Research Article

Soil Organic Carbon Distribution in Different Land Use Sources of Namsai District, Arunachal Pradesh

Navamallika Gogoi*, Bhabna Sonowal and Ashika Begum

Department of Chemistry, Arunachal University of Studies, Namsai, Arunachal Pradesh-792103

Abstract

The carbon storage capacity of soil has attracted attention over the recent years due to its relation with global climate change processes. A study was conducted in Arunachal Pradesh of Namsai, to compare soil organic carbon (SOC) stocks of four different land use sources such as agricultural field(AUSAF), forest(MF), tea garden(DGTG) & paddy field(BMPF) lands from different depths (0-15)cm and (15-30)cm. Our results indicate that forest soil able to sequester higher SOC compared to the other soil. The mean SOC_{stock} at 0-15 cm depth has the order MF> BMPF DGTG> AUSAF while at 15 -30 cm depth followed the trend AUSAF > DGTG >MF > BMPF The results of Texture analysis showed dominance of sand in all the sites with marked decrease in forest soil. Strong Positive correlation between SOC and Clay observed entire study while a significant negative relationship exists between SOC with soil pH and BD.

Keywords: SOC, SOC_{stock} , BD, pH, Texture, depth

***Correspondence**
Author: Navamallika Gogoi
Email: navamallikagogoighy@gmail.com

Introduction

Soil is recognized as the natural reservoir of the terrestrial carbon pool and plays an important role in reducing global climate change [1]. Soil sequester around 75% of the total carbon reservoir on land, which is three times higher than all the plant life and also two times more than that present in the atmosphere [2]. Soil contains 1500 Pg of C up to 1.0 m depth and 2 500 Pg of C up to 2 m (1 Pg = 1 x 10^{15} g = 1 giga tonne) compared to 650 Pg of C in flora and 750 Pg of C in the environment. The ability of soil to store carbon depends on many factors such as soil physicochemical properties, environmental condition, soil and crop kind, land use pattern, management practices etc. Soil carbon and its correlation to various land use practices help in assessing carbon storage capacity of soil. Several anthropogenic factors including changes in land use and agricultural practices have significant impacts on global carbon cycle. Different studies have been reported that the physical and chemical properties of soils are influenced by changes in land use pattern [3]. Higher SOC observed in the conversion of land use to grassland and forest from cropland where as the conversion to cropland lowers the SOC content [4]. The land use change from agricultural field to vegetable cultivation is connected with a lowering SOC stock [5]. Agro forestry system have considered as having higher potential for increasing soil carbon content [6]. Yimer et al. compared crop lands, forest lands, and grazing lands and found that soil organic carbon decreased in crop lands as compared to forest land [3].

Distribution of SOC is closely related with soil depth. In tropical region global estimates of the SOC pool to 2-m soil depth were lower than for soils from all other regions. Major SOC research has focused on top layer soil but it is also being reported that subsurface soils also play an important role in SOC storage [7]. Physicochemical properties of the soil significantly influence the decomposition of SOC [8]. Soil pH has an enormous influence on crop production, discharge of soil nutrient and reaction of soil microorganism. Decomposition of organic matter in the top soil will lead to the formation of humic and organic acid and thereby lowering the topsoil pH values [9]. BD bulk density helps in developing appropriate soil management practices and it is one of the most influencing parameters used to quantify SOC storage [10]. Variation of soil particle size distribution i.e. soil texture also influence on Soil organic matter dynamics. The availability of oxygen in sandy soil is more than that of fine textured soil due to which decomposition of organic matter quicker in sandy soil.

The main purpose of soil carbon sequestration are to increase the SOC storage capacity and to storage it in soil for a longer duration and thus help to reduce the overall release of the greenhouse gases. In our study, we discuss the variations of SOC sequestration in relation to land use types of Namsai district, Arunachal Pradesh. Accordingly the present study aimed to (1) determine the SOC concentration of soil under different land use types (2) determine the influence of landuse sources on SOC stock (3) determine the impact of soil depth on SOC concentration (4) correlate the SOC concentration with soil physicochemical properties.

Materials and Methods
Study area

Namsai district of Arunachal Pradesh, India is a foothill district. The Namsai district is well known for its rich wealth of medicinal plant diversity. The major field crops in the district are paddy (winter and summer varieties), black gram, wheat, jute, summer moong, pea, mustard, sesame, etc. Horticultural crops include vegetables like tomato, potato, brinjal, all kind of cucurbits, etc. Spices grown are chillies, onion, garlic, turmeric, coriander, etc. Important plantation commercially cultivated plant include ginger, Orange, bamboo, lemon, etc.

The district receives annual rainfall of about 228mm with 75% received during the monsoon months (June to September). Both pre- and post- monsoon months have unpredictable and erratic rainfall. The mean maximum temperature varies from 33 to 16.60ºC and the mean minimum temperature varies from 26 to 12.20ºC. Out of the geographical area of 1587 Sq. Km in the district, 191.31 Sq.Km described as the net cultivated area [11].

Collection of the soil sample

The field study and sampling of soil was carried out from February 2019 to March 2020. The study included Agricultural field, Forest area, Tea Garden and Paddy Field. The details of the sampling sites are shown in **Table 1**.

Table 1 Location of the sampling sites

Sample ID	Name	Latitude/Longitude	Dominant vegetation
AUSAF	Arunachal University of Studies agricultural field	27º38′50.25″N 95º52′13.75″ E	Vegetables, grains, sugarcane, banana, pulse crop
MF	Manabhum Reserve Forest	27º45′41.90″N 95º57′13.27″ E	Common trees include in this forest are Holong , Meka , Holok, Nahor etc.
DGTG	Dirak Gate tea garden	27º38′59.19″N 95º52′27.79″ E	Tea
BMPF	Bordumsa-Mahadevpur Paddy Field	27º38′11.51″N 95º47′39.66″ E	Paddy is grown throughout the year in three seasons- winter (Sali crop), autumn (ahu) and summer (boro).

Sampling and handling of soil

At each location, soil samples were collected within 1000m^2 (approx) areas (four diagonally opposite corner and one from the centre) from two different depth (0-15cm and 15-30cm) using soil cores. Soil samples were brought to the laboratory in polythene bags, air dried, lumps broken and kept spread over a white paper and were homogenized to form a complex sample. Soil samples were air dried and sieved with a 2mm sieve and keep in air-tight glass containers (stock sample).

Analysis of soil properties

Soil organic carbon (SOC) concentration was determined by using Walkey-Black method with $K_2Cr_2O_7$ and concentrated H_2SO_4 as the oxidizing agent [12]. The water-holding capacity(WHC) was determined by using the equation; WHC (%) = (mass of wet soil –mass of dry soil) x 100 [12]. Soil pH were measured in 1:5 soil-water suspensions with a digital pH meter (Elico101E). The texture of the soil samples in terms of clay, silt and sand composition was determined by the Bouyoucos hydrometer method and the texture class was read from the ISSS texture triangle [12]. The bulk density (BD) of the soil was determined by dry weight of the soil in a cylinder of known volume and the volume of the sample [13]. Soil carbon protective capacity (g C kg^{-1} soil) is calculated on the basis of the formula; SOC_{PC} = 0.21 × (silt+clay) content + 14.75) [14].Soil organic Carbon stocks were calculated using the equation;SOC_{stock} (t ha^{-1}) = C content(%) x Bulk density (mg m^{-3}) x Depth(m) x 100 [15].

Results and Discussion
Physicochemical properties of soil

The SOC, SOC_{stock}, SOC_{pc}, Clay, Silt, Sand, Texture class, pH, BD, WHC data for both sampling year are presented in **Tables 2** and **3**. The average pH recorded at 0-15 cm depth and 15-30 cm depth was 5.26 and 5.81 respectively for first sampling batch. While for second sampling batch at 0-15 cm depth and 15-30 cm depth the mean pH value was 5.78 and 5.72 respectively. In this work we observed that all sampling sites are acidic in nature. The acidity of the sampling sites might be due to the high rainfall condition. Negative correlation exists between SOC and soil pH [16]. SOC can decrease the soil pH by introducing humic and organic acid and thereby increasing the solubility of the metal complex. The results of Texture analysis showed dominance of sand in all the sites with marked decrease in forest soil (MF). At various scale sand dominate soil show variable morphological, chemical and ecological properties [17]. Sand fractions of the soils showed variation at 0-15 cm and 15-30 cm depth ranging from 79.28% - 67.28% and 85.84% - 72.56% respectively for first sampling batch (2019). For second sampling batch (2020) the variation ranging from 88.88 % -69.00% and 89.13 % - 72.00% at 0-15 cm and 15-30 cm depth respectively. Strong negative correlation observed between sand and clay fraction (r = -0.94, r = -0.99 at 0-15cm and 15-30 cm depth respectively for first sampling batch and r = -0.98, r = -0.72 at 0-15 cm and 15-30 cm depth respectively for second sampling batch (**Tables 4** and **5**). Silt fractions of the soils showed variation at 0-15 cm and 15-30 cm depth ranging from 10.72% - 6.44% and 14.72% - 5.44% respectively for first sampling batch. Wide range of variation of silt fraction observed at 15-30 cm depth (13.12% - 0.87%) for second sampling batch. Entire study forest soil showed the high values of clay fraction for both sapling depths. Positive correlation between SOC and Clay observed entire study (Tables 4 and 5). It was reported that clay accumulate C relatively quickly [18]. Increases concentration of clay in the surface soil enhance water holding capacity and act as a warehouse of soil microbial activity. Among the textural classes SCL (sandy clay loamy) soil holds maximum SOC (MF = 3.24%, BMPF = 2.03% first sampling batch and MF = 1.99%, 1.77% for second sampling batch). It has been observed that Bulk density is negatively correlated with the SOC (for first sampling batch r = -0.89 and r = -0.93 at 0-15 cm and 15-30 cm depth respectively and for second sampling depth r = -0.86 and -0.73 at 0-15 cm and 15-30 cm depth respectively (Tables 4 and 5). Similar negative correlations also reported by Rudrappa et al. [19]. The BD of the soil were found to be influenced by texture of the soils which was evident from highly significant relation of clay with BD. Six et al. reported that low water holding capacity enhances the loss of the soil organic carbon [20]. It is to be noted that all the sampling sites dominated by Sand, which have poor water capturing capacity. Sand dominated soil made up mainly quartz, resulting in higher soil organic matter oxidation.

Table 2 Soil properties of the different soil sample at 0-15cm and 15-30cm depth for first sampling batch(2019)

Site	SOC (%)	pH	BD (g cm^{-3})	WHC (%)	Sand (%)	Silt (%)	Clay (%)	Texture	SOC_{stock} (t ha^{-1})	SOC_{PC}
0-15 cm depth										
AUSAF	2.24	6.45	0.91	48.95	76.56	10.72	12.72	SL	30.58	19.67
MF	3.24	3.71	0.80	59.33	67.28	10.00	22.72	SCL	38.88	21.62
DGTG	2.13	5.76	1.02	48.27	79.28	10.72	10.00	SL	32.59	19.10
BMPF	2.03	5.13	1.09	53.08	73.56	6.44	20.00	SCL	33.19	20.30
Mean	2.41	5.26	0.96	52.41	74.17	9.47	16.36		33.81	20.17
Max	3.24	6.45	1.09	59.33	79.28	10.72	22.72		38.88	21.62
Min	2.03	3.71	0.80	48.27	67.28	6.44	10.00		30.58	19.10
15-30 cm depth										
AUSAF	2.13	6.62	0.93	35.46	75.40	13.16	11.44	SL	29.71	19.92
MF	2.11	4.68	0.85	48.66	72.56	14.72	12.72	SL	26.90	20.51
DGTG	1.85	6.42	1.06	39.44	85.84	5.44	8.72	LS	29.42	17.72
BMPF	2.30	5.52	0.82	59.28	78.56	10.72	10.72	SL	28.29	19.25
Mean	2.10	5.81	0.92	45.71	78.09	11.01	10.90		28.58	19.35
Max	2.30	6.62	1.06	59.28	85.84	14.72	12.72		29.71	20.51
Min	1.85	4.68	0.82	35.46	72.56	5.44	8.72		26.90	17.72

Where WHC: Water holding capacity; SOC: Soil organic Carbon; SOC stock: Soil Organic carbon stock, BD: Bulk density; SL=Sandy Loamy, SCL= Sandy Clay Loamy; LS= Loamy Sand;
AUSAF: Arunachal university of studies agricultural field; MF: Manabhum Reserve Forest;
DGTG: Dirak Gate tea garden ;BMPF: Bordumsa-Mahadevpur Paddy Field

Distribution of SOC showed the value to be higher in the 0-15 cm depth and lower in the bottom depth for both sampling batch. Among the four land use type forest soil (MF) showed highest value of SOC concentration. At 0-15 cm depth higher values of SOC content in forest area for both sampling batch 2019 and 2020. But no distinct trend was observed for 15-30 cm depth. Yimer et al. [3] also reported the higher values of SOC in the forest area compared to crop lands [3]. In our study SOC concentration showed decreasing trend with depth (except BMPF at 15-30 cm depth at first sampling batch).For both depth, most of the soil sources from agricultural farm had the lowest value of SOC stock in the entire study (Tables 2 and 3).

Table 3 Soil properties of the different soil sample at 0-15cm and 15-30cm depth for first sampling batch(2020)

Site	SOC (%)	pH	BD (gcm^{-3})	WHC (%)	Sand (%)	Silt (%)	Clay (%)	Texture	SOC_{stock} ($t\ ha^{-1}$)	SOC_{pc}
0-15 cm										
AUSAF	1.95	6.64	1.45	37.90	72.00	11.28	16.72	SL	42.41	32.24
MF	1.99	4.90	1.50	35.44	69.00	9.28	21.72	SCL	44.78	31.19
DGTG	1.81	6.10	1.55	33.80	78.56	8.72	12.72	SL	42.08	33.08
BMPF	1.76	5.49	1.68	35.00	88.88	4.56	6.72	SAND	44.35	34.37
Mean	1.88	5.78	1.55	35.54	77.11	8.46	14.47		43.41	32.72
Max	1.99	6.64	1.68	37.90	88.88	11.28	21.72		44.78	34.37
Min	1.76	4.90	1.45	33.80	69.00	4.56	6.72		42.08	31.19
15-30 cm										
AUSAF	1.68	6.54	1.58	38.70	77.00	13.12	9.88	SL		33.68
MF	1.77	4.75	1.47	40.25	72.00	8.00	20.00	SCL	39.03	31.55
DGTG	1.62	6.30	1.60	35.60	89.13	0.87	10.00	LS	38.88	33.65
BMPF	1.60	5.28	1.54	39.60	78.28	8.44	13.28	SL	36.96	32.96
Mean	1.67	5.72	1.55	38.54	79.10	7.61	13.29		38.67	32.96
Max	1.77	6.54	1.60	40.25	89.13	13.12	20.00		39.82	33.68
Min	1.60	4.75	1.47	35.60	72.00	0.87	9.88		36.96	31.55

Where WHC: Water holding capacity; SOC: Soil organic Carbon; SOC stock: Soil Organic carbon stock,BD: Bulk density; SL=Sandy Loamy ,SCL= Sandy Clay Loamy ;LS= Loamy Sand AUSAF:Arunachal university of studies agricultural field;MF: Manabhum Reserve Forest;DGTG: Dirak Gate tea garden ;BMPF: Bordumsa-Mahadevpur Paddy Field

Table 4 Pearson correlation at 0-15 cm and 15-30 cm depth for 2019

0-15 cm	SOC	pH	BD	WHC	Sand	Silt	Clay
SOC	1						
pH	-0.81	1					
BD	-0.89	0.45	1				
WHC	0.85	-0.96	-0.57	1			
Sand	-0.85	0.90	0.62	-0.99	1		
Silt	0.30	0.23	-0.60	-0.25	0.24	1	
Clay	0.63	-0.85	-0.33	0.94	-0.94	-0.55	1
15-30 cm	**SOC**	**pH**	**BD**	**WHC**	**Sand**	**Silt**	**Clay**
SOC	1						
pH	-0.40	1					
BD	-0.93	0.70	1				
WHC	0.68	-0.68	-0.75	1			
Sand	-0.62	0.57	0.76	-0.17	1		
Silt	0.63	-0.53	-0.76	0.15	-0.9	1	
Clay	0.58	-0.65	-0.76	0.21	-0.99	0.99	1

The SOC_{stock} was varied from 38.88 t ha^{-1} - 30.58 t ha^{-1} and 29.71 t ha^{-1} - 26.90 t ha^{-1} at 0-15 cm and 15-30 cm depth respectively for first sampling batch. While for second sampling batch SOC_{stock} was in the range of 44.78 t ha^{-1} - 42.08 t ha^{-1} and 39.82 t ha^{-1} -36.96 t ha^{-1} at 0-15 cm and 15-30 cm depth respectively for second sampling batch. The lower SOC_{stock} observed in the deep soil layer could be attributed to the lower amount of input from external sources. For both sampling batch forest soil have the high value of SOC_{stock} at 0-15cm depth. Looking at the average values, considering both sampling batch(2019 &2020) the mean SOC_{stock} at 0-15 cm depth has the order: MF(41.83 t ha^{-1}) > BMPF (38.77 t ha^{-1})>DGTG(37.34 t ha^{-1}) > AUSAF (36.49 t ha^{-1}) while at 15 -30 cm depth followed the trend AUSAF (34.76 t ha^{-1}) > DGTG (34.15 t ha^{-1}) >MF (32.63 t ha^{-1}) > BMPF (34.76 t ha^{-1}).The SOC_{stock} in topsoil significantly greater than the bottom layer soil. SOC_{pc} help to determine the stability of organic matter in soil. For both sampling batch the average SOC_{pc} (g C kg^{-1}) in this work followed the trend at 0-15 cm depth BMPF(27.34 g C kg^{-1}) > MF(26.41 g C kg^{-1}) >DGTG (25.09 g C kg^{-1}) >AUSAF (25.96 g C kg^{-1}) and at 15-30 cm depth has the order

(26.80 g C kg^{-1}) > BMPF (26.11 g C kg^{-1}) >MF(26.03 g C kg^{-1}) >DGTG (25.69 g C kg^{-1}).

Table 5 Pearson correlation at 0-15 cm and 15-30 cm depth for 2020

0-15 cm	**SOC**	**pH**	**BD**	**WHC**	**Sand**	**Silt**	**Clay**
SOC	1						
pH	-0.10	1					
BD	-0.86	-0.36	1				
WHC	0.60	0.44	-0.59	1			
Sand	-0.95	-0.01	0.94	-0.44	1		
Silt	0.79	0.46	-0.99	0.56	-0.89	1	
Clay	0.96	-0.19	-0.85	0.36	-0.98	0.78	1
15-30 cm	**SOC**	**pH**	**BD**	**WHC**	**Sand**	**Silt**	**Clay**
SOC	1						
pH	-0.45	1					
BD	-0.73	0.93	1				
WHC	0.52	-0.71	-0.82	1			
Sand	-0.71	0.62	0.82	-0.96	1		
Silt	0.32	-0.01	-0.24	0.71	-0.76	1	
Clay	0.74	-0.93	-0.98	0.70	-0.72	0.08	1

Impact of sampling depth on SOC

Sampling depth is an important consideration for the quantification of SOC concentration [21]. A decreasing trend in SOC with increasing depth of the sampling sites was observed for most of the soil samples (**Figure 1**). With the increase in soil depth there was a gradual decrease of Clay fraction observed for all sampling sites (except BMPF for second sampling batch) which could be due to the content of higher SOC in the top layer of the sampling sites. Previous study also reported that average SOC content decreased with increasing soil depth (3.78 g C kg^{-1} for 0-20 cm depth while at 20-40 cm and 40-60 cm soil layer SOC content decrease by 0.90 and 1.26 g C kg^{-1}) estimates for agricultural soils [22]. Slow and stable decomposition of rice straw increases the C input to the surface layer [23]. The SOC_{stock} decreased with increasing soil depth for tea garden soil also reported by Kalita et al. [24]. High SOC on top soil has important effect on several soil quality because surface soil receives fertilizer and pesticides and it also act as a partitions of gas-water fluxes into and out of the soil . Therefore, higher amount of SOC on surface soil help to filter contaminates, influence food productivity, regulates terrestrial water flow and act as a storehouse of soil microorganisms.

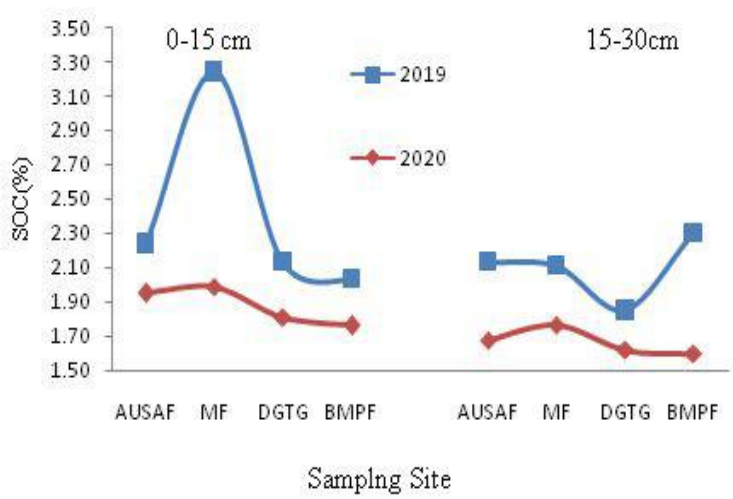

Figure 1 Variation of SOC (%) for the years 2019 and 2020 at 0-15 cm and 15-30 cm depth

Effect of land use system on SOC

It has been observed from our study that, the SOC potential showed no distinct significant influences on different land use type. The surface soil layer contains high values of clay fraction in the forest soil more likely to accumulate dissolved organic matter [2]. Some researcher report that for tepid climate the critical limit of SOC concentration is 2% [25] while that in tropical soil is 1.1% [26]. In our present study, all the study area has SOC concentrations above the critical limit (1.1%). For the most cases in our study, the SOC concentration was observed higher in the forest soil. While minimum value was observed in the Tea garden soil. Lower soil disturbance and higher organic input in the Forest soil enhances the SOC concentration compared to cultivated land [20]. Higher SOC stock in surface layer could be attributed to high organic matter content, low soil disturbance, higher plant biomass and returns of crop residue [27]. For both depths, most of the soil sources from agricultural farm had the lowest value of SOC stock in the entire study. Improper use of inorganic fertilizer on fields may be the reasons for the lack of SOC stock.

Conclusion

Soil Carbon sequestration is a slow process and a short period of measurements would not be sufficient to obtain significant conclusion on SOC potential. However from the correlation study, it is observed that SOC concentration show positive correlation with Clay and WHC of soil while negative correlation observed with pH and BD. Our results revealed that forest soil able to sequester higher SOC compared to the other soil. Therefore forest land use pattern in our study may be an important example to keep a balance of high SOC stocks. In addition, higher SOC concentration observed at top soil layer compared to the lower soil layer. These results are likely to contribute the fundamental information of different soil sources of Arunachal Pradesh in terms of quality and also help to improve the management practice

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