



Effect of different fertilizer treatment and soil texture on the emission of CO₂ in the atmosphere from the soil

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General Note



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ABSTRACT

The objectives of the present study were to investigate the effect of different fertilization treatment on Total Organic Carbon (TOC) and Total Nitrogen (TN) pool in different soil texture up to 0-30cm soil depth during the fallow period of agriculture and to calculate the amount of CO₂ released into the atmosphere from the soil in different fertilizer treatment in three different soil textures. A short term column experiment was done on three different soil texture, loamy, sandy loam and siltyclay, subjected to six treatments: 1)

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Organic Manure(OM), 2) Chemical fertilizer(CF), 3)7OM:3CF(70%Organic Manure +30% Chemical Fertilizer) 4) 5OM:5CF (50% Organic Manure +50% Chemical Fertilizer) 5) 3OM:7CF (30 % Organic Manure +70 % Chemical Fertilizer) and 6)CK (Check, means Without Fertilizer treatment). Amount of Carbon di oxide (CO_2) released into the atmosphere from the soil by using different fertilizer treatment in three different soil textures was calculated on the basis of the percentage change in TOC and comparative analysis was done in various permutation and combinations of fertilizer treatment and soil texture. The result of multiple regression taking OM and sandy loam as reference in fertilizer treatment and soil texture respectively reveals that if we shift from OM to CF treatment in sandy loam, loam or siltyclay soil, the potential of additional amount of CO_2 release in the atmosphere from one hectare agriculture land would be 40.10, 40.21, 40.62 tons respectively. Similarly the same was calculated with shifting to other fertilizer treatment from manure in different soil texture and it was found that the more use of CF the more CO_2 emission potential would be in the atmosphere. As the experiment represents fallow period so even the CK has less contribution than any combination of CF in terms of CO_2 emission in the atmosphere. Strong positive correlation was observed between percentage change in TOC and change in TN(g/Kg) (0.86, 0.79, 0.86, 0.85, 0.89, and 0.78). As per the statistical analysis of experimental data the predictability ($R^2, p < 0.05$) (0.73, 0.62, 0.73, 0.73, 0.79, 0.61) and coefficient of change in TN (g/Kg) (1.210, 0.314, 0.700, 0.548, 0.546, 0.535) with respect to percentage change in TOC decreases as we shift in fertilizer treatments OM, 7OM:3C, 5OM:5CF, 3OM:7CF, CF, CK respectively.

Keywords: Total Organic Carbon (TOC), Soil Carbon Sequestration, Fertilization, Chemical Fertilizer, Manure.

1. INTRODUCTION

Total Organic Carbon (TOC) in Soil is not only important to maintain soil fertility and to sustain productivity (Su et al. 2006; Kundu et al. 2007) but it is also important in the context of global climate change (Lal et al. 1995). Nature has provided soil as the second major sink of Carbon but Anthropogenic disturbances slowly and steadily converted them as one of the major sources of carbon. According to recent FAO's report, in 2011, 44 % of agriculture-related Green House Gasses (GHG) outputs occurred in Asia, followed by the Americas (25%), Africa (15%), Europe (12%), and Oceania (4%), according to FAO's data agricultural from crop and livestock production grew from 4.7 billion tonnes of carbon dioxide equivalents (CO_2eq) in 2001 to over 5.3 billion tonnes in 2011, a 14% increase. The increase occurred mainly in developing countries, due to an expansion of total agricultural outputs. Emissions generated during the application of synthetic fertilizers accounted for 13 per cent of agricultural emissions (725 Mt CO_2 eq.) in 2011, and is the fastest-growing emissions source in agriculture, has increased some 37% since 2001 (FAO, 2011; Devi Prasad Juvvadi, 2017). Being the largest Carbon pool in terrestrial biosphere a small change in soil carbon stocks could lead to significant impacts on atmospheric CO_2 concentration (Davidson and Janssens, 2006; Ram Asheshwar Mandal et al. 2017). Thus there is the call to action to natural scientists to further explore how organic farming functions and is better than chemical farming in terms of lesser Greenhouse gas emission by retaining large percentage TOC within the soil. Application of fertilizer increases TOC in soil because fertilization increases biomass production that leads to increasing C input (Schuman et al. 2002) to the soil and its humification (Lal 2004). But there is the lack of study on the effect of residual fertilizer on the soil during the fallow period of agriculture. Our short term column studies try to focus on this matter by focusing on the objectives: (1) To investigate the effect of different fertilization treatment on TOC and TN pool during the fallow period of agriculture in 0-30cm soil depth during the fallow period of agriculture and (2) to examine how different soil texture respond with these treatments.

2. MATERIAL AND METHODS

2.1. Experimental set up

A short term, six month (June-November.) controlled column experiment was conducted in 2016 on soil brought from Organic Farming and Chemical Farming fields located in Bulandsahar (Uttar Pradesh state in northern India having coordinates $28^{\circ}26'N$ $77^{\circ}50'E$), Ghaziabad, UP to know the response of soil organic carbon (SOC) on different fertilization treatment. Three sets of different soil texture were formed from the soils of fields, loamy (original field condition), sandy loam and siltyclay by mechanical sieving. Soils were compactly filled in 18 cylindrical columns (6*3, six of each three texture of soil) having a dimension of 30cm*5cm (Fig.1). The first column has soil of organic farming field only, the second and sixth column had soils of the chemical farming field only, third, and fourth and fifth column had the soil of both organic farming field and chemical farming field mixed in the ratio 7:3, 5:5 and 3:7 respectively. All the columns were kept in a rectangular box having an open upper side. Columns filled with soil left one week for normalizing. Experimental set up was on the atmospheric temp in a covered shed. The average atmospheric temp during

experimental period was 24.4^o C. Soil texture analysis, bulk density, pH and Electrical Conductivity (EC) of all soils of all 18 columns was done (Table 1 & Table 2). The TOC pool was calculated as given below: Tons carbon per ha = TOC (%) x Soil bulk density (Mg/m³) x Depth (cm). Tons (t) of CO₂ released into the atmosphere for every ton (t) of Total organic carbon that is decomposed is calculated by the formula: (t) CO₂ released in atmosphere = (t)TOC decomposed*3.67 (DAFWA,n.d.).

Table 1 Physical characteristics of three texture of soil

Texture	Loamy	Sandy Loam	SiltyClay
Sand (%)	40	70	5
Silt (%)	35	25	55
Clay (%)	25	5	40
Bulk Density(g/cm ³)	1.37	1.67	1.19

Table 2 pH and EC of soil subjected to different fertilizer treatment

Fertilizer Treatment	Loamy Soil		Sandy Loam		SiltyClay	
	pH	EC (ds/m)	pH	EC (ds/m)	pH	EC(ds/m)
OM	7.80	502	7.12	470	7.15	483
CF	8.00	420	7.35	424	7.34	390
OM: CF (7:3)	7.84	475	7.15	469	7.19	475
OM: CF (5:5)	7.94	459	7.19	450	7.28	455
OM:CF (3:7)	7.96	423	7.29	432	7.31	405
CK	8.00	420	7.35	420	7.34	390

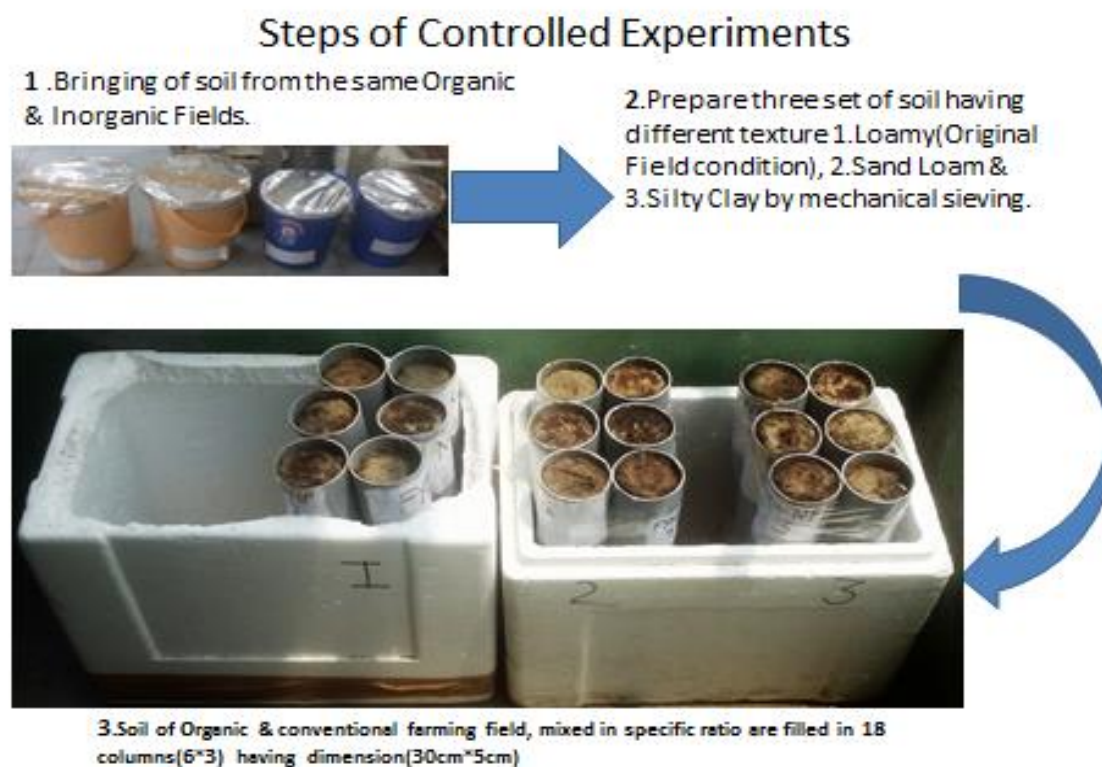


Figure 1 Steps showing the experimental setup of the controlled experiments

2.2. Fertilization treatment and management

The experiment is subjected to six fertilizer treatment on three soil texture which is as follows: 1.Organic Manure (OM), 2.Chemical Fertilizer (CF), 3. 7OM:3CF (70% Organic Manure + 30% Chemical Fertilizer) 4. 5OM:5CF (50% Organic Manure +50% Chemical Fertilizer) 5. 3OM:7CF (30 % Organic Manure + 70 % Chemical Fertilizer) and 6. CK (Check, means Without Fertilizer treatment). Now equal amount of analysed, crushed plant residue (5g) with different fertilizer treatment (10 g) is loaded on the top of each column in the first week of June and September months and is completely covered with moist soil on the top, 10ml water is provided after every 15 days to all columns throughout the experimental duration. Urea is used as chemical fertilizer whereas ripe manure of cow dung is used as organic manure.

2.3. Soil sampling and analysis

Soil samples of all 18 columns were collected thrice of five depth intervals: 0-5cm,5-10cm, 10-15cm, 15-20cm, 20-30cm by Soil Recovery Probe (1/2In*40IN) made in the USA for analysis and mixed to obtain a composite sample needed for analysis. The collected soil samples were air-dried, ground to pass through 2mm sieve and analysed for pH, electrical conductivity (EC), bulk density (BD), TN and TOC. Soil pH and EC were measured by using a soil water suspension ratio of 1:2(Sparks et al., 1996). Initial samples were collected in Jun first week after normalizing the soil and later two were collected just before second loading (September first week) and at the end of the experiment (November first week) respectively. Core samples were taken from each column for determination of bulk density. Total Organic and Inorganic Carbon was analysed by dry combustion method using Shimadzu Solid Sample Module, Model: SSM-5000A.

2.4. Statistical analysis

Two-Way ANOVA without replication was applied to analyze the significant differences of change in TOC(%) and TN(g/kg) among soil samples of different depth subjected to different fertilizer treatment. Regression coefficient was calculated between percentage change in TOC and change in TN during the experimental period. Multiple regressions were done to study the influence of different fertilizer treatment and change in TN on percentage change of TOC. SPSS statistical package & Excel (Window Version13.0) were used for data analysis. All statements reported in this study are at the $P < 0.05$ levels.

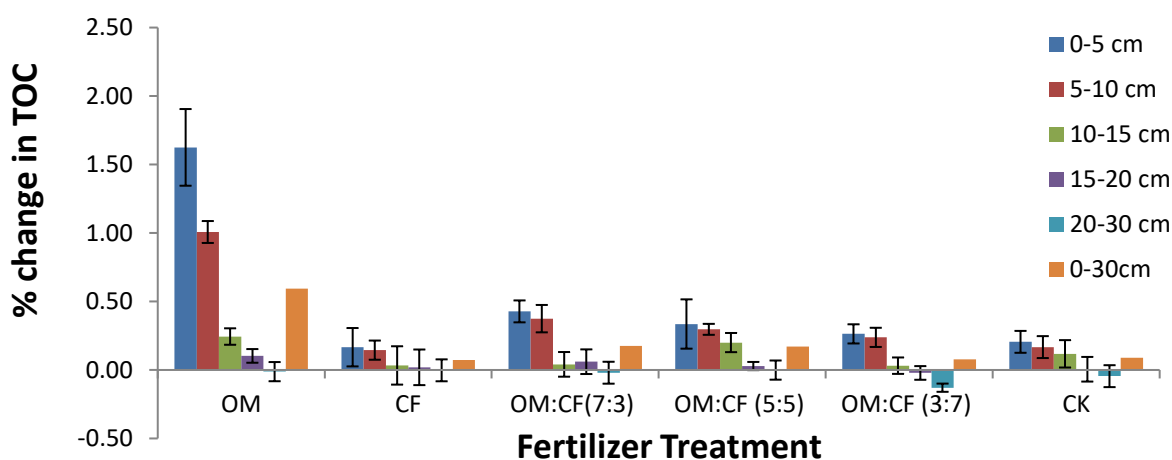
3. RESULT AND DISCUSSION

3.1. Influence of different fertilization modes and soil texture on the percentage change of TOC

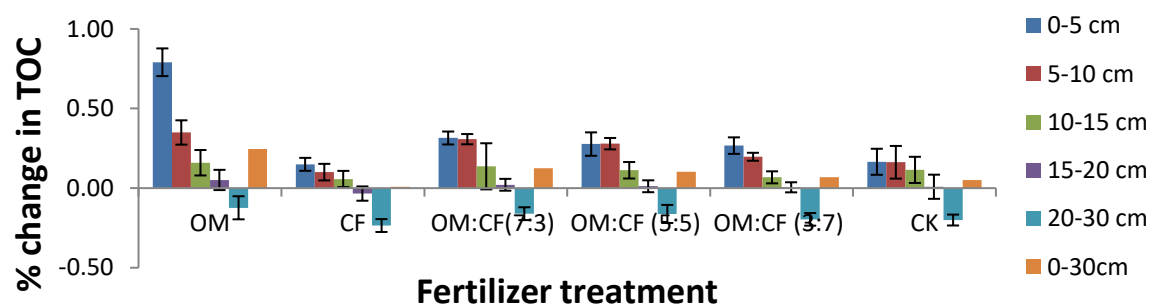
The TOC contents showed statistically significant differences among the six treatments (Fig.2). We observed that the application of OM had remarkably improved percentage change in TOC compared with the other treatment in all the texture of the soil. CF treatment showed the least improvement in percentage change in TOC among all treatment in all the three soil textures. Even the CK (checked or without any fertilizer treatment) showed improved result than CF treatment in almost all soil texture. Percentage increase in TOC in all treatment is highest in 0-5 cm depth and is decreases as we go down and is least at 20-30cm depth. The same pattern is observed in all the three soil texture. Compared with initial percentage of TOC at 0-30 cm depth the significant percentage increasing trend in TOC percentage was found as follows: OM>OM:CF(7:3)>OM:CF(5:5)>CK>OM:CF(3:7)> CF, consistent trend was observed in other studies (Wang et al.2012; Bhattacharya et al.,2010; Pan et al., 2009; Hao X.Y. et al.,2003) differing only with CK treatment because in present study fallow period of agriculture is considered subjected to same input of organic residues so no positive impact of excess production and returned input due to fertilization in the soil which leads to improving SOC (Li Z.Z. et al., 2006; Bi et al., 2009). The present study showed the impact of different fertilizer treatment, remained in the soil after harvesting of the crop, on TOC retaining capacity of the soil. No, statistically significant difference in percentage change in inorganic carbon was observed both depths wise as well as among different fertilization in all the three soil textures, same was reported by Scholten and He (2012). It may be due to the short study period, the significant difference may be observed in the long period. A statistically significant difference in carbon pool due to the texture of soil was observed in loamy, sandy loam and siltyclay soil in 0-30cm soil depth (Fig.3). siltyclay soil gave the best response in terms of retaining the highest TOC pool in all depth of soil whereas sandy lomy soil has the least storing capacity of TOC in comparison to the loamy and siltyloamy. The observed percentage change in six months in TOC in 0-5cm in loamy, sandy loam and siltyclay with OM treatment were 1.63, 0.79, 1.76 respectively, the observed percentage change in TOC decrease with depth and they were found at 20-30cm soil depth -0.01, -0.12, 0.08 respectively. With CF treatment the percentage change in 0-5cm in loamy, sandy loam and siltyclay were 0.17, 0.15, 0.54 respectively whereas the same at 20-30cm depth were as follows: 0.00, -0.24, 0.03.The observed trend to retain TOC in different soil texture were siltyclay > loam > sandy loam, which is similar to the trend observed by E. Sakin (2012), Hassink (1997), Kiem et al. (2002), and Six et al. (2002) they found that mineral soil particles (clay-silt) protected organic carbon against chemical weathering. Clay constitutes organo-

mineral complexes by combining with SOC in soil and helps to retain carbon within the soil for long periods. The carbon entering into the layers are trapped and thus protected against oxidation and weathering of organisms. Some metals in soil, clay minerals, Ca and Fe constitutes complexes with carbon in soil and protects carbon (Hassink and Whitmore, 1997). Kölbl and Kögel-Knabner (2004), determined that the amount of organic carbon in soil increased with the increase for clay. Inconsistent with the findings of the present study and previous studies in the literature, some researchers have reported a very weak relationship between SOC and texture. In a study of New Zealand soils, Percival et al. (2000) found a low relationship between clay and carbon concentration ($r^2 < 0.05$). McLauchlan (2006) reported a very slight relationship between SOC and texture, and thus texture had a lesser effect on SOC storage in comparison to other parameters.

(a)



(b)



(c)

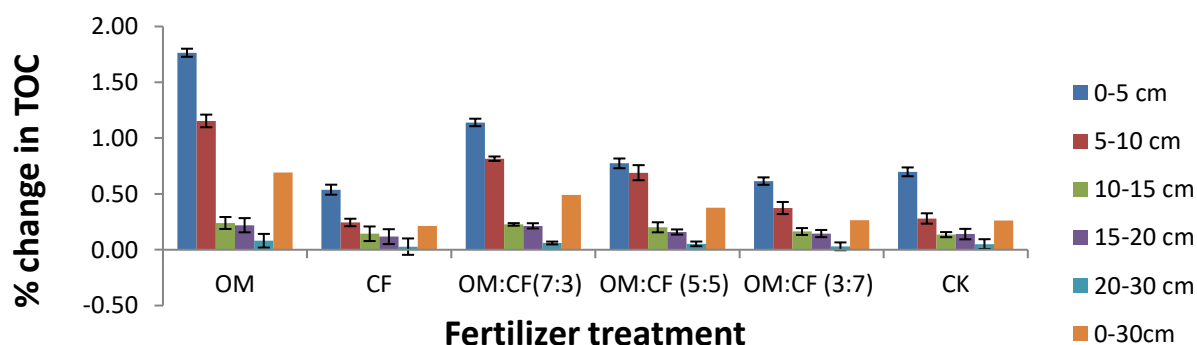


Figure 2 Average percentage change in TOC in different fertilizer treatment in different soil depth in (a) Loamy soil, (b) Sandy Loam soil & (c) Silty Clay soil. Error bars represent standard deviation. Each value refers to mean $\pm$ SD (n=3)

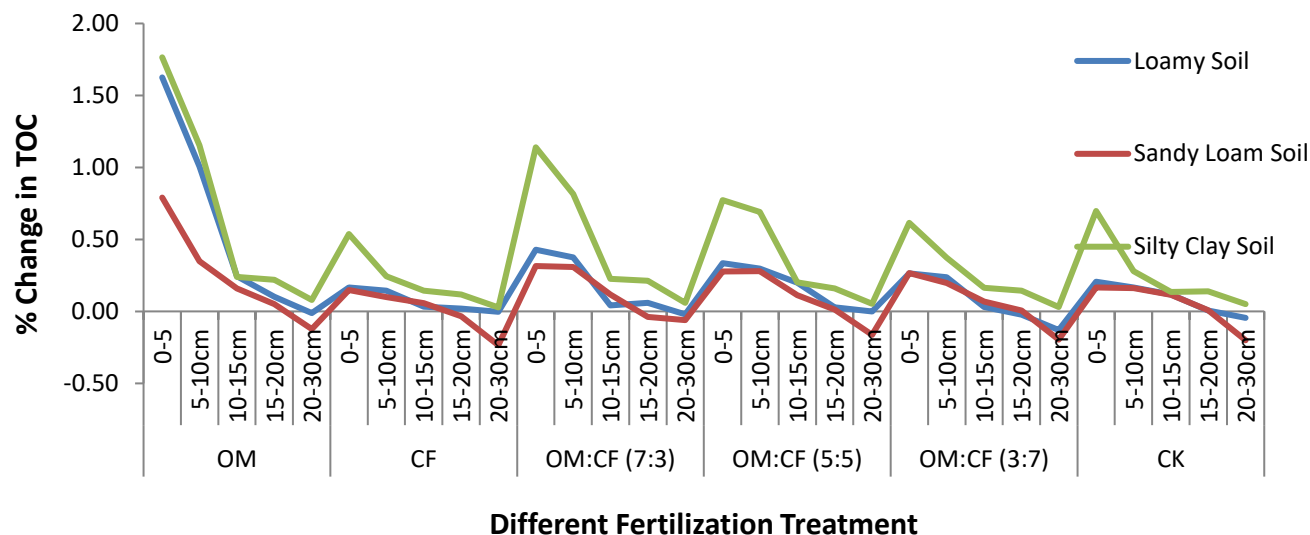
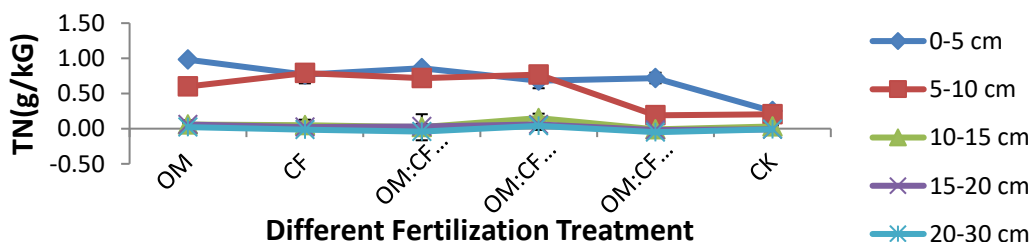


Figure 3 Average percentage change in TOC in different soil texture in different soil depth. Each value refers to mean $\pm$ SD (n=3)

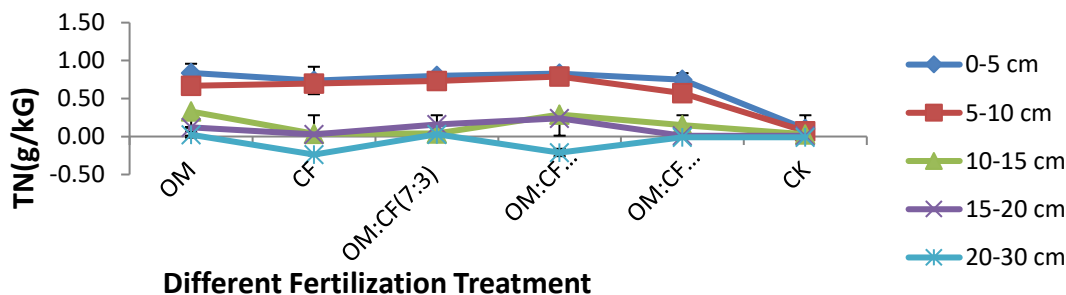
3.2. Influence of different fertilization modes on the percentage change of TN pool

The TN content showed statistically significant differences among the six treatments (Fig. 4). Specially OM treatment resulted in the highest increase TN concentration (0.34g/kg, 0.40 and 0.66g/kg) and CK the least (0.09g/kg, 0.04g/kg, 0.41g/kg) in 0-30cm in loamy, sandy loam and siltyclay soil respectively, among all soil treatment in the six month duration of the experiment. Similar to TOC percentage differences trend, TN concentration also decreases as we go down from the ground level (0 to 30 cm). Statistically significant differences in TN pool were observed in all the three observed soil texture. The siltyclay soil showed the significantly higher increase in TN Concentration in all the analysed soil depths than loamy and Sandy Loam soil in all the six treatment (Fig.5). Consistent with the finding of (Cote et al. 2000; McLauchlan et al., 2006) TN contains was found greater in the soil having higher percentage of clay and showed similar trend as shown by TOC i.e the siltyclay showed higher retaining capacity of TN than loamy and the least retaining capacity was observed in sandy loam soil texture. According to Cote et al. (2000), N mineralization increases as the percentage of clay contain increases in the soil which show positive correlation between N and Clay content. to But our finding was differing with Vejre et al. (2003) who reported an inverse relationship between clay content and Nitrogen within soil depth of 100 cm. The soils they worked as spodosol, alfisol that was well weathered and formed under high precipitation.

(a)



(b)



(c)

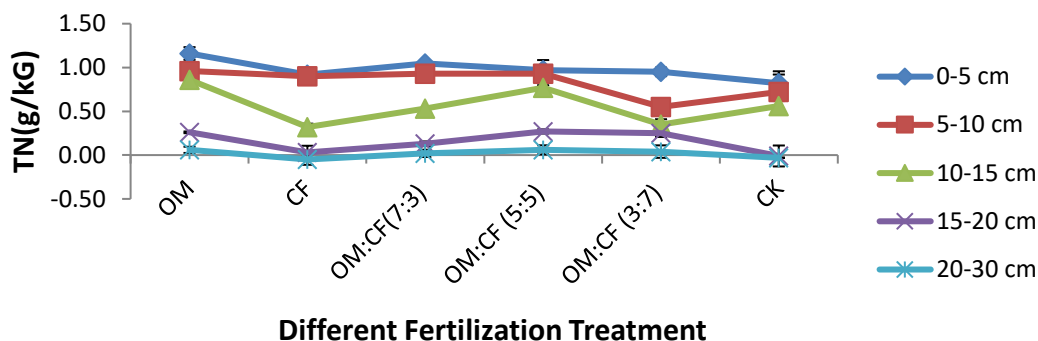


Figure 4 Average percentage change in TN(g/kg) in different fertilizer treatment in different soil depth in (a) Loamy soil, (b) Sandy Loam soil &(c) SiltyClay soil. Error bars represent standard deviation. Each value refers to mean $\pm$ SD(n=3)

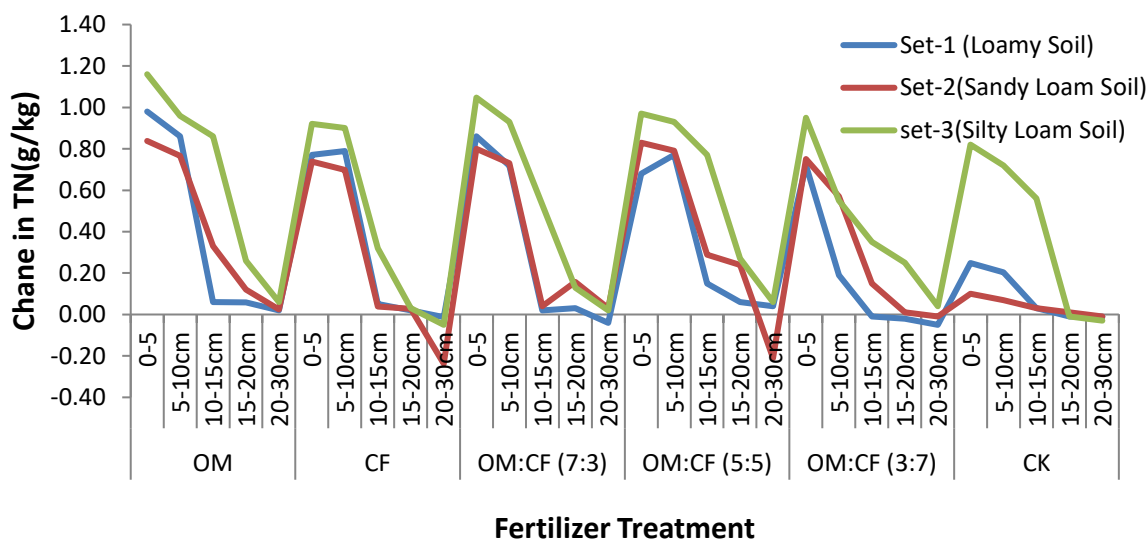


Figure 5 Average percentage change in TN in different soil texture in different soil depth, Each value refers to mean $\pm$ SD(n=3)

3.3. Relationship between change of TOC and change in TN

A linear response of percentage change in TOC to change in TN (g/kg) was observed (Fig.6). All the fertilizer treatment showed the positive correlation between percentage change in TOC and change in TN(g/kg). The observed significant correlation ($R, p < 0.05$) in fertilizer treatments OM, 7OM:3CF, 5OM:5CF, 3OM:7CF, CF, CK were 0.86, 0.79, 0.86, 0.85, 0.89, 0.78 respectively (Table 3), which states that there is strong correlation between TOC & TN in soil. Surveillance of experimental results states the R^2 value i.e. the predictability of change in TN with respect to percentage change in TOC decreases as we move towards more percentage of CF treatment (0.73, 0.62, 0.73, 0.73, 0.79, 0.61) even the positive coefficient of change in TN(g/kg) at every percentage change in TOC also decreases as we go toward more percentage of CF treatment (1.210, 0.314, 0.700, 0.548, 0.546, 0.535). So according to the experimental observation, we can interfere that practicing manure treatment not only enhances soil TOC retaining capacity thus minimizes emission of CO_2 from soil but also maintains more TN pool in soil rather than CF treatment. So we can interpret that deficiency of Nitrogen content in soil can be overcome by manure treatment too but there is need of a proper combination of crops in the farmyard to maintain the balance of nutrients in the soil.

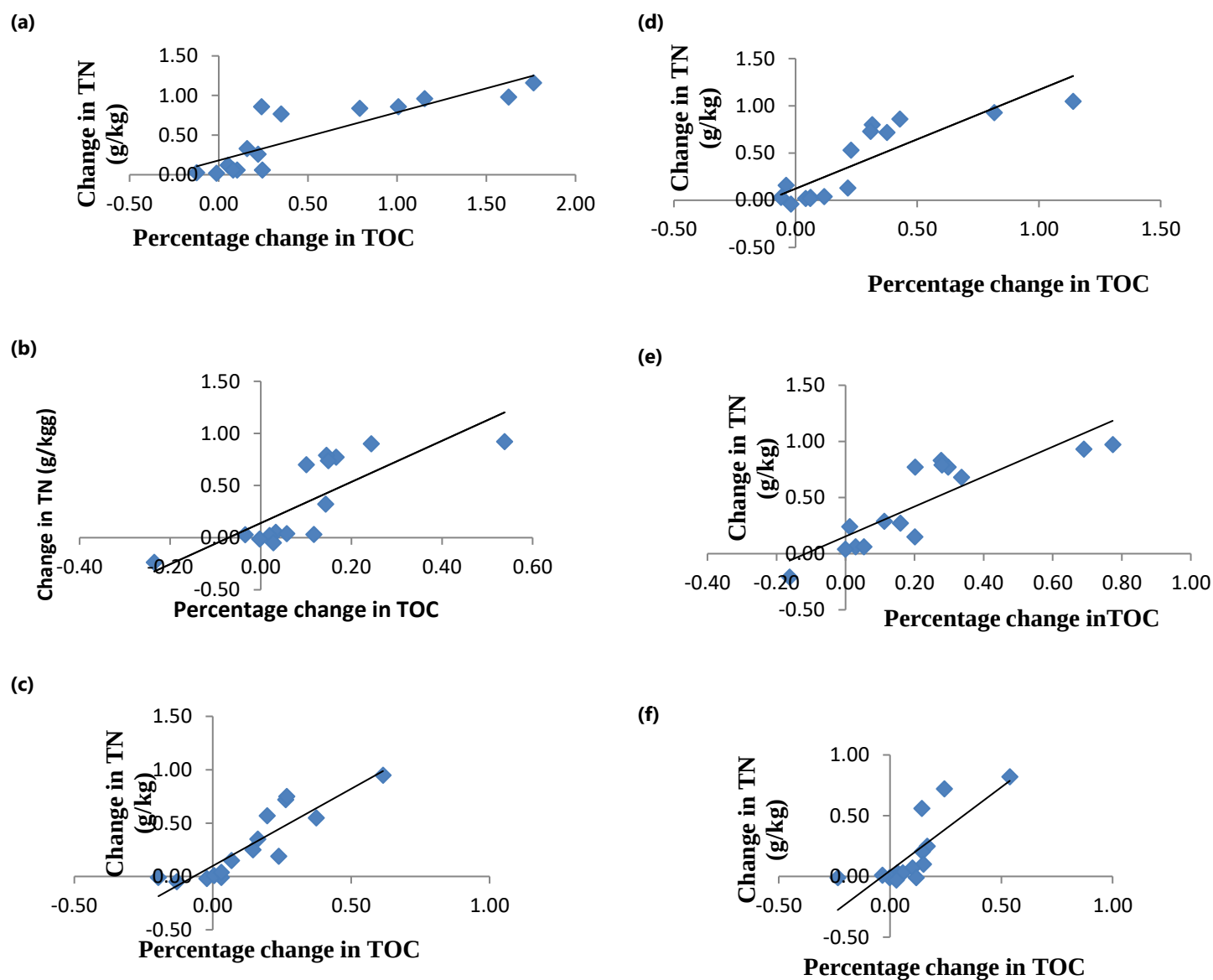


Figure 6 Regression Analysis of Change in TN in relation with percentage change in TOC(a); OM treatment (b); CF treatment (c); 7OM:3CF treatment (d);5OM:5CF treatment (e); 3OM:7CF treatment (f)CK treatment. Each value refers to mean $\pm$ SD(n=15)

Table 3 Table of regression model showing the relationship of TN with respect to TOC in the soil.

Fertilizer Treatment	Multiple R	R ²	Adjusted R ²	Standard Error	Observation	Significance F (ANOVA)	Coefficient	p-value
OM	0.86	0.73	0.71	0.33	15	0.000	1.210	5E-05
CF	0.79	0.62	0.59	0.11	15	0.000	0.314	5E-04
7OM:3CF	0.86	0.73	0.71	0.18	15	0.000	0.700	5E-05
5OM:5CF	0.85	0.73	0.71	0.13	15	0.000	0.548	5E-05
3OM:7CF	0.89	0.79	0.77	0.10	15	0.000	0.546	1E-05
CK	0.78	0.61	0.58	0.13	15	0.001	0.535	6E-04

3.4. Influence of Different Fertilizer Treatment and TN on percentage change in TOC

A Statistically significant multiple linear regression model is developed taking manure treatment as a reference in fertilizer treatment and sandy loam soil in texture (Table-4) considering other parameter constants for all permutation and combination of fertilizer treatment and soil texture. The significance F (0.000) value which is less than .05 and less than 0.05 P value of all Independent variables states that the model of predicted change in percentage change in TOC corresponding to different fertilizer treatment in different soil texture is statistically significant. Negative Sign in the coefficient of CK, CF, and 7CF:3OM, 5CF:5OM, 3CF:7OM states that the retention capacity of TOC in soil decreases as we opt other fertilizer treatment than manure. The positive coefficient value for loamy and siltyclay soil texture states that TOC retention capacity of soil increases of with 0.14 and 0.11 times respectively from sandy loam soil. The model states that in sandy loam soil if we shift from manure treatment to CK, CF, 7CF:3OM, 5CF:5OM and 3CF:7OM there would be 0.18, 0.310, 0.25, 0.26 and 0.19 per cent more degradation of TOC from soil respectively. Similarly, change in TOC percentage could be calculated for all permutation and combinations.

Net emission of CO₂ in the atmosphere is calculated taking all permutation and combinations (Table-5) which reveal how chemical fertilizer contributing in increasing CO₂ concentration in the atmosphere. The more percentage of CF has used in fertilizer the more CO₂ released into the atmosphere due to high degradation of TOC from the soil. In fallow period even controlled or checked treatment (CK) has less contribution to CO₂ emission than any combination of CF and if we 100% shifts from manure to CF treatment in siltyclay, loamy or sandy loam soil there would be 40.10, 40.21, 40.62 ton more CO₂ would be released in atmosphere respectively.

Percentage Change in TOC =

$$0.11 + 0.64 (\text{Change in TN(g/Kg)}) - 0.18(\text{CK}) - 0.31(\text{CF}) - 0.25(7\text{CF:3OM}) - 0.26(5\text{CF:5OM}) - 0.19(3\text{CF:7OM}) + 0.11(\text{Lomy}) + 0.14(\text{SiltyClay})$$

Table 4 Table of the regression model with eight explanatory variables taking Manure treatment as the reference in Fertilizer treatment variables and Sandy Loam soil in texture variable.

Regression Statistics					
Multiple R					0.83
R Square					0.69
Adjusted R Square					0.66
Standard Error					0.20
Observations					90.00

ANOVA					
	df	SS	MS	F	Significance F
Regression	8	7.498	0.937	22.843	0.000
Residual	81	3.323	0.041		
Total	89	10.821			

Table 5 Tonnes of CO₂ released in atmosphere per hectare of farm if we shift from Manure

Fertilizer Treatment	SiltyClay Soil	Loamy Soil	Sandy Loam soil
CF	40.10	40.21	40.62
7CF:3OM	32.24	32.35	32.75
5CF:5OM	33.55	32.35	34.06
3CF:7OM	24.38	24.49	24.89
CK	23.07	23.18	23.58

4. EXPERIMENTAL LIMITATION

The most important limitations of this study are (1) too short experimental duration and (2) to study the effect of fertilizer treatment without Plantation. The long-term agricultural studies indicate that the rate of change in SOC may be greatest at the beginning of the experiment but that reaching a new steady state may take more than 100 years (Johnston et al. 2009).

5. CONCLUSION

The result suggests that the fertilization treatment has significant effects on the TOC retaining capacity in all soil texture even in a fallow period of agriculture. In all the three texture of the soil, there was significant difference in percentage change in TOC & TN pools both depths wise as well as with different fertilizer treatment. In the entire column percentage change in TOC & TN was highest on topsoil (0-5cm) and it decreases as we go down the depth. In all the three soil texture, the observed significant percentage increasing trend of TOC were: OM > 7OM:3C > 5OM:5CF > 3OM:7CF > CK > CF. According to experimental data, it was observed that the potential to retain more TOC in subjected soil texture are: siltyclay > loam > sandy Loam. The result of Multiple regression taking OM as the reference in fertilizer treatment and sandy loam as reference in texture reveals that if we shift from OM to CF treatment in sandy loam, loam or siltyclay soil, the amount of CO₂ released in atmosphere from one hectare agriculture land is 40.10, 40.21, 40.62 tons respectively. So farmers are not only entitled to claims for carbon credits by opting OM instead of CF but also they will improve the fertility of their soil in every cycle of farming. As this experiment reveals that even in a fallow period of agriculture CF has its adverse effect on TOC and TN retaining capacity of the soil. By using OM we are not only preventing the soil from being converting into a source of carbon instead of the sink but also are saving our earth from that carbon which is emitting during the synthesis of these chemical fertilizers. On the contrast, during the synthesis of OM, we can generate biogas which can be used as the source of energy.

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