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Effect of long term tillage and fertilization on carbon stock in rice-lentil cropping sequence under dry land ecosystem

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Abstract
The long term fertilization experiment was conducted at BHU from 2003 with rice-lentil cropping system. To monitor organic carbon storage in soils with inorganic, 50% organic and organic manures under three tillage practices. The experiments included main plot as three tillage i.e. conventional tillage (T_1), reduced tillage (T_2) and minimum tillage (T_3) and sub plot as three fertilization i.e. inorganic (F_1), 50% organic (F_2) and organic (F_3). Soil samples were collected at 0-60 cm depth at 5 cm increment from the wall of the rectangular pit using stainless steel cores measuring 5 cm in length and 5.1 cm in diameter after rice-lentil cropping sequence in 2012-13. Two such cores were collected from each pit, one for the determination of bulk density and the other for determination of TOC. It was observed that there was no significant difference among the tillage treatments except at 10-15 cm depth. The influence of fertilization however had significant effect on bulk density at 0-5, 5-10 and 10-15 cm depths. The effect of addition of organic manure did not bring in significant changes in bulk density at depths lower than 15 cm. The average bulk density in the inorganically fertilized plots was 1.35 Mg m^{-3} in the 0-5 cm depth and increased to 1.37 Mg m^{-3} in the 5-10 cm depth and to 1.40 Mg m^{-3} in the 10-15 cm. The corresponding value for organically fertilized plot was 1.27 Mg m^{-3} for 0-5 cm depth which increased to 1.31 Mg m^{-3} for 5-10 cm depth and 1.35 Mg m^{-3} for 10-15 cm depth. The increase in TOC content was more in minimum tillage rice-lentil cropping system than conventional tillage of rice-lentil cropping system. Sole organic manures resulted in increased TOC compared to mineral fertilizer alone. Lower soil layers showed no significant difference in TOC under different fertilization. The carbon stock for each 5 cm soil depth was found to decrease with increasing soil depth. The effect of tillage and fertilization was mainly found to influence soil carbon stock upto 0-15 cm soil depth; however their interaction was not significant. At depths lower than 15 cm, soil organic carbon stock was not significantly influenced by either tillage or fertilization. The cumulative carbon stock upto 60 cm depth was however significantly influenced both by tillage and fertilization (Table-3& Fig.-1) and varied from as low as 22.7 Mg ha^{-1} in conventional tillage with inorganic fertilization and as high as 37 Mg ha^{-1} in minimum tillage with organic manuring.

Keywords: tillage; fertilization; carbon stock

1. Introduction

Soils of the world's agro ecosystems (i.e., croplands, grazing lands, rangelands) are depleted of their soil organic carbon (SOC) stock by 25-75% depending on climate, soil type, and historic management, and the magnitude of this loss may be 10 to 50 Mg C ha^{-1} (Lal 2011) [8]. Soils with severe depletion of their SOC stock have low agronomic yield and low use efficiency of added input. Conversion to a restorative land use and adoption of best management practices (BMPs) can enhance the SOC stock, improve soil quality, increase agronomic productivity, advance global food security, enhance soil resilience and adapt to extreme climatic events, and mitigate climate change by off-setting fossil fuel emissions. Soil organic carbon is the most important attribute and chosen as the most important indicator of soil and environment quality and agricultural sustainability. Maintaining of soil carbon stocks and other nutrient proved as the most important challenge of arable lands. It depends on soil type, surrounding climate and long term land use. Management of both SOC and soil inorganic carbon (SIC) pools in semi-arid ecosystems can play a major role in reducing the rate of enrichment of atmospheric CO_2. The SOC pool includes highly active humus and relatively inert charcoal C. The SIC pool includes elemental C and carbonate minerals (*e.g.* gypsum, calcite, dolomite, aragonite and siderite). The SOC stocks vary with land-cover and land-use change, with significant losses occurring through disturbance and cultivation (Edmondson *et al.* 2014) [14]. All over the world including India, most of the soil carbon stock based studies has been conducted with lesser number of observations of soil profiles per unit area. The first comprehensive study of organic carbon (OC) status in

Indian soils was conducted by Jenny and Raychaudhuri (1960) and they confirmed the effects of climate on carbon reserves in the soils. However, these authors did not make any estimate of the total carbon reserves in the soils. The first attempt in estimating OC stock was made by Gupta and Rao (1994) [6]. They reported OC stock of 24.3 Pg (1 Pg = 1015 g) for the soils ranging from surface to an average sub-surface depth of 44 to 186 cm with the database of 48 soil series. However, this estimate was based on a hypothesis of enhancement of OC level judging by success stories of afforestation programmes on certain unproductive soils. An attempt has also been made to estimate the SOC stock in physiographic regions by NATMO (1980). Very recently, Bhattacharyya *et al.* (2000) [2] computed 63 Pg SOC in various physiographic regions of India in first 150 cm depth of soils. Studies of various research reports indicates that agricultural management practice; crop rotation, residue management, reduced tillage, green manuring and organic matter amendment has identified for its contribution to the improvement of soil organic matter stocks and some other nutrients. Implementing of reduced or no tillage operation has underlined in increasing organic carbon stock of the soil through delaying of organic matter decomposition and N mineralization. Long term adoption of legume based crop rotation notably increases soil organic carbon and N contents, helped with natural gift of atmospheric nitrogen fixation. Organic sources of fertilizer are reservoirs of plant nutrients and organic carbon, and hence amendment with adequate and quality manure ultimately enhances the soil nutrients and SOC stocks of the soil. In general, soil and crop management practices allow the soil to sequester more atmospheric carbon in to the soil. The circumstances ultimately contribute to agricultural sustainability, environmental and soil quality and mitigation of climate change at large. Tillage systems, farm manures and chemical fertilizers had variable effects on rice yield and growth. The farm manure improves the organic carbon by application of farm manure (Khan *et al*., 2010) [7]. The soil properties must be favourable to crop growth. Organic carbon performs additional functions of increasing soil organic matter content, and CEC, enhance biological activity, improve soil structure. (Uwah and Iwo, 2011). Manure is excellent fertilizer containing most of the major and micro nutrients. It also adds organic matters to the soil which improves soil health. Organic matter promotes microorganism those are beneficial to plant growth because they fix certain nutrients, which lasts in soil until consumed by the plants. The principle value of manure is it's extended available of nitrogen of particular value in the more readily leached sandy soils. Manure is also helpful in improving soil fertility in eroded areas from land levelling.

2. Materials and Methods

2.1 Experimental Site

The study was conducted in a long-term experimental field established at Agricultural Research Farm, Institute of Agricultural Sciences, B.H.U Varanasi in rice (cv ND-97) - lentil (cv Malyiya Vishwanath) cropping sequence to test the possible effects of tillage and incorporating fertilizer on soil fertility. Institute of Agriculture Sciences, B.H.U is situated under the greater periphery of the Holy city Varanasi at 82.52 ^{0}E longitude and 25.10" N latitude and 76.19 m above mean sea level. The Varanasi district of Uttar Pradesh lies between the parallels of 24^{0} 43 and 25^{0}35' latitude and 82^{0}11' E longitude covering a geographical area of about 1578 km^2. Varanasi lies in the middle of the Indo-Gangetic plain and falls under the agro ecological zone (AEZ). This AEZ has an area of 12.1 million hectares (3.7% of the total geographical area of India) and covers 11.62 million hectares of total gross cropped area. The experimental soil is an Inceptisol with sandy loam texture.

2.2 Treatments

The experimental design was a split-plot with three main treatments, three sub treatments and three replications. The three main-treatments were: conventional tillage (T1), reduced tillage (T2) and minimum tillage (T3) and Sub-treatments included fertilization i.e. inorganic or RDF (F1), 50% organic (F2) and organic (F3). The conventional tillage constituted of two passes of disk followed by one pass of cultivator. The reduced tillage constituted of one pass of disk and one pass of cultivator whereas the minimum tillage constituted of one pass of cultivator. Treatments are applied to rice and followed up in lentil (except one common minimum tillage given for sowing lentil).The experiment stand by conventional tillage for field preparation and layout of permanent plot under split plot design. Rice was planted during the kharif of each year and harvested by the end of October. During rabi season, lentil was planted and standard agronomic practices were followed for cultivation. Paddy seeds were sown directly in lines 30 cm apart after field preparation usually in the 13 July 2012. Lentil was sown 30 cm apart after a common tillage given after rice harvest usually in the month of October because of the monsoon rains.

The experiment comprises of 3 fertilizer treatments. Fertilizer treatments consisted of recommended dose of fertilizer (RDF) (N-P_2O_5-K_2O @ 80:40:30 kg ha^{-1}) for rice and RDF (N-P_2O_5-K_2O @ 20:40:20 kg ha^{-1}) for lentil. Organic manures in the form of FYM was integrated with inorganic fertilizers. The basic idea was to reduce the dependence on chemical fertilizers and supplement them with locally available organic resource. The whole amount of P and K was applied as basal dressing through diammonium phosphate (DAP) and muriate of potash (MOP), while nitrogen was applied in three splits viz. 40 kg N ha^{-1} as basal and remaining 40 kg N in two equal splits at active tillering and panicle initiation stage. A uniform basal application of phosphorus and potassium was made through diammonium phosphate (DAP) and muriate of potash (MOP), respectively to all the plots. In case of lentil, RDF was applied in each plot for initial growth of plant.

2.3 Sample analysis

Soil samples were collected at 0-60 cm depth at 5 cm increment from the wall of the rectangular pit using stainless steel cores measuring 5 cm in length and 5.1 cm in diameter after rice-lentil cropping sequence in 2012-13. Two such cores were collected from each pit, one for the determination of bulk density and the other for determination of TOC. Carbon stock was determined by multiplying BD (Mg m^{-1}), TOC (g Kg^{-1}) and soil depth (m).

2.4 Data statistical analysis

The data obtained were analyzed for Analysis of Variance (ANOVA) using excel and means separated using critical difference and presented in tables.

3. Results and Discussion

3.1 Soil Bulk Density

The depth-wise BD of the experimental soil of the long-term fertilizer experiment, and the treatment-wise data are presented in Table-1. Soil BD was lower with organic than with mineral fertilization. The lowest BD was observed with combination of minimum tillage and 16 ton ha^{-1} FYM (T_3F_3) treatments, and the highest in combination of conventional tillage with inorganic fertilizer (T_3F_3) in 0-5 cm soil depth. Soil BD decreased with the application of organic manure due to higher TOC concentration. BD increased with increase in soil depth. It was observed that there was no significant difference among the tillage treatments except at 10-15 cm depth. The influence of fertilization however had significant effect on bulk density at 0-5, 5-10 and 10-15 cm depths. The average bulk density in the inorganically fertilized plots was 1.35 Mg m^{-3} in the 0-5 cm depth and increased to 1.37 Mg m^{-3} in the 5-10 cm depth and to 1.40 Mg m^{-3} in the 10-15 cm. The corresponding value for organically fertilized plot was 1.27 Mg m^{-3} for 0-5 cm depth which increased to 1.31 Mg m^{-3} for 5-10 cm depth and 1.35 Mg m^{-3} for 10-15 cm depth. The values for 50% organic plots were intermediate between organic and inorganic plots. Lower value of bulk density of organically fertilized plot was due to addition of FYM @ 16 t ha^{-1} in these plots and higher values in inorganically fertilized plots were due to complete absence of organic fertilization. The effect of addition of organic manure did not bring in significant changes in bulk density at depths lower than 15 cm. Bahremand *et al.* (2003) [1] observed that application of farmyard manure reduced the soil bulk density. Zorita (2000) concluded from his studies on deep tillage and N fertilization interactions that bulk density significantly decreased as tillage intensity was increased. Lo´pez-Fando (2010) worked on no tillage (NT), reduced tillage (MT) and conventional tillage (CT) shows the data of soil bulk density for the period 1992-2009. In the 17 years studied, there were significant differences between tillage systems ($P < 0.05$). In all treatments, when the 0-5 and 5-10 cm depths were compared, higher values of bulk density were observed in the 5-10 cm layer. Chen *et al* (2009) [3] worked on conventional tillage with residue removal (CT), shallow tillage with residue cover (ST), and no-tillage with residue cover (NT) were evaluated and reported at 0-15 cm soil depth, bulk density was significantly higher under conventional tillage than shallow tillage or no tillage, whereas no significant difference occurred between shallow tillage and no tillage. At 15-30 cm, bulk density increased with soil depth and did not differ among the three tillage treatments.

3.2 Changes in Total Organic carbon

Influence of long term tillage and fertilization on total organic carbon (g kg^{-1}) at different depths after lentil in rice - lentil cropping sequence is given in table-2. The total organic carbon decrease with increased in soil depth from 7.93 to 0.87 g kg^{-1}. Higher total organic carbon was found in surface soil is because of more organic matter addition. Tillage played a significant effect on influencing the total organic carbon content in the 5-10 and 10-15 cm depths only. No significant effect was found at other depths. As discussed for bulk density the system of tillage played an important role in influencing the TOC content at different depths. Since both the tillage equipments used viz. disking and cultivator mixed the soil of the 0-5 cm uniformly; there was no significant difference among the three tillage treatments. But in ihe 5-10 and 10-15 cm depth, disk does not reach whereas the cultivator does. Hence there has been significance difference in soil disturbance and TOC contents. The main effect of tillage on TOC at 0-5, 5-10, 10-15 and 15-20 cm soil depths has been depicted in Table-2. Although the effects at 0-5 and 15-20 cm depth are non-significant, significantly higher TOC content is observable in minimum tillage followed by reduced tillage and least in conventional tillage. This is because of maximum amount of soil disturbance in conventionally tilled plots that result in oxidation of organic carbon from soil. Addition of organic inputs played a significant role in influencing the TOC content upto 15-20 cm soil depth. There was no influence of further lower depths. Fig-1 show the main effect of organic matter addition. It can be seen that greater amounts of organic matter accumulated in organically fertilized plots and least in conventional plots. The amount of TOC decreased with depths and difference in TOC between fertilization treatments were more prominent at 0-5 and 5-10 cm depths than in 10-15 are 15-20 cm depth. Chen *et al* (2009) [3] worked on conventional tillage with residue removal (CT), shallow tillage with residue cover (ST), and no-tillage with residue cover (NT) were evaluated and reported the effect of tillage on SOC. At 0-15 cm, soil organic C contents were significantly higher under ST (11.9 g kg^{-1}) and NT (11.1 g kg^{-1}) than CT (8.9 g kg^{-1}), while ST and NT were similar. Tillage had no significant effect on SOC at 15-30 cm. All the tillage treatments showed higher SOC surface soil (0-15 cm) as compared to subsurface soil (15-30 cm). Wander *et al*. (1998) found NT practices increased SOC and POM-C contents by 25 and 70%, respectively compared with conventional tillage at the surface (0-5 cm). This gain was at the expense of SOC at 5-17.5 cm depth, where SOC and POM-C decreased by 4 and 18%, respectively.

3.3 Changes in Carbon Stock in Soil

The carbon stock for each 5 cm soil depth was found to decrease with increasing soil depth. The effect of tillage and fertilization was mainly found to influence soil carbon stock upto 0-15 cm soil depth; however their interaction was not significant. At depths lower than 15 cm, soil organic carbon stock was not significantly influenced by either tillage or fertilization. The cumulative carbon stock upto 60 cm depth was however significantly influenced both by tillage and fertilization (Table-3 & Fig.-1) and varied from as low as 22.7 Mg ha^{-1} in conventional tillage and inorganic fertilization and as high as 37 Mg ha^{-1} in minimum tillage and organic manuring. Thus the positive influence of organic manuring and minimum tillage is brought out in this experiment. Surface horizons are known to store higher soil organic carbon. Gallalia (2010) reported 0.405 Pg C in the 0-30 cm and 1.006 Pg C in the 0 to 100 cm in Tunisian soils. Investigating the influence of tillage systems on soil carbon stocks, Lopez-Fando (2011) [9] reported higher carbon stocks in the no till plots as compared to minimum tilled and conventionally tilled plots. The average carbon stock in the conventional tillage plots in the 0-5 cm depth was 4.31 Mg ha^{-1} and decreased to 3.79 Mg ha^{-1} in the 5-10 cm depth and 3.34 Mg ha^{-1} in the 10-15 cm depth in the present study. In comparison, minimally tilled plots had higher carbon stock in the 0-5 cm (4.31 Mg ha^{-}1) and 10-15 cm (3.79 Mg ha^{-1}). This is because of lower disturbance in minimally tilled plots that resulted in lower oxidation of carbon as compared to conventionally tilled plots. Olson and Al-Kaisi (2015) [11] observed that no tillage (NT) sequestered organic carbon on a sloping and eroding site and had greater organic carbon stock as compared to the pre-treatment baseline, whereas mouldboard plough (MP) best considerable carbon as compared to the base line values. Thus in NT was loosing carbon as much lower rate as compared to MP plots. Scopel *et al*., (2005) [12] showed that adsorption of no tillage in fields previously under conventional tillage between 7 to 10 years had the ability to accumulate carbon. This is in line with the expectation because there is generally an increase in carbon inputs and less carbon loses through erosion and decomposition with no tillage.

Table 1: Influence of long term tillage and fertilization on soil bulk density (Mg m^{-3}) at different depths after lentil in a rice-lentil cropping sequence.

Depth (cm)	Tillage									CD 5%		
	Conventional			Reduced			Minimum					
	Fertilization											
	F1	F2	F3	F1	F2	F3	F1	F2	F3	T	F	T x F
0-5	1.36	1.33	1.30	1.35	1.32	1.27	1.33	1.31	1.25	NS	0.05	NS
5-10	1.39	1.36	1.32	1.38	1.35	1.31	1.36	1.33	1.30	NS	0.05	NS
10-15	1.44	1.40	1.38	1.42	1.39	1.37	1.36	1.34	1.31	0.05	0.04	NS
15-20	1.47	1.45	1.42	1.45	1.42	1.40	1.44	1.42	1.39	NS	NS	NS
20-25	1.53	1.49	1.45	1.52	1.48	1.44	1.50	1.47	1.43	NS	NS	NS
25-30	1.58	1.57	1.56	1.53	1.52	1.49	1.55	1.53	1.51	NS	NS	NS
30-35	1.61	1.59	1.59	1.59	1.61	1.60	1.61	1.61	1.61	NS	NS	NS
35-40	1.65	1.64	1.62	1.64	1.63	1.61	1.63	1.62	1.61	NS	NS	NS
40-45	1.67	1.65	1.65	1.65	1.65	1.67	1.66	1.64	1.66	NS	NS	NS
45-50	1.68	1.67	1.67	1.68	1.63	1.63	1.68	1.66	1.68	NS	NS	NS
50-55	1.69	1.67	1.65	1.64	1.65	1.66	1.67	1.68	1.67	NS	NS	NS
55-60	1.70	1.68	1.69	1.69	1.67	1.67	1.71	1.71	1.69	NS	NS	NS

T= Tillage; F= fertilization; F_1= Inorganic; F_2= 50% Organic; F_3= Organic

Table 2: Influence of long term tillage and fertilization on total organic carbon (g kg^{-1}) at different depths after lentil in rice - lentil cropping sequence.

Depth (cm)	Tillage									CD 5%		
	Conventional			Reduced			Minimum					
	Fertilization											
	F1	F2	F3	F1	F2	F3	F1	F2	F3	T	F	T x F
0-5	5.53	6.77	7.20	5.73	6.87	7.43	6.47	6.83	7.93	NS	0.23	0.63
5-10	4.83	5.30	6.70	5.60	6.40	6.93	6.20	6.30	7.60	0.81	0.56	NS
10-15	4.07	4.63	5.57	4.97	5.43	5.93	5.59	5.70	6.20	0.63	0.74	NS
15-20	3.73	4.17	4.77	4.67	4.97	5.20	4.59	4.70	5.30	NS	0.55	NS
20-25	3.13	3.70	3.77	4.23	4.43	4.70	4.41	4.50	4.90	NS	NS	NS
25-30	3.00	3.23	3.40	3.30	3.40	3.90	3.51	3.53	3.70	NS	NS	NS
30-35	2.60	2.77	2.90	2.90	3.00	3.33	3.37	3.60	3.67	NS	NS	NS
35-40	2.23	2.33	2.43	2.53	2.57	2.80	2.67	2.73	2.80	NS	NS	NS
40-45	2.07	2.37	2.30	2.23	2.52	2.57	2.38	2.53	2.77	NS	NS	NS
45-50	1.47	1.57	1.74	1.53	1.60	1.73	1.59	1.70	1.77	NS	NS	NS
50-55	1.27	1.40	1.45	1.30	1.43	1.47	1.53	1.61	1.68	NS	NS	NS
55-60	0.87	1.07	1.25	1.17	1.20	1.37	1.18	1.33	1.43	NS	NS	NS

T= Tillage; F= Fertilization; F_1= Inorganic; F_2= 50% Organic; F_3= Organic

Table 3: Influence of long term tillage and fertilization on soil organic carbon stock (Mg ha^{-1}) at different depths after rice-lentil cropping sequence.

Depth (cm)	Tillage									CD 5%		
	Conventional			Reduced			Minimum					
	Fertilization											
	F1	F2	F3	F1	F2	F3	F1	F2	F3	T	F	T x F
0-5	3.78	4.50	4.66	3.87	4.53	4.73	4.30	4.74	5.38	0.39	0.26	NS
5-10	3.34	3.59	4.42	3.85	4.33	4.53	4.22	4.19	4.95	0.42	0.38	NS
10-15	2.94	3.26	3.83	3.34	3.78	4.05	3.73	4.02	4.13	0.45	0.52	NS
15-20	2.74	2.99	3.37	3.37	3.53	3.64	3.30	3.33	3.69	NS	NS	NS
20-25	2.39	2.77	2.73	3.20	3.29	3.38	3.32	3.32	3.50	NS	NS	NS
25-30	2.37	2.54	2.65	2.52	2.57	2.90	2.71	2.71	2.79	NS	NS	NS
30-35	2.09	2.21	2.30	2.30	2.41	2.66	2.71	2.90	2.95	NS	NS	NS
35-40	1.81	1.91	1.98	2.08	2.10	2.24	2.18	2.21	2.25	NS	NS	NS
40-45	1.72	1.95	1.91	1.84	2.08	2.14	1.97	2.09	2.29	NS	NS	NS
45-50	1.24	1.29	1.45	1.29	1.31	1.40	1.34	1.41	1.49	NS	NS	NS
50-55	1.07	1.17	1.20	1.07	1.18	1.20	1.28	1.35	1.40	NS	NS	NS
55-60	0.73	0.88	1.06	0.98	1.00	1.10	1.01	1.13	1.21	NS	NS	NS
0-60	22.79	26.21	30.32	27.16	30.20	35.14	29.72	33.34	37.01	5.19	4.93	NS

T= Tillage; F= fertilization; F_1= Inorganic; F_2= 50% Organic; F_3= Organic

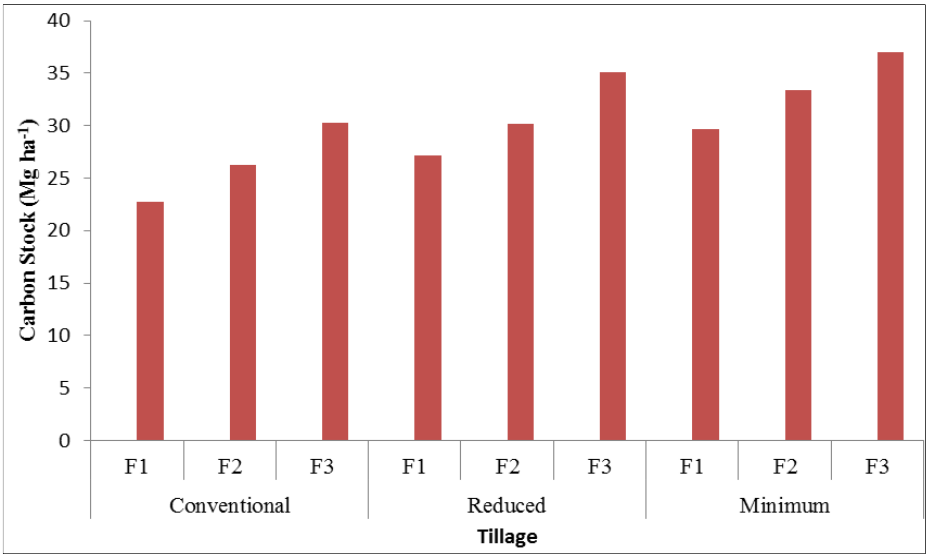

Fig 1: Influence of long term tillage and fertilization on soil organic carbon stock (Mg ha^{-1}) in 0-60 cm depth in a rice-lentil cropping sequence

4. Conclusion
In the present investigation, it was found that Bulk density decreased with depth irrespective of tillage or fertilization. Fertilization effects were greater than tillage and lower BD was observed with increasing organic matter addition. One Cultivator ploughing (minimum tillage) resulted in lower BD over disking + cultivator (conventional or reduced tillage).TOC decreased with depth. Fertilization effects were greater than tillage TOC increased with increase in manuring. Minimum tillage resulted in higher TOC over conventional or reduced tillage. The carbon stock upto 60 cm depth decreased with increasing tillage and increased with increased manuring. Carbon stock increased by 63% in changing from conventional tillage +inorganic fertilization to minimum tillage + organic manuring.

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