, carbon sequestration, carbon stock, soil microbial properties

Introduction

Conservation Agriculture (CA) with universal principles of providing minimum soil disturbance, permanent soil cover (through crop residues/cover crops) and crop rotations is considered as a principle way to achieve goals of higher productivity while protecting natural resources and environment. Conservation agriculture based sustainable crop production intensification must not only reduce the impact of climate change on crop production but also mitigate the factors that cause climate change by reducing emissions and by contributing to carbon sequestration in soil while improving food security and enhanced productivity of resources. Kassam and Friedrich (2009) [6] reported the beneficial effects of CA system as higher stable yields and income, climate change adaptation and reduced vulnerability, reduced green house gas emissions, carbon sequestration, better ecosystem functioning and service with increased agro biodiversity. At present there is no scientific data to prove the benefits of Conservation Agriculture (CA) practices for upland rice based cropping systems. Hence more trials and much scientific research should be done to validate and explain the merits of Conservation Agriculture (CA) practices. In this study, rice - okra- green manure cropping system with conservation practice were compared with rice - okra cropping system without conservation practices with specific objective to study the carbon stock, soil carbon sequestration potential and changes in physical, chemical and biological properties of soil due to conservation agriculture practices.

Materials and Methods

Field experiments were conducted in the district Sultanpur, U.P. from May 2019 to March 2021. The soil at the experimental site was sandy loam with a pH of 4.74, an EC of 0.71 dS/m, an OC of 1.18 percent, N (174.4 kg ha⁻¹), P (63.00 kg ha⁻¹), and K (201.00 kg ha⁻¹). Rice was planted in May as the first crop, followed by okra in September as the second crop, and cowpea in January as the third crop. The experiment was carried out for two years, keeping the same layout in both years. The experiment consists of ten treatments and replicated in randomised block design. Treatments consists of T1- Direct seeding rice in flat bed + Brown manuring - okra+ green manuring-cowpea, T2- Direct seeding rice in flat bed + Brown manuring - okra + crop residue mulch-cowpea, T3- Direct seeding rice in flat bed + Green manuring - okra + green manuring-cowpea, T4- Direct seeding rice in flat bed + Green manuring - okra + crop residue mulch-cowpea, T5- Direct seeding rice in raised bed + Brown manuring - okra + green manuring-cowpea, T6- Direct seeding rice in raised bed + Brown manuring - okra + crop residue mulch-cowpea, T7- Direct seeding rice in raised bed + Green manuring - okra + green manuring-cowpea, T8- Direct seeding rice in raised bed + Green manuring - okra + crop residue mulch-cowpea, T9- Direct seeding rice in flat bed - okra-fallow, T10- Direct seeding rice in raised bed - okra-fallow. Paddy variety Vaisakh was used for this study. Field was ploughed by tractor in the first year. Weeds and previous crop residues were removed and leveled. Rice

seeds were planted in flat bed and raised bed. The plot size of flat bed was 5m x 4 m. For raised bed planting 3 beds (5 m x 1 m x 30 cm each) were taken in a plot area of 5 mx4m. The same layout was used for raising the subsequent crops with minimum soil disturbance. Paddy seeds were dibbled @ 80 kg/ha at a spacing of 20x10 cm. The treatment T1 to T4 of rice is raised in two plots each to raise second crop okra and third crop cowpea in T1 to T8. Cowpea seeds were also dibbled in alternate rows in treatments T1 to T4 for brown manuring and in situ green manuring. In situ green manuring was done by uprooting the cowpea plants at 25DAS and placed between the paddy rows as mulch. For brown manuring cowpea was incorporated by spraying of 2, 4- D @ 1.25 kgha-1 at 25 DAS. Uniform hand weeding was done in all the plots at 30DAS. Soil organic carbon (SOC) data obtained from analysis of horizon wise soil samples was used for estimating SOC stocks in pedons. The horizon wise samples from the pedons were collected as part of the profile study and per cent organic carbon content was estimated. The bulk density data necessary for the SOC stock estimation was found out by using the core samples collected horizon wise. The product of bulk density (Mg m⁻³), organic carbon (%) and the depth interval gave the SOC stocks in Mg ha⁻¹ for each depth interval (Wilson and Warren, 2015) ^[19].

Carbon stock in soil (Mg ha⁻¹) = Organic carbon content X bulk density X depth

Carbon sequestration (Mg ha⁻¹) = Final carbon stock – initial carbon stock

Soil microbial biomass carbon (µg/g soil) was extracted using fumigation extraction method ((Jenkinson and Powlson, 1976) ^[5] and the Dehydrogenase activity (µg TPF g⁻¹ soil day⁻¹) was estimated by Reduction of 3 % TTC to methanol soluble formazon (TPF) and estimation using spectrophotometry (Lenhard, 1953).

Data pertaining to different observations were tabulated and subjected to statistical analysis by Wasp 2.0. and the significance among the treatments was estimated at 5 per cent of probability and pooling was done for two years data

Results and Discussion

Soil carbon stock

Soil carbon stocks was analysed after each crop at 15, 30 and 45 cm depth from all the treatments and the data presented in Tables 1,2 and 3. Results showed that the carbon stock was higher in the 15cm depth followed by 30 cm depth and the lowest in 45 cm depth in all the treatments (Fig1,2,3). The carbon stock at 15 cm depth after all the crops was found higher in direct seeding rice in flat bed + brown manuring-okra + crop residue mulch –cowpea (T2) followed by T4- Direct seeding rice in flat bed + Green manuring - okra + crop residue mulch-cowpea. Similar trend noticed in these treatments at 30 and 45 cm soil depth. Nideesh and Sureshkumar (2019) also reported similarly that carbon stock was comparatively less in lower layers compared to the surface layers. After each crop the carbon stock value increased in all conservation treatments compared to control. Pursual of post experiment data recorded the highest carbon stock at 15 and 30 cm in direct seeding rice in flat bed + green manuring- okra+ crop residue mulch-cowpea (T4) of 36.72 Mg ha⁻¹ and 29.58 Mg ha⁻¹ respectively and it was on par with T2 (Table-3). At 45 cm the highest carbon stock of 18.19 Mg ha⁻¹ was observed

in direct seeding rice in flat bed + brown manuring- okra+ crop residue mulch-cowpea (T2) and it was on par with T4 and T8. The treatments where the conservation agriculture practice is not followed ie direct seeding rice in flat bed – okra-fallow showed significantly low carbon atock after each crop at different soil depth compared to the best conservation treatments (Fig-3). It indicated the loss of carbon in conventional method. The carbon stock of each treatments at the end of the experiment ie., after six cropping seasons (Fig 4.) indicated that there was a significant increase in carbon stock in all conservation agriculture treatments compared to treatment without conservation practices. The highest soil carbon stock at 15 and 30 cm soli depth was recorded in direct seeding rice in flat bed + green manuring- okra+ crop residue mulch-cowpea followed by direct seeding rice in flat bed + brown manuring- okra+ crop residue mulch-cowpea.

Carbon sequestration

Soil carbon sequestration was analysed after each crop at 15, 30 and 45 cm depth of soil from all the treatments. Conservation agriculture practices resulted in significant increase in organic carbon % and carbon sequestration at top soil (15 cm) compared to non-conservation practice. Similar results of beneficial effect of conservation agriculture in carbon sequestration was also reported by Kassam and Friedrich (2009) ^[6]. The highest carbon sequestration was recorded for direct seeding rice in flat bed + brown manuring- okra+ crop residue mulch-cowpea. The carbon loss was recorded in control and that might be due to the absence of conservation practices. Surface mulching by crop residues in the conservation agriculture treatments might have resulted in carbon sequestration. This results agree with the findings of Sudha and George (2011) ^[15] and Thulasi *et al.*, 2013 ^[16] reported that mulching at top layers improves the carbon sequestration.

From the post experiment data the highest carbon sequestration at 15 and 30 cm was observed in direct seeding rice in flat bed + green manuring- okra+ crop residue mulch-cowpea (T4) of 10.17 Mg ha⁻¹ and 6.07 Mg ha⁻¹ respectively and it was on par with direct seeding rice in flat bed + brown manuring- okra+ crop residue mulch-cowpea (T2) of 9.52 Mg ha⁻¹ and 6.03 Mg ha⁻¹ respectively (Table-6). The lowest carbon sequestration of -9.64 Mg ha⁻¹, -9.78 Mg ha⁻¹ and -4.40 Mg ha⁻¹ at 15, 30, 45 cm respectively was recorded in direct seeding rice in flat bed + okra –fallow (T9) and it was on par with direct seeding rice in raised bed-okra –fallow (T10). From the post experiment data, it was clearly evident that carbon was sequestered in all the conservation treatments both in flat bed and raised bed at 15 cm depth (Fig-1). The treatments where the conservation agriculture practice is not followed ie direct seeding rice in flat bed –okra-fallow showed a negative value for sequestration than the best conservation treatments (Fig-3, Fig-6). It indicated the loss of carbon in conventional method.

In 30 and 45 cm depth of the entire soil profile the sequestration for all the conservation treatments not followed the similar trend. A slow increase in sequestration after each crop was clearly observed. It indicated that conservation agriculture practices for a long run will sequester the carbon to entire soil profile (Fig-2). This result is in consonance with the findings of Powlson *et al.*, 2014 ^[12] that different trend was observed in depth wise

distribution for a short period of conservation agriculture (less than five years) the no till increases soil organic carbon concentration compared to plough till method only on surface layer and not for entire soil profile. For better improvement to the entire profile a long time continuous conservation practice is required. Alavarez (2005) ^[1] also reported similarly that accumulation of soil organic carbon under reduced and zero tillage was an s shaped time dependent process which reached a steady stage to the entire profile after a long term continuous practice only.

The combined effect of all three principles like minimum soil disturbance, permanent soil cover, crop diversification was involved in the present study. Minimum disturbance of soil after the rice i.e., before planting of okra and before planting of cowpea resulted in better carbon sequestration. Similar result was reported by Haddaway *et al.* (2017) ^[4] that the transition of tilled crop lands to no tillage and conservation tillage has been credited with substantial potential to mitigate climate change via carbon storage. This practices aim at maintaining organic matter on the surface or in the upper soil layer there by increasing soil organic carbon concentration especially in the top soil. Second principle of permanent soil cover was done by growing cowpea as insitu green manure and as brown manure in rice, and for okra, cowpea as green manure and crop residue mulch. The decomposition of this plant material to simple carbon compounds and assimilation and repeating cycling of carbon through the microbial biomass with formation of new cells may enhance the carbon storage. Cover crops provide soil organic carbon sequestration by increasing the input of plant residue. So the decrease of residue carbon input might be the cause of lowering the carbon sequestration in control. This results agree with the findings of Yan *et al.*, 2011 ^[20] that the long-term fertilizer experiments suggest that the fertilizer application significantly influence soil organic carbon contents in paddy field and the addition of green manure or straw may be an effective way for enhancing the carbon storage. The third principle crop diversification was followed in rice-okra-green manure system. That might be a reason for more carbon stock and sequestration in the conservation plots where the land is not kept fallow in the third season. In control treatments with out conservation practice, the land was kept fallow at third season. Negative values in control plots indicated the carbon loss and positive values in conservation treatments indicated carbon storage (Fig.3). These results were in conformity with the findings of Vanden Bygaert *et al.*, 2003 that the replacement of fallow with legume green manure such as lentil appeared to be an effective carbon storage potential. Similar benefits of crop rotation in sequestration was reported by Govaerts *et al.*, 2009 ^[3] that the effect of crop rotation on carbon sequestration can be due to the increase biomass carbon inputs because of the intensified production or due to the changed quality of residue input. Wani *et al.*, 2003 ^[18] reported that legume based cropping system improves the carbon sequestration.

Soil microbial biomass carbon

Soil biological attributes are early warner of soil degradation and good indicators for comparing the relative performance of different soil management practices. Soil microbial biomass is the living component of the soil organic matter excluding macro fauna and plant roots. It is a

well-established parameter to monitor the soil biological changes. Results of the study indicated that during both the years there was an significant influence of conservation treatments on microbial biomass carbon after the experiment (Table 7). Soil microbial biomass carbon was found to be highest in direct seeding rice in flat bed + brown manuring - okra + crop residue mulch-cowpea (T2) (134.83 $\mu\text{g g}^{-1}$) followed by direct seeding rice in flat bed + brown manuring-okra+green manuring-cowpea (T1) of 121.50 $\mu\text{g g}^{-1}$ and it in turn was on par with direct seeding rice in flat bed + green manuring-okra+crop residue mulch-cowpea (T4) (119.50 $\mu\text{g g}^{-1}$). Direct seeding rice in flat bed-okra-fallow (T9) registered the lowest value of 74.67 $\mu\text{g g}^{-1}$ followed by direct seeding rice in raised bed -okra -fallow (79.67 $\mu\text{g g}^{-1}$) and they both are on par to each other. Direct seeding rice in flat bed + brown manuring - okra + crop residue mulch - cowpea recorded the highest microbial biomass carbon. For brown manuring in rice 2-4-D was used as herbicide and for degradation of herbicide the microbial population may increase and there by SMBC might have improved. Similar results was reported by Ramalakshmi *et al.* (2017) ^[14] that the herbicides at recommended rate in rice decreased the soil microbial population initially and after that microbial population was increased due to degradation of herbicide, which acted as a nutrient source for the growth of microorganisms. Basilla (2020) also reported that the SMBC was higher under brown manuring on 25 DAS and pyrazosulfuron-ethyl on 6 DAS. Minimum tillage also might be a reason for increase in SMBC in conservation practices than in the conventional method. Similar results were reported by Lal and Jacinthe, 2009 ^[7]; Murugandam *et al.*, 2009; Ma *et al.*, 2016 ^[9] that conservation tillage increased SMBC than conventional. The conventional practice of direct seeding rice in flat bed - okra- fallow recorded the lowest SMBC and it might be due to lack of nutrient source for microbial growth.

Dehydrogenase activity

Dehydrogenase activity is a valued bio marker of soil quality indicator which is strongly correlated with the organic carbon present in the soil and soil microbial biomass. It can be used as a tool for assessing the sustainability of agricultural ecosystem. Significantly higher dehydrogenase activity was in direct seeding rice in flat bed + brown manuring - okra + crop residue mulch-cowpea followed by direct seeding rice in flat bed + green manuring -okra + crop residue mulch-cowpea and recorded 23.33 % higher dehydrogenase activity than in the conventional practice (Table 7). Dehydrogenase activity was found to be significantly higher in direct seeding rice in flat bed + brown manuring - okra + crop residue mulch-cowpea (57.17 $\mu\text{g TPF g}^{-1} \text{soilday}^{-1}$) and it was on par with direct seeding rice in flat bed + green manuring -okra + crop residue mulch-cowpea (57.17 $\mu\text{g TPF g}^{-1} \text{soilday}^{-1}$). Direct seeding rice in flat bed-okra-fallow (T9) registered the lowest dehydrogenase activity of 43.83 $\mu\text{g TPF g}^{-1} \text{soilday}^{-1}$ followed by direct seeding rice in raised bed -okra -fallow (47.81 $\mu\text{g TPF g}^{-1} \text{soilday}^{-1}$). The increase in the enzyme activity might be due to increase in soil organic carbon content by microbial decomposition of organic matter. Similar result was reported by Rajanand (2018) ^[13] that the dehydrogenase activity increased with increase in soluble organic carbon content in the soil with a corresponding increase in the degrading soil biota. Addition of cowpea

either as green manure or brown manure and crop residue triggered the activity of dehydrogenase due to increased organic carbon. Minimum soil disturbance also might be a reason for improvement of enzyme activity. The lowest dehydrogenase activity was reported in direct seeding rice in flat bed-okra-fallow it might be due to less soil microbial

activity, soil moisture and organic carbon. The results are in conformity with the findings of Rajanand (2018) ^[13] that the lack of sufficient organic carbon and soil moisture might have hindered the activity and multiplication of soil biota in rice-rice-fallow system which in turn might have reduced the enzyme activity.



Awareness among farmers for soil sampling and soil testing at ICAR-CISH, Lucknow by Soil Science, SMS, Dr. Trilok Nath Rai

Conclusion

Rice - okra- green manure cropping system with conservation practice had a significant influence on carbon stock, soil carbon sequestration and soil biological properties compared with Rice - okra cropping system without conservation practices. The highest soil carbon stock and sequestration at 15 and 30 cm was recorded in direct seeding rice in flat bed + green manuring- okra+ crop residue mulch –cowpea. In direct seeding rice in flat bed - okra-fallow without conservation agriculture practices showed a negative value for sequestration. A slow increase in sequestration after each crop of

this study clearly indicated that conservation agriculture practices for a long run will sequester the carbon to entire soil profile. Soil biological properties like microbial biomass carbon and dehydrogenase activity were significantly improved by conservation agriculture practices. Long term conservation agriculture practices in upland rice –vegetable cropping system by applying the three principles such as minimum soil disturbance, permanent soil cover and crop diversification by the elimination of fallow can be recommended as a viable option to increase the carbon sequestration and to mitigate the climate change.

Table 1: Effect of treatments on carbon stock (Mg ha⁻¹) (after rice, before okra) of soil

Treatments	15 cm depth			30 cm depth			45 cm depth		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
T ₁ - Direct seeding rice in flat bed + Brown manuring - okra+ green manuring	22.67	27.89 ^{cd}	25.28 ^{bc}	20.84 ^a	21.86 ^{cd}	21.35 ^{cd}	17.51 ^a	16.30 ^{abc}	16.90 ^b
T ₂ -Direct seeding rice in flat bed + Brown manuring - okra + crop residue mulch	25.31	35.73 ^a	30.52 ^a	17.57 ^{bc}	29.16 ^a	23.36 ^{ab}	17.46 ^a	15.62 ^{cd}	16.54 ^b
T ₃ -Direct seeding rice in flat bed + Green manuring - okra + green manuring	25.30	26.21 ^{cd}	25.76 ^{bc}	14.61 ^f	26.33 ^b	20.47 ^d	14.96 ^c	14.63 ^{de}	14.80 ^c
T ₄ -Direct seeding rice in flat bed + Green manuring - okra + crop residue mulch	25.84	34.35 ^{ab}	30.10 ^a	15.46 ^{df}	29.95 ^a	22.70 ^{bc}	14.77 ^c	14.59 ^{de}	14.68 ^c
T ₅ -Direct seeding rice in raised bed + Brown manuring - okra + green manuring	19.34	24.01 ^d	21.68 ^c	17.00 ^{cde}	22.68 ^c	19.84 ^{de}	16.53 ^b	16.15 ^{bc}	16.34 ^b

T6-Direct seeding rice in raised bed + Brown manuring -okra+ crop residue mulch	23.16	27.62 ^{cd}	25.39 ^{bc}	17.19 ^{cd}	24.25 ^{bc}	20.72 ^d	16.43 ^b	16.14 ^{bc}	16.28 ^b
T7-Direct seeding rice in raised bed + Green manuring - okra + green manuring	25.93	30.17 ^{bc}	28.05 ^{ab}	19.76 ^a	28.93 ^a	24.34 ^a	17.98 ^a	17.28 ^{ab}	17.63 ^a
T8-Direct seeding rice in raised bed + Green manuring - okra+ crop residue mulch	25.35	29.48 ^{bc}	27.41 ^{ab}	19.25 ^{ab}	29.35 ^a	24.30 ^a	17.91 ^a	17.41 ^a	17.66 ^a
T9-Direct seeding rice in flat bed – okra	17.66	27.35 ^{cd}	22.51 ^c	15.03 ^{ef}	19.68 ^d	17.36 ^f	14.51 ^c	13.88 ^e	14.20 ^c
T10-Direct seeding rice in raised bed – okra	19.44	25.45 ^{cd}	22.44 ^c	15.31 ^{def}	22.08 ^{cd}	18.69 ^{ef}	14.82 ^c	14.11 ^e	14.47 ^c
SEm	-	1.18	0.99	0.68	1.19	0.75	0.44	0.40	0.41
CD(0.05)	NS	4.98	4.19	1.98	2.50	1.59	0.75	1.17	0.71

In a column, means followed by common letters do not differ significantly at 5% level by DMRT

Table 2: Effect of treatments on carbon stock (Mg ha⁻¹) (after okra, before cowpea) of soil

Treatments	15 cm depth			30 cm depth			45 cm depth		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
T1- Direct seeding rice in flat bed + Brown manuring - okra+ green manuring -cowpea	25.85 ^{bc}	27.87 ^{cd}	26.86 ^{cd}	23.30 ^{abc}	24.86 ^{bc}	24.08 ^{bcd}	19.67 ^a	18.78 ^a	19.23 ^a
T2-Direct seeding rice in flat bed + Brown manuring - okra + crop residue mulch - cowpea	33.56 ^a	35.70 ^a	34.63 ^a	27.21 ^a	30.23 ^a	28.72 ^a	18.34 ^{ab}	17.95 ^a	18.15 ^a
T3-Direct seeding rice in flat bed + Green manuring - okra + green manuring -cowpea	25.47 ^{bc}	30.07 ^{bc}	27.77 ^c	25.23 ^{abc}	25.99 ^b	25.61 ^{abc}	15.31 ^d	14.74 ^{cd}	15.02 ^{bc}
T4-Direct seeding rice in flat bed + Green manuring - okra + crop residue mulch - cowpea	28.44 ^{ab}	33.02 ^{ab}	30.73 ^b	26.74 ^{ab}	26.43 ^b	26.58 ^{ab}	17.46 ^{bc}	16.70 ^{abc}	17.08 ^{ab}
T5-Direct seeding rice in raised bed + Brown manuring - okra + green manuring - cowpea	22.51 ^{cd}	25.64 ^{de}	24.07 ^{de}	21.26 ^{cde}	21.63 ^{cd}	21.45 ^{de}	15.43 ^{cd}	15.17 ^{bcd}	15.30 ^{bc}
T6-Direct seeding rice in raised bed + Brown manuring -okra+ crop residue mulch-cowpea	24.79 ^{bcd}	29.14 ^d	26.97 ^{cd}	21.62 ^{cd}	23.51 ^{bcd}	22.56 ^{cd}	17.66 ^{ab}	17.34 ^{ab}	17.50 ^a
T7-Direct seeding rice in raised bed + Green manuring - okra + green manuring - cowpea	22.62 ^{cd}	25.90 ^d	24.26 ^d	22.29 ^{bc}	21.87 ^{cd}	22.08 ^d	17.61 ^{ab}	17.73 ^a	17.67 ^a
T8-Direct seeding rice in raised bed + Green manuring - okra+ crop residue mulch -cowpea	26.16 ^{bc}	27.23 ^{cd}	26.69 ^{cd}	23.83 ^{abc}	24.24 ^{bc}	24.03 ^{bcd}	18.76 ^{ab}	19.06 ^a	18.91 ^a
T9-Direct seeding rice in flat bed – okra-cowpea	17.01 ^e	16.65 ^f	16.83 ^f	16.88 ^e	16.37 ^e	16.63 ^f	14.16 ^d	13.50 ^d	13.83 ^c
T10-Direct seeding rice in raised bed – okra-cowpea	20.00 ^{de}	22.34 ^e	21.17 ^e	17.31 ^{de}	20.26 ^d	18.79 ^{ef}	14.48 ^d	13.55 ^d	14.01 ^c
SEm	1.44	1.69	1.55	1.10	1.20	1.14	0.60	0.66	0.62
CD(0.05)	5.20	3.51	2.91	4.60	3.31	3.15	2.08	2.52	2.19

In a column, means followed by common letters do not differ significantly at 5% level by DMRT

Table 3: Effect of treatments on soil carbon stock (Mg ha⁻¹) after the experiment

Treatments	15 cm depth			30 cm depth			45 cm depth		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
T1- Direct seeding rice in flat bed + Brown manuring - okra+ green manuring -cowpea	27.26 ^{bc}	29.59 ^b	28.42 ^c	24.70 ^b	25.59 ^b	25.15 ^c	16.94 ^{abc}	16.85 ^{abc}	16.89 ^{bc}
T2-Direct seeding rice in flat bed + Brown manuring - okra + crop residue mulch -cowpea	35.83 ^a	36.31 ^a	36.07 ^a	30.34 ^a	28.73 ^a	29.54 ^a	18.09 ^{ab}	18.28 ^a	18.19 ^a
T3-Direct seeding rice in flat bed + Green manuring - okra + green manuring -cowpea	29.54 ^b	34.80 ^a	32.17 ^b	25.40 ^b	30.02 ^a	27.71 ^b	14.70 ^{de}	15.68 ^c	15.19 ^d
T4-Direct seeding rice in flat bed + Green manuring - okra + crop residue mulch -cowpea	36.02 ^a	37.42 ^a	36.72 ^a	29.04 ^a	30.12 ^a	29.58 ^a	17.13 ^{abc}	18.33 ^a	17.73 ^{ab}
T5-Direct seeding rice in raised bed + Brown manuring - okra + green manuring -cowpea	23.10 ^d	28.18 ^b	25.64 ^d	21.90 ^{cd}	23.70 ^b	22.80 ^{de}	15.08 ^{de}	15.74 ^c	15.41 ^d
T6-Direct seeding rice in raised bed + Brown manuring -okra+ crop residue mulch-cowpea	28.22 ^{bc}	29.50 ^b	28.86 ^c	22.06 ^{cd}	23.94 ^b	23.00 ^{de}	15.77 ^{cd}	16.49 ^{bc}	16.13 ^{cd}
T7-Direct seeding rice in raised bed + Green manuring - okra + green manuring -cowpea	25.46 ^{cd}	28.93 ^b	27.22 ^{cd}	20.09 ^d	23.89 ^b	21.99 ^e	16.70 ^{bc}	15.53 ^c	16.11 ^{cd}
T8-Direct seeding rice in raised bed + Green manuring - okra+ crop residue mulch -cowpea	28.40 ^{bc}	29.64 ^b	29.02 ^c	22.51 ^c	24.38 ^b	23.44 ^d	18.24 ^a	17.95 ^{ab}	18.09 ^a
T9-Direct seeding rice in flat bed – okra-cowpea	16.17 ^e	17.66 ^c	16.91 ^e	13.67 ^e	13.81 ^c	13.74 ^f	13.26 ^f	13.22 ^d	13.24 ^e
T10-Direct seeding rice in raised bed – okra-cowpea	18.06 ^e	19.89 ^c	18.98 ^e	14.12 ^e	14.89 ^c	14.51 ^f	13.77 ^{ef}	13.63 ^d	13.70 ^e
SEm	2.06	2.03	2.03	1.74	1.78	1.74	0.55	0.57	0.55
CD(0.05)	3.44	3.06	2.67	1.98	2.10	1.38	1.43	1.51	1.07

In a column, means followed by common letters do not differ significantly at 5% level by DMRT

Table 4: Effect of treatments on carbon sequestration (Mg ha⁻¹) (after rice, before okra) of soil

Treatments	15 cm depth			30 cm depth			45 cm depth		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
T ₁ - Direct seeding rice in flat bed + Brown manuring - okra+ green manuring	-3.88	1.34 ^{cd}	-1.27 ^{bc}	-2.67 ^a	-1.65 ^{cd}	-2.16 ^{cd}	-0.13 ^a	-1.34 ^{abc}	-0.74 ^a
T ₂ -Direct seeding rice in flat bed + Brown manuring - okra + crop residue mulch	-1.24	9.18 ^a	3.97 ^a	-5.95 ^{bc}	5.65 ^c	-0.15 ^{ab}	-1.02 ^b	-2.02 ^{cd}	-1.52 ^b
T ₃ -Direct seeding rice in flat bed + Green manuring - okra + green manuring	-1.25	-0.34 ^{cd}	-0.79 ^{bc}	-8.90 ^f	2.82 ^b	-3.04 ^d	-3.52 ^d	-3.01 ^{de}	-3.26 ^c
T ₄ -Direct seeding rice in flat bed + Green manuring - okra + crop residue mulch	-0.71	7.80 ^{ab}	3.55 ^a	-8.06 ^{def}	6.44 ^a	-0.81 ^{bc}	-3.71 ^d	-3.05 ^{de}	-3.38 ^c
T ₅ -Direct seeding rice in raised bed + Brown manuring - okra + green manuring	-7.21	-2.54 ^d	-4.87 ^c	-6.51 ^{cde}	-0.84 ^c	-3.67 ^{de}	-1.95 ^c	-1.49 ^{bc}	-1.72 ^b
T ₆ -Direct seeding rice in raised bed + Brown manuring -okra+ crop residue mulch	-3.39	1.07 ^{cd}	-1.16 ^{bc}	-6.32 ^{cd}	0.74 ^{bc}	-2.79 ^d	-2.05 ^c	-1.50 ^{bc}	-1.77 ^b
T ₇ -Direct seeding rice in raised bed + Green manuring - okra + green manuring	-0.62	3.62 ^{bc}	1.50 ^{ab}	-3.76 ^a	5.42 ^a	0.83 ^a	-0.51 ^{ab}	-0.36 ^{ab}	-0.43 ^a
T ₈ -Direct seeding rice in raised bed + Green manuring - okra+ crop residue mulch	-1.20	2.93 ^{bc}	0.86 ^{ab}	-4.27 ^{ab}	5.84 ^a	0.79 ^a	-0.57 ^{ab}	-0.23 ^a	-0.40 ^a
T ₉ -Direct seeding rice in flat bed – okra	-8.89	0.80 ^{cd}	-4.04 ^c	-8.48 ^{ef}	-3.83 ^d	-6.16 ^f	-3.97 ^d	-3.76 ^e	-3.86 ^c
T ₁₀ -Direct seeding rice in raised bed – okra	-7.11	-1.10 ^{cd}	-4.11 ^c	-8.20 ^{def}	-1.43 ^{cd}	-4.82 ^{ef}	-3.66 ^d	-3.53 ^e	-3.59 ^c
SEm	-	1.18	0.99	0.68	1.19	0.75	0.48	0.40	0.43
CD(0.05)	NS	4.98	4.19	1.98	2.50	1.59	0.75	1.17	0.74

In a column, means followed by common letters do not differ significantly at 5% level by DMRT

Table 5: Effect of treatments on carbon sequestration (Mg ha⁻¹) (after okra, before cowpea) of soil

Treatments	15 cm depth			30 cm depth			45 cm depth		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
T ₁ - Direct seeding rice in flat bed + Brown manuring - okra+ green manuring -cowpea	-0.70 ^{bc}	1.32 ^{cd}	0.31 ^{cd}	-0.21 ^{abc}	1.35 ^{bc}	0.57 ^{bcd}	2.04 ^a	1.14 ^a	1.59 ^a
T ₂ -Direct seeding rice in flat bed + Brown manuring - okra + crop residue mulch -cowpea	7.01 ^a	9.15 ^a	8.08 ^a	3.70 ^a	6.72 ^a	5.21 ^a	0.70 ^{ab}	0.31 ^a	0.51 ^a
T ₃ -Direct seeding rice in flat bed + Green manuring - okra + green manuring -cowpea	-1.08 ^{bc}	3.52 ^{bc}	1.22 ^c	1.72 ^{abc}	2.48 ^b	2.10 ^{abc}	-2.33 ^d	-2.90 ^{cd}	-2.62 ^{bc}
T ₄ -Direct seeding rice in flat bed + Green manuring - okra + crop residue mulch -cowpea	1.89 ^{ab}	6.47 ^{ab}	4.18 ^b	3.23 ^{ab}	2.92 ^b	3.07 ^{ab}	-0.18 ^{bc}	-0.94 ^{abc}	-0.56 ^{ab}
T ₅ -Direct seeding rice in raised bed + Brown manuring - okra + green manuring -cowpea	-4.04 ^{cd}	-0.91 ^{de}	-2.48 ^{de}	-2.25 ^{cde}	-1.88 ^{cd}	-2.07 ^{de}	-2.21 ^{cd}	-2.47 ^{bcd}	-2.34 ^{bc}
T ₆ -Direct seeding rice in raised bed + Brown manuring -okra+ crop residue mulch-cowpea	-1.76 ^{bcd}	2.59 ^{cd}	0.42 ^{cd}	-1.89 ^{cd}	-0.08 ^{bcd}	-0.95 ^{cd}	0.02 ^{ab}	-0.30 ^{ab}	-0.14 ^a
T ₇ -Direct seeding rice in raised bed + Green manuring - okra + green manuring -cowpea	-3.93 ^{cd}	-0.65 ^d	-2.29 ^d	-1.22 ^{bc}	-1.65 ^{cd}	-1.43 ^d	-0.04 ^{ab}	0.09 ^a	0.03 ^a
T ₈ -Direct seeding rice in raised bed + Green manuring - okra+ crop residue mulch -cowpea	-0.38 ^{bc}	0.68 ^{cd}	0.14 ^{cd}	0.32 ^{abc}	0.73 ^{bc}	0.53 ^{bcd}	1.12 ^{ab}	1.42 ^a	1.27 ^a
T ₉ -Direct seeding rice in flat bed – okra-cowpea	-9.54 ^e	-9.90 ^f	-9.72 ^f	-6.63 ^e	-7.14 ^e	-6.88 ^f	-3.48 ^d	-4.14 ^d	-3.81 ^c
T ₁₀ -Direct seeding rice in raised bed – okra-cowpea	-6.55 ^{de}	-4.21 ^e	-5.38 ^e	-6.20 ^{de}	-3.25 ^d	-4.72 ^{ef}	-3.16 ^d	-4.10 ^d	-3.63 ^c
SEm	1.44	1.69	1.55	1.11	1.20	1.14	0.60	0.66	0.63
CD(0.05)	5.20	3.51	2.91	4.60	3.32	3.15	2.08	2.52	2.19

In a column, means followed by common letters do not differ significantly at 5% level by DMRT

Table 6: Effect of treatments on soil carbon sequestration (Mg ha⁻¹) after the experiment

Treatments	15 cm depth			30 cm depth			45 cm depth		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
T ₁ - Direct seeding rice in flat bed + Brown manuring - okra+ green manuring -cowpea	0.70 ^{bc}	3.04 ^b	1.87 ^c	1.19 ^b	2.08 ^b	1.64 ^c	-0.70 ^{abc}	-0.79 ^{abc}	-0.75 ^{bc}
T ₂ -Direct seeding rice in flat bed + Brown manuring - okra + crop residue mulch -cowpea	9.28 ^a	9.76 ^a	9.52 ^a	6.83 ^a	5.22 ^a	6.03 ^a	0.45 ^{ab}	0.64 ^a	0.55 ^a
T ₃ -Direct seeding rice in flat bed + Green manuring - okra + green manuring -cowpea	2.99 ^b	8.25 ^a	5.62 ^b	1.89 ^b	6.51 ^a	4.20 ^b	-2.94 ^{de}	-1.96 ^c	-2.45 ^d

T4-Direct seeding rice in flat bed + Green manuring - okra + crop residue mulch -cowpea	9.47 ^a	10.87 ^a	10.17 ^a	5.53 ^a	6.61 ^a	6.07 ^a	-0.51 ^{abc}	0.69 ^a	0.09 ^{ab}
T5-Direct seeding rice in raised bed + Brown manuring - okra + green manuring -cowpea	-3.45 ^d	1.63 ^b	-0.91 ^d	-1.61 ^{cd}	0.19 ^b	-0.71 ^{de}	-2.56 ^{de}	-1.90 ^c	-2.23 ^d
T6-Direct seeding rice in raised bed + Brown manuring -okra+ crop residue mulch-cowpea	1.67 ^{bc}	2.95 ^b	2.31 ^c	-1.45 ^{cd}	0.43 ^b	-0.51 ^{de}	-1.87 ^{cd}	-1.15 ^{bc}	-1.51 ^{cd}
T7-Direct seeding rice in raised bed + Green manuring - okra + green manuring -cowpea	-1.10 ^{cd}	2.44 ^b	0.67 ^{cd}	-3.42 ^d	0.38 ^b	-1.52 ^e	-0.94 ^{bc}	-2.11 ^c	-1.53 ^{cd}
T8-Direct seeding rice in raised bed + Green manuring - okra+ crop residue mulch -cowpea	1.85 ^{bc}	3.09 ^b	2.47 ^c	-1.00 ^c	0.87 ^b	-0.07 ^d	0.60 ^a	0.31 ^{ab}	0.45 ^a
T9-Direct seeding rice in flat bed – okra-cowpea	-10.38 ^e	-8.89 ^c	-9.64 ^e	-9.84 ^e	-9.71 ^c	-9.78 ^f	-4.38 ^f	-4.42 ^d	-4.40 ^e
T10-Direct seeding rice in raised bed – okra-cowpea	-8.49 ^e	-6.66 ^c	-7.58 ^e	-9.39 ^e	-8.62 ^c	-9.00 ^f	-3.87 ^{ef}	-4.01 ^d	-3.94 ^e
SEm	2.07	2.03	2.03	1.74	1.78	1.74	0.55	0.57	0.54
CD(0.05)	3.44	3.06	2.68	1.98	2.10	1.38	1.42	1.51	1.07

In a column, means followed by common letters do not differ significantly at 5% level by DMRT

Table 7: Effect of treatments on biological properties of soil after the experiment

Treatments	Microbial biomass carbon ($\mu\text{g g}^{-1}$)			Dehydrogenase activity ($\mu\text{g TPF g}^{-1} \text{soil day}^{-1}$)		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled
T1- Direct seeding rice in flat bed + Brown manuring - okra+ green manuring -cowpea	115.33 ^a	127.67 ^{bc}	121.50 ^b	53.52 ^{ab}	56.18 ^b	55.82 ^b (54.86)
T2-Direct seeding rice in flat bed + Brown manuring - okra + crop residue mulch -cowpea	101.33 ^c	168.33 ^a	134.83 ^a	54.03 ^{ab}	60.29 ^a	58.71 ^a (57.17)
T3-Direct seeding rice in flat bed + Green manuring - okra + green manuring -cowpea	103.67 ^{bc}	119.33 ^{bcd}	111.50 ^c	53.81 ^{ab}	56.00 ^{bc}	55.80 ^b (54.91)
T4-Direct seeding rice in flat bed + Green manuring - okra + crop residue mulch -cowpea	109.67 ^{ab}	129.33 ^b	119.50 ^b	55.03 ^a	59.30 ^a	58.40 ^a (57.17)
T5-Direct seeding rice in raised bed + Brown manuring - okra + green manuring -cowpea	99.67 ^c	107.67 ^d	103.67 ^{cd}	51.66 ^b	55.30 ^{bcd}	54.58 ^c (53.48)
T6-Direct seeding rice in raised bed + Brown manuring - okra+ crop residue mulch-cowpea	91.67 ^d	107.33 ^d	99.50 ^d	52.15 ^b	52.90 ^e	53.17 ^d (52.53)
T7-Direct seeding rice in raised bed + Green manuring - okra + green manuring -cowpea	97.00 ^{cd}	116.33 ^{cd}	106.67 ^{cd}	53.15 ^{ab}	54.77 ^{cd}	54.74 ^{bc} (53.96)
T8-Direct seeding rice in raised bed + Green manuring - okra+ crop residue mulch -cowpea	96.73 ^{cd}	114.67 ^d	105.70 ^{cd}	52.33 ^b	54.33 ^d	54.17 ^{cd} (53.33)
T9-Direct seeding rice in flat bed – okra - fallow	77.67 ^e	71.67 ^e	74.67 ^e	42.33 ^d	45.33 ^g	44.74 ^f (43.83)
T10-Direct seeding rice in raised bed – okra - fallow	81.00 ^e	78.33 ^e	79.67 ^e	47.00 ^c	48.62 ^f	48.54 ^e (47.81)
SEm	3.69	8.53	5.78	1.23	1.43	1.35
CD(0.05)	7.62	12.02	7.90	2.44	1.30	1.21

* R (weighted MSE) transformed values, original values in parentheses.

In a column, means followed by common letters do not differ significantly at 5% level by DMRT

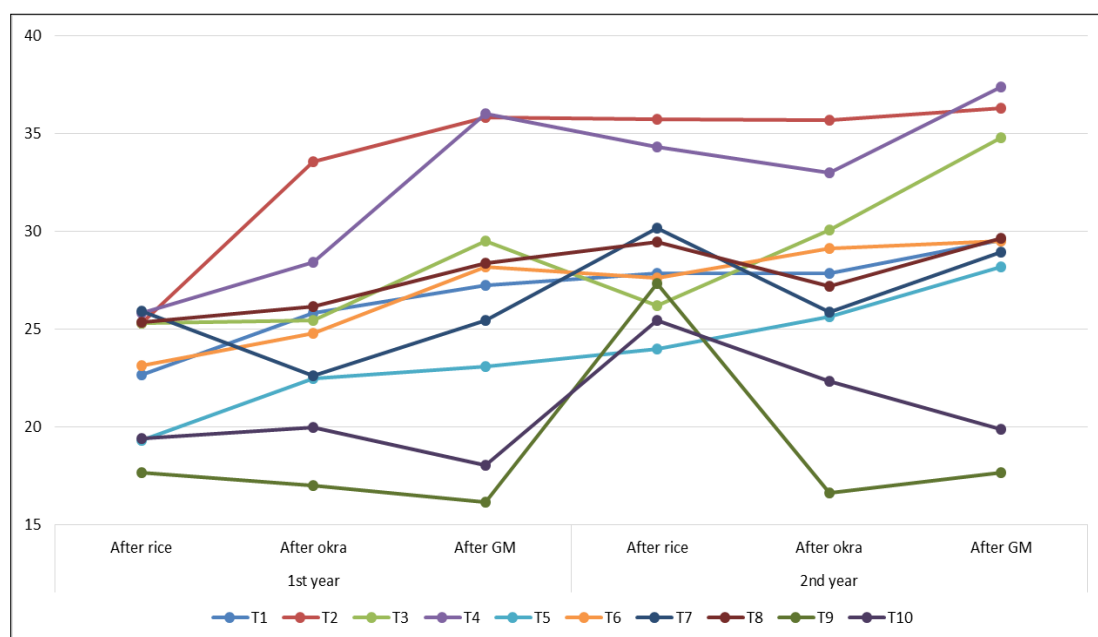


Fig 1: Change in soil carbon stock (Mg ha^{-1}) at 15 cm depth of soil after each cropping season

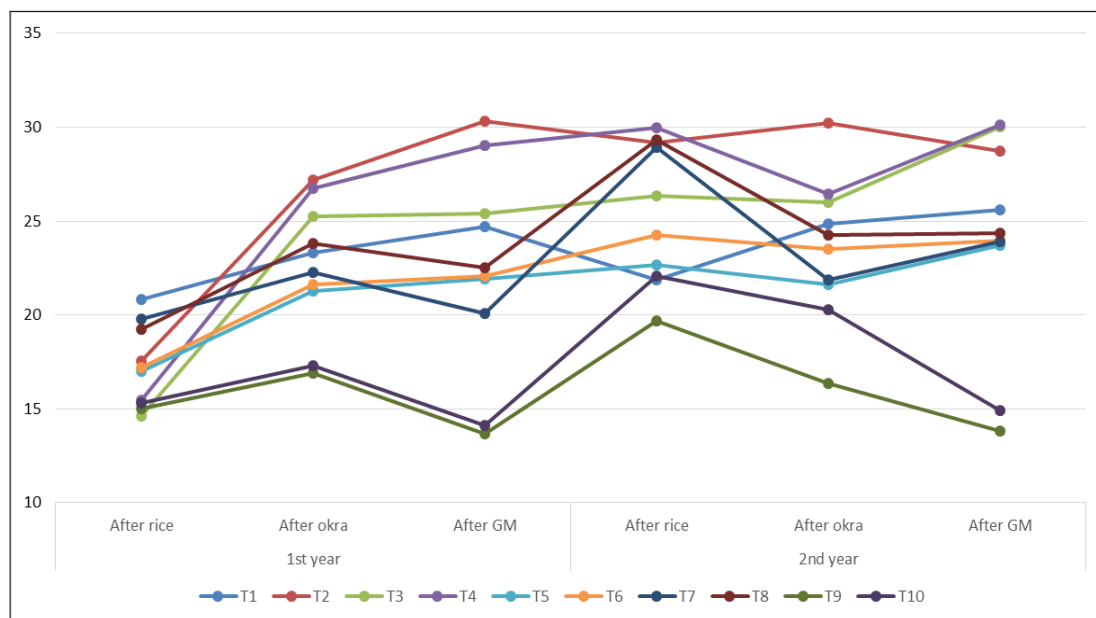


Fig 2: Change in soil carbon stock (Mg ha⁻¹) at 30 cm depth of soil after each cropping season

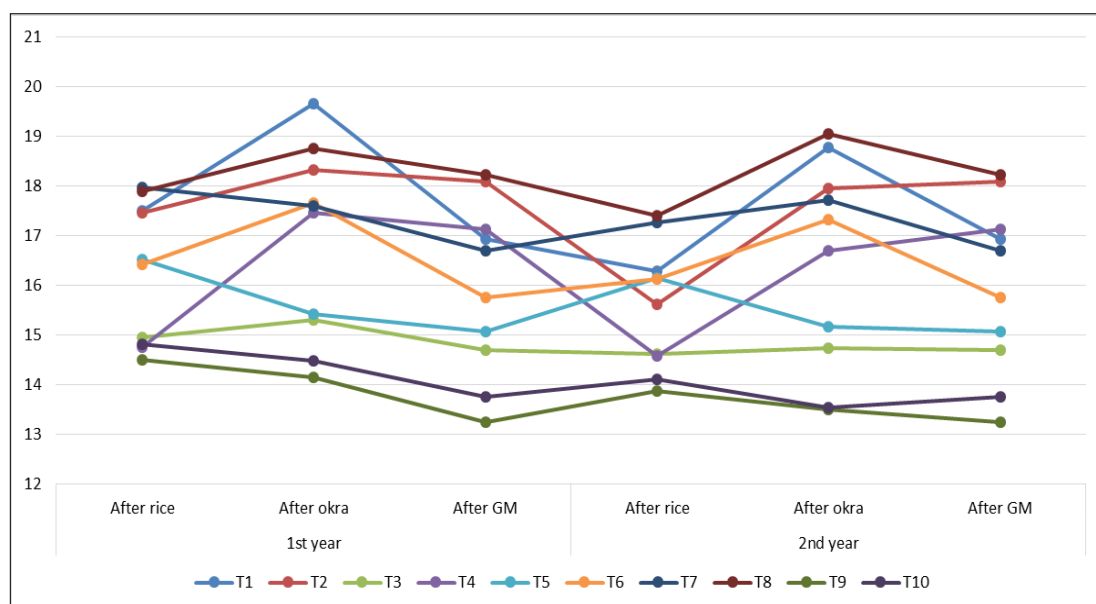


Fig 3: Change in soil carbon stock (Mg ha⁻¹) at 45 cm depth of soil after each cropping season

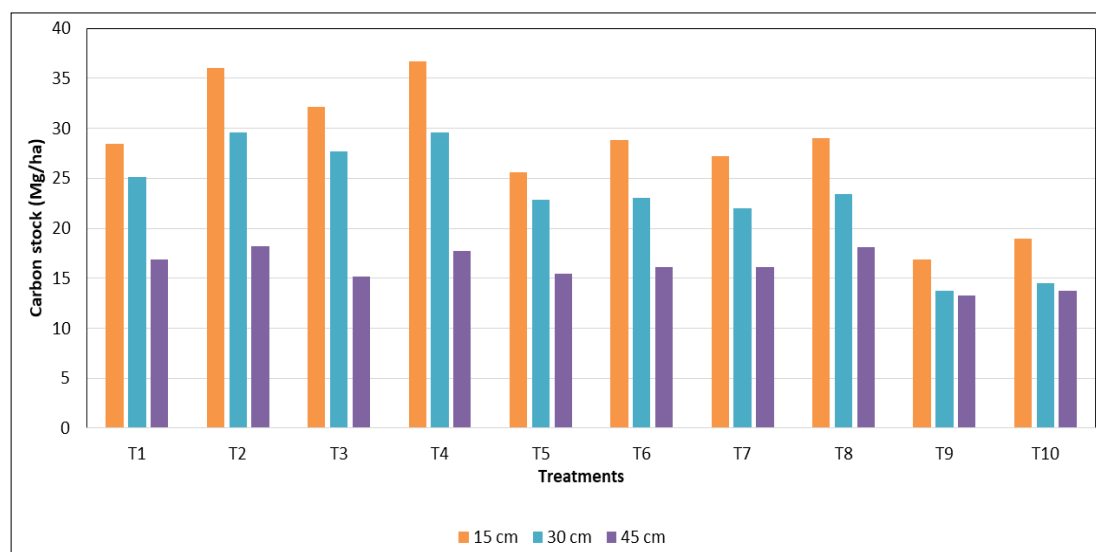


Fig 4: Effect of conservation treatments on carbon stock of soil after the experiment

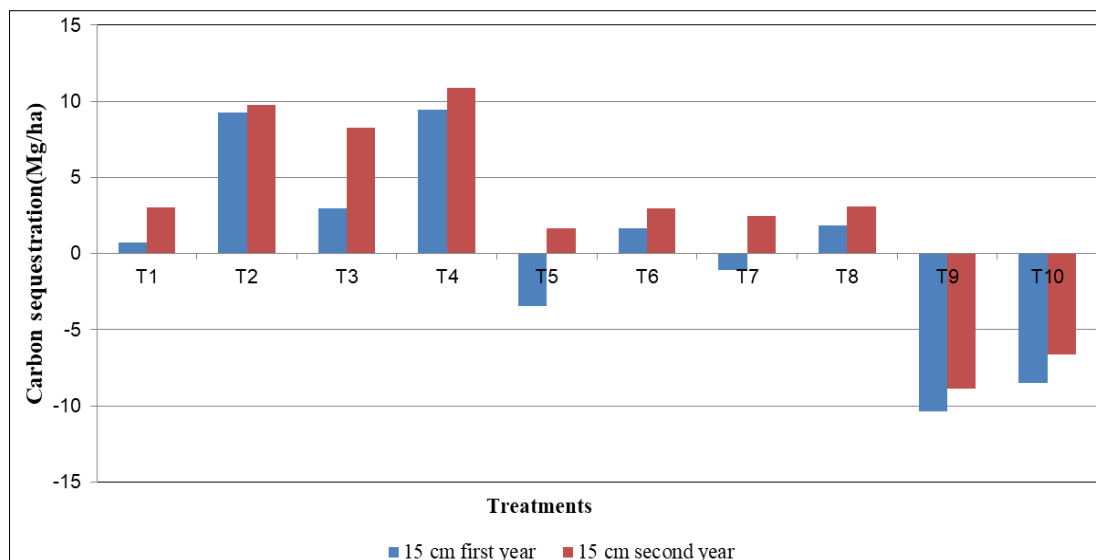


Fig 5: Effect of conservation treatments on carbon sequestration (Mg/ha) on both the years after the experiment at 15 cm depth

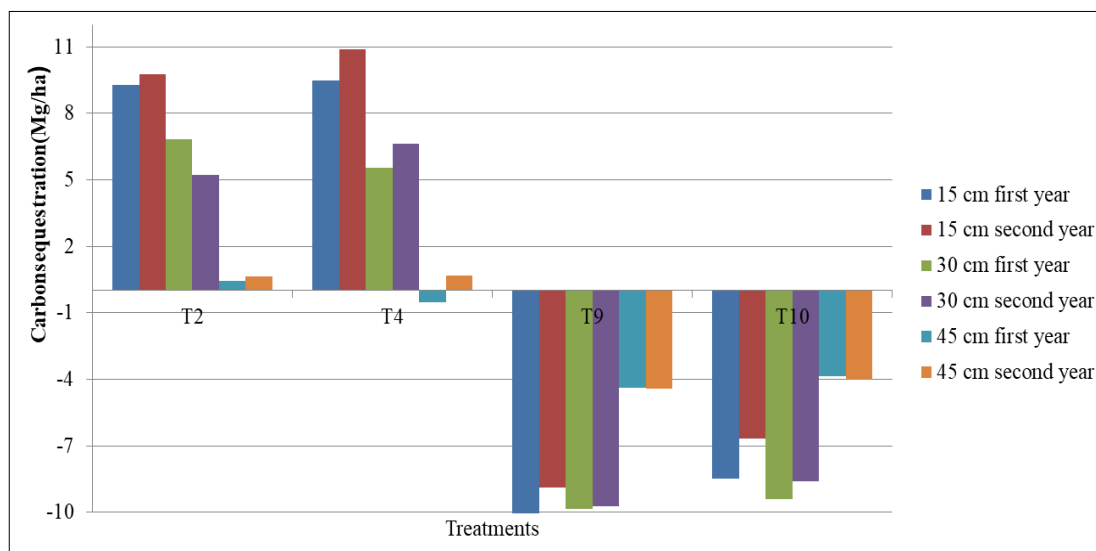


Fig 6: Comparison of carbon sequestration (Mg/ha) for best treatments vs control in both the years after the experiment

Competing interests disclaimer

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Author Dr. Trilok Nath Rai thankful to corresponding author Dr. Kedar Nath Rai, KNIPSS, Sultanpur, U.P. for preparation of manuscript & financial supports.

References

- Alvarez R. A review of nitrogen fertilizer and conservation tillage effects on soil organic carbon storage. *Soil use manag*,2005;21(1):38-52.
- Basila Y, Anitha S, Menon MV, Sreelakshmi K, Beena VI. In situ green manuring and herbicide on weed biomass, productivity and profitability of upland rice. *Indian J. Weed Sci*,2020;53(1):81-84.
- Govaerts B, Verhulst N, Castellanos NA, Sayre KD, Dixon J, Dendooven L. Conservation agriculture and soil carbon sequestration: between myth and farmer reality. *Critical Reviews in Plant Sci*,2009;28(3):97-122.
- Haddaway NR, Hedlund K, Jackson LE, Kätterer T, Lugato E, Thomsen IK, *et al*. How does tillage intensity affect soil organic carbon? A systematic review. *Environl Evidence*,2017;6(1):1-48.
- Jenkinson DS, Powlson DS. The effects of biocidal treatments on metabolism in soil-V. A method for measuring soil biomass. *Soil Biol. Biochem*,1976;8:209-213.
- Kassam AH, Friedrich T. Perspectives- nutrient management in conservation agriculture. In: *Invited paper, IV World Congress on Conservation Agriculture*, 4-7 February 2009, New Delhi, India., 2009. <https://pdfs.semanticscholar.org/b767/79d929148288fb02747135e427233d6805c7.pdf>
- Lal R, Jacinthe PA. Tillage effects on carbon sequestration and microbial biomass in reclaimed farmland soils of south-western Indiana. *Soil Sci. Society Am. J*,2009;73(2):605-613.

8. Lenhard G. The dehydrogenase activity in soil as a measure of the activity of soil microorganisms. *Z. Pflanzenernaehr. Dueng. Bodenkd*,1956:73:1-11.
9. Ma X, Liu M, Li Z. Shifts in microbial biomass and community composition in subtropical paddy soils under a gradient of manure amendment. *Biol. Fertil. Soils*,2016:52(6):775-787.
10. Muruganandam S, Israel DW, Robarge WP. Nitrogen transformations and microbial communities in soil aggregates from three tillage systems. *Soil Sci. Soc. Am. J*,2009:74(1):120-129.
11. Nidheesh PV, Suresh Kumar M. An overview of environmental sustainability in cement and steel production. *J. cleaner prod*,2019:231:856-871.
12. Powlson DS, Gregory PJ, Whalley WR, Quinton JN. Soil management in relation to sustainable agriculture and ecosystem services. *Food Policy*,2014:36:572-587.
13. Rajanand H. Productivity and soil health of rice based cropping systems under organic management. Ph.D. (Ag.) thesis, Kerala Agricultural University, Thrissur, 2018, 245.
14. Ramalakshmi A, Arthanari PM, Chinnusamy C. Effect of Pyrasosulfuron Ethyl, Bensulfuron Methyl, Pretilachlor and Bispyribac Sodium on Soil Microbial Community and Soil Enzymes under Rice-Rice Cropping System. *Int. J. Curr. Microbiol. App. Sci*,2017:6(12):990-998.
15. Sudha B, George A. Tillage and residue management for organic carbon sequestration in coconut (*Cocos nucifera*) based cropping systems. *Indian J. Agron*,2011:56(3):223-227.
16. Thulasi V, Moossa PP, Narayanankutty MC. Influence of long term application of farm yard manure and in situ green manures on crop productivity and soil organic carbon under rice-rice system in a typic haplustalf. *Adv. Res. J. Crop Improv*,2013:7(1):111-115.
17. VandenBygaart AJ, Gregorich EG, Angers DA. Influence of agricultural management on soil organic carbon: A compendium and assessment of Canadian studies. *Canadian J. Soil Sci*,2003:83(4):363-380.
18. Wani SP, Pathak P, Jangawad LS, Eswaran H, Singh P. Improved management of Vertisols in the semiarid tropics for increased productivity and soil carbon sequestration. *Soil use manage*,2003:19(3):217-222.
19. Wilson TM, Warren JG. Bulk density and carbon concentration variance influence on soil carbon stock measurements. *Commun. Soil Sci. Plant Anal*,2015:46(18):2342-2356.
20. Yan X, Cai Z, Wang S, Smith P. Direct measurement of soil organic carbon content change in the crop lands of China. *Glob. Change Biol*,2011:17:1487-1496.