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Organic carbon sequestered in the secondary forest soils of Ukhrul District, Manipur, North East India

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Abstract

Soil plays an important role in the global carbon cycle. It acts as both sink and source of carbon in the atmosphere depending on the land use system. The objective of the present study is to estimate the amount of carbon that can be sequestered in the forest soils of Ukhrul district in Manipur, North-east India. The samples were collected from the forest area ofMatiyang village situated in the eastern side of Ukhrul District, which is located near the Indo-Myanmar frontier. The soil samples (100 each) were collected at 0-15cm and 15-30cm depths. The samples were randomly collected from 100 pits of 30m x 30m x 30m and marked using Global Positioning System (GPS). The soil samples were then analysed for soil organic carbon content (SOC). The mean organic carbon content in the forest soil of the area was worked out taking into account all the 100 samples each from the two depths. For the purpose of statistical analysis, the area was categorised into three elevation - lower, middle and upper, and only 28 samples from each elevation was considered. The mean organic carbon content in the forest soil of the area is 2.93 and 2.04 at 0-15 cm and 15-30 cm respectively, while the organic carbon content in the soil at 0-30 cm is 2.48%. An independent samples t-test was conducted to compare the means of SOC between the two depths and between the three elevations. The results of this t-test revealed a significant difference ($p<0.05$) in the mean of SOC% between the two depths suggesting that the depth has an effect on the distribution of organic carbon in the soil while on the other hand there was no significant difference ($p>0.05$) in the mean of SOC% between the elevations suggesting that the amount of organic carbon is randomly distributed irrespective of the elevation.The data presented in the study indicates a fairly large amount of soil organic carbon present in this forest area.

Keywords: Soil, secondary forests, soil organic carbon, global carbon cycle, independent samples t-tests, North-east India

INTRODUCTION

Soil is the largest pool of carbon in the terrestrial ecosystem. The soil holds about twice the amount of carbon contained in the atmosphere and three times more than the vegetation biomass (Post et al., 1990; Johnson and Kerns, 1991). Soil organic carbon constitutes an important role in the global carbon cycle and making our planet earth capable of sustaining life. Since carbon present in the atmosphere is one of the green houses gases that contributes to global warming, soil plays a vital role in regulating the global climate scenario by acting as a carbon sink. The sequestered carbon in the soil is, however, loss or released back into the atmosphere when there is disturbances of any kind to the land use system or unstable land management practices (Lal 2010 a,b). Thus, soil functions both as a sink and source of carbon to the atmosphere. The role of soil organic carbon in modifying and ameliorating the effects of global warming and climate change has drawn the interests of researchers and scientists working in these fields (Jensen et al., 1996).

The world's soil stores nearly 75 per cent of the terrestrial carbon (Henderson, 1995) and according to Dixon et al. (1994) and Huntington (1995) the organic carbon of the forest soils constitutes 40 per cent of all the total belowground carbon. The estimate of carbon in the world's soil varies between 1000 Pg to 2500 Pg. According to Buringh (1984) the world's soil contains 1477 Pg of carbon, and Post et al. (1990) and Johnson and Kerns (1991) projected the estimates to be at 1500 Pg of carbon,Sombroek et al. (1993) estimated the value to be 1220 Pg of carbon, while Eswaran et al. (1993), Houghton (1995) and Batjes (1996) estimated it as 1576 Pg of carbon, 1431 Pg of carbon and 2200 Pg of carbon, respectively. A report by WBGU (1998) stated that the soil is the largest reservoir of carbon, accounting for 2011 Gt of carbon, which is approximated to be 81 per cent of the total carbon in the terrestrial biosphere. Based on a recent study, the global soil organic carbon was estimated to be 1502 Pg of carbon (Jobággy and Jackson, 2000), a value which is much closer to that given by Post et al. (1990) and Johnson and Kerns (1991). The total soil organic carbon stock of Indian soil is 47.53 Pg which constitute to about only 3 per cent of the world's total soil organic carbon stock (Velayutham et al., 2000). Thus, the Indian soil has been categorized as having low organic carbon content (Manna and Rao, 2012). However, the forest soils in the hills of northeast and south are rich in organic carbon especially the surface layer (Velayutham et al., 2000). It was found that at an elevation of 610m to 1311m the organic carbon percentage in the native forests is 4.82 (Jenny and Raychaudhuri, 1960).

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Soil carbon consists of both inorganic and organic carbon. The soil organic carbon constitutes a considerable part of the soil organic matter, approximately 58 per cent of the organic matter content (Buringh, 1984).The organic carbon content in the soil is highly susceptible to anthropogenic activities like fire (Fernandez et al., 1997; Haslam et al., 1998; Johnson and Curtis, 2001; Kumar et al., 2013), land use system like deforestation (Houghton et.al., 1983) or conversion of forest to cultivated land (Vitousek, 1983; Arrouays et al., 2001; Murty et al., 2002, Don et al., 2011) and afforestation (Paul et al., 2002). Therefore, proper land use system and management of soil is crucial for maintaining the organic carbon. Soil organic carbon is the basis of soil health, fertility and quality, which is essential for maintaining the productivity of soils (Henderson, 1995).

The objective of this study is to estimate the amount of soil organic carbon in the forest soils of Ukhrul district in Manipur, one of the North-eastern states of India. Since soil organic carbon is an essential indicator of soil quality and fertility, having knowledge of the amount of organic carbon content in the soil will be necessary to preserve the productivity of this valuable resource. Besides, the study will enable us to assess the potential and capacity of the forest soil, in this area, to capture or store carbon in the forest soils.

MATERIALS AND METHODS

Study area

Manipur, one of the seven sisters of the North Eastern Region of India, is an isolated hill-girt state stretching between 93º03′ to 94º78′ E longitudes and 23º80′ to 25º68′N latitudes. It has a geographical area of 22,327 sq. km, out of which 20,089 sq. km is covered by hills and the remaining area is valley covering 2,238 sq. km and accounting for only one-tenth of the total area of the state.

The study was conducted in Ukhrul district, one of the hill districts of Manipur. Ukhrul district is situated on the Eastern part of Manipur at an altitude ranging from 388m to 2834m above MSL. It shares its boundary with Chandel district in the South, Imphal and Senapati district in the West and Nagaland in the North. In the East, it lies on the International Border of Myanmar. The climate is temperate in nature and varies between a minimum of 5ºC and a maximum of 27ºC and with an average rainfall of 1,449.3 mm (Working plan of Eastern Forest Division, Ukhrul district, Manipur, 2001). Ukhrul district occupies an area of 4,544 sq. km (20.37% of the total geographical area of Manipur). The district comprises of 230 villages and has a population of 1,83,115 (Census 2011). The Tangkhul tribe constitutes the 90% of the Ukhrul District's population. They are one of the major Naga tribes. The tribal community largely practice slash-and-burn cultivation and it is the chief land use practice in this region. Most of the area in this region has been subjected to slash-and-burn cultivation and cycles, with an exception of very few forest areas, which remain untouched due to various reasons like inaccessibility, rugged terrain, unsuitable for cultivation, sacred grooves and distance from the village.

Soil sample collection and analysis

The soil samples were collected from the forest area of Matiyang village situated in the eastern side of Ukhrul District, which is located near the Indo-Myanmar frontier. The forest area where the soil samples were collected falls under a secondary forest. This area is mostly inaccessible most part of the year except during the dry seasons, with only a mud track road reaching only up to Chamu village, and has a difficult terrain and therefore the area remains thickly forested. The soil samples were collected randomly in the month of January-February 2013 for the analysis of soil organic carbon content at two different depths - 0 - 15 cm and 15 - 30 cm. The samples were collected from 100 pits of 30cm x 30cm x 30cm and a total 200 samples were obtained. Each sample pit was marked using Trimble Juno 3B Global Positioning System.The soil samples collected were grouped into three elevation categories - lower elevation (1000-1090m), middle elevation (1091-1170m) and upper elevation (1171-1300m) to test statistically whether there is any significant difference in the sequestered soil organic carbon.The soil samples were then analysed for soil organic carbon content for the area using wet digestion or titrimetric determination method of Walkley and Black (1934). The mean organic carbon content in the forest soil of the area was worked out taking into account all the 100 samples each from the two depth. For the purpose of statistical analysis, 28 samples each from the three elevations were taken into account. An independent samples t-tests was conducted to compare the mean of SOC% between the two depths - 0-15cm and 15-30cm of the study area as well as at the three elevation ranges. The t-test was also conducted to compare the means of SOC% between top layer of the three elevations and between bottom layers of these elevations. Statistical analysis was carried out using IBM SPSS-19 Statistical software.

RESULTS

The soil organic carbon (SOC) content in the forest soils of the present study area is estimated to be 2.48% at 0-30 cm depth. The mean percentage of SOC of the study area was recorded as 2.93 and 2.04 at 0-15cm and 15-30cm depth respectively. A statistical analysis was done using independent samples t-test to compare the mean of soil organic carbon percentage in the top (0-15cm) and bottom (15-30cm) layersof the study area.

The results, for the independent samples t-test are given in Table 1, suggest that there is a significant difference ($p<0.05$) in the mean of the percentage of soil organic content in the top (M=2.93; SD=0.77) and in the bottom (M=2.04; SD=0.77) layer; $t(198)=8.161$, $p=0.000$.

Table I: Independent samples t-test of mean percentage of soil organic carbon (SOC) between the top and bottom layer of the study area

Variables and pairs	Percentage of SOC (Mean)	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed) P
Top	2.93	0.77	0.07	8.161	198	0.000
Bottom	2.04	0.77	0.07			

Note: Top=0-15cm depth; Bottom=15-30cm depth.

The study area falls under the elevation of 1000 - 1300m. The area was categorised into three elevation ranges - lower, middle and upper, and the mean SOC content of the soil samples in each elevation was compared between the two depths of 0-15cm and 15-30cm. An independent samples t-test was conducted again. Once again the results (Table 2) show that there is a significant difference ($p<0.05$) in the mean of SOC% between the top layer and the bottom layer of all the three elevation groups. The results in Table 1 and Table 2 indicate that the depth has an effect on the distribution of organic carbon content in the soil.

Table 2: Independent samples t-test of mean percentage of SOC between the top layer and bottom layer at the three elevations.

Variables and pairs	Percentage of SOC (Mean)	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed) P
Low_top	3.04	0.55	0.10	6.358	54	0.000
Low_bot	2.09	0.55	0.10			
Mid_top	3.22	0.47	0.08	10.492	54	0.000
Mid_bot	1.98	0.40	0.07			
Up_top	3.26	0.54	0.10	4.494	39.240	0.000
Up_bot	2.22	1.10	0.20			

Note: Low=lower elevation (1000-1090m); Mid=middle elevation (1091-1170m); Up=upper elevation (1171-1300m); top=0-15cm depth; bot=15-30cm depth.

An independent samples t-test was also conducted to compare the percentage mean of SOC between the upper layer of lower, middle and upper elevations(Table 3), the bottom layer of the three elevations(Table 4) and mean percentage of organic carbon in the soil samples at 0-30cm depth between the three elevation ranges (Table 5). However, the results of these t-tests indicates that there is no significant difference ($p>0.05$) in the mean percentage of SOC. The outcome of these independent samples t-tests suggests that the organic carbon in the soil are randomly distributed irrespective of the elevation ranges.

DISCUSSION

The mean percentage of organic carbon content of the soil in the present study area is 2.48 %, which is comparatively lower to the amount reported by Jenny & Raychaudhuri (1960) for the Himalayan range of North-east India (4.82%) andNoordwijk et al. (1997) for a secondary forest in Sumatra (6.66%). However, the present study shows a higher percentage of organic carbon than those reported for soil in natural forests (1.92%) of Meghalaya, North-east India (Majumdar et al., 2004), forest soil (0.59-2.00%) in Madhya Pradesh (Velmurugan et al., 2009), forest soil in Senapati district (1.20%), Manipur (Binarani and Yadava, 2010) and Chittagong hill tracts (1.55%), Bangladesh (Biswas et al., 2012). The SOC percentage in the upper layer from this study is far less than that reported by Tivet et al. (2012) in the forest soil of Southern Brazil (5.98±0.22)and Gharwal Himalaya (4.44) as noted by Gairola et al. (2012). Although, the top layer of the forest soils in the current study area contains more percentage of SOC when compared with the forest of Terrai zone in West Bengal. Tawnenga et al. (1997) noted 2.65±0.2 per cent of organic carbon in the top layer soil of secondary forest in Mizoram, which is quite closer to the estimates found in the current study area. Considering the 0-30 cm layer of soil, this study,which recorded an estimate of 2.48% is comparatively higher than the soil organic carbon content found in Eastern Ghats (1.4% at 0-30 cm), Tamil Nadu (Ramachandran et al., 2007).

Table 3: Independent samples t-test of mean percentage of SOC of the top layer between the three elevations.

Variables and pairs	Percentage of SOC (Mean)	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed) P
Low_top	3.04	0.55	0.10	-1.341	54	0.185
Mid_top	3.22	0.47	0.08			
Mid_top	3.22	0.47	0.08	-0.302	54	0.764
Up_top	3.26	0.53	0.10			
Low_top	3.04	0.55	0.10	-1.548	54	0.127
Up_top	3.26	0.54	0.10			

Table 4: Independent samples t-test of mean percentage of SOC of the bottom layer between the three elevations.

Variables and pairs	Percentage of SOC (Mean)	Std. Deviation	Std. Error Mean	T	df	Sig. (2-tailed) P
Low_bot	2.09	0.55	0.10	0.852	54	0.398
Mid_bot	1.98	0.40	0.07			
Mid_bot	1.98	0.40	0.07	-0.537	54	0.595
Up_bot	2.22	1.10	0.20			
Low_bot	2.09	0.55	0.10	-1.062	34.099	0.295
Up_bot	2.22	1.10	0.20			

Table 5: Independent samples t-test of mean percentage of SOC at 0-30cm between the three elevations.

Variables and pairs	Percentage of SOC (Mean)	Std. Deviation	Std. Error Mean	T	df	Sig. (2-tailed) P
Low	2.56	0.50	0.09	-0.307	54	0.760
Mid	2.60	0.39	0.07			
Mid	2.60	0.39	0.07	-1.156	54	0.253
Up	2.74	0.49	0.09			
Low	2.56	0.50	0.09	-1.319	54	0.193
Up	2.74	0.49	0.09			

The results from the analysis also show a decrease in the mean percentage of soil organic carbon from the top (upper) layer to the bottom (lower) layer, which corresponds with earlier studies carried out for soil organic carbon content both in India and abroad (Tawnenga et al., 1997; Ramachandran et al., 2007; Koul et al., 2011; Tivet et al., 2012; Gairola et al. 2012). The higher percentage of soil organic carbon in the upper layer can be attributed to the fact that most of the organic matter is found in the upper layer as a result of organic input from the aboveground biomass and their rapid and continuous production and decomposition of litter (Palm et al., 1996, Koul et al., 2011). Jobbágy and Jackson (2000) also suggested through their study that the plant functional types, through differences in allocation, regulate the distribution of soil organic carbon with depth in the soil. Batjes (1996) reported that on an average 39-70% of total organic carbon are held in the upper layer and that the first 30 cm of the soil layer stores a large amount of carbon. He also stated that carbon, which occurs in deeper layer is in a fairly stable form and do not contribute to gaseous emission.

CONCLUSION

Sequestering carbon in the soil has a potential to reduce the carbon dioxide concentration in the atmosphere (Lal, 2005). The data presented in this study shows the potential of sequestering carbon in the forest soil of the present study area. The study indicates the large amount of percentage of organic carbon stored in the soils of this forest area. Any changes in the land use system like conversion of the forest into agricultural land use, will cause the soil to release the sequestered carbon into the atmosphere. The estimates of carbon in the forest soil of this present study area also indicate the status of the soil health. High percentage of organic carbon in the forest soil indicates a good and productive soil. To sustain the productivity and quality of the soil in the present area proper management of soil is crucial.

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