Article

Soil organic carbon sequestration potential of primary and secondary forests in Northeast India

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Abstract
Plant, animal and microbial residues in all stages of decomposition contribute to soil organic carbon (SOC). Measurement of SOC will not only help us to assess the productivity and the sustainable fertility of the soil but it will also give us an idea about the potentials of the soil for sequestering carbon from the atmosphere or the emission potential when the soil is disturbed. The objective of this paper is to estimate and compare the SOC content in the primary and secondary forests up to 30 cm depth in Ukhrul District, Manipur. The secondary forest has been subjected to many cycles of shifting cultivation. The samples were analysed for the organic carbon content using Walkley-Black method. The mean SOC was found to be much higher in both upper (0-15cm) and lower (15-30cm) layer of the primary forest (5.25% and 3.12%) than the secondary forest (2.97% and 1.88%) respectively. Independent samples t-test shows that these means of SOC differ significantly between the two sites and the two layers. This study proves, based on the comparison of SOC content in the primary and secondary forest, the ability of forest soil to sequester carbon, if it remained undisturbed. It implies that the soil in these forests can be a chief source or sinks of carbon in nature and can play an important role in the mitigation and adaptation to climate change.

Keywords soil organic carbon; community forest; primary forest; secondary forest; climate change.

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1 Introduction

Climate change is one of the major issues of the present century (Zhang and Liu, 2012). Various anthropogenic activities contribute to the ever rising concentration of carbon in the atmosphere leading to shifts in the global temperature. Forest plays a crucial role in mitigating climate change by regulating the global carbon cycle. Forest acts as the sink for the atmospheric carbon and has the potential to sequester and store it in the vegetation and soils. The forest soils sequester a large amount of carbon from the atmosphere (Lal, 2005). The upper layer of the world's soil stores nearly three times more than the amount of carbon held in the atmosphere

(UNEP 2012). However, this large storage also implies that any disturbances to the land use system can cause emission of the sequestered carbon into the atmosphere (Lal, 2010).The sequestered carbon in the soil is mainly stored in the form of soil organic carbon (SOC). Plant, animal and microbial residues in all stages of decomposition contribute to SOC. Lal (2005) stated that the amount and concentration of soil organic carbon in the forest soil are affected by a variety of factors. Studies have shown that factors such as precipitation (Post et al., 1982; Mehta et al., 2014), temperature (Telles et al., 2003), slope (Prichard et al. 2000), landscape (Gulledge and Schimel, 2000), vegetation (Jobággy and Jackson, 2000), cation exchange properties of soil (Chandler, 1939), soil texture (Paul, 1984; Borchers and Perry, 1992; Banfield et al., 2002), 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; Murty et al., 2002, Don et al., 2011, Tabi et al., 2013) and afforestation (Paul et al., 2002), affect the ability of the soil to store organic carbon.

SOC is an indicator of soil productivity. It is an important constituent of the soil's chemical, physical and biological health. Measurement of SOC will help us to assess the productivity and the sustainable fertility of the soil. Besides, quantifying the SOC content will also provide us with an idea about the potentials of the soil for sequestering carbon from the atmosphere or the emission potential when the soil is disturbed. The objective of this paper is to estimate and compare the SOC content in the primary and secondary forests in Ukhrul District, Manipur.

2 Study area and Methodology

2.1 Study site

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. The remaining area is valley covering 2,238 sq. km.

The study was conducted in Ukhrul District in the eastern part of Manipur state. It is located at 94º6' to 94 º45' E longitudes and 24 º20' to 24 º42' N latitude. The terrain is hilly with altitudes ranging from 913m to 3114m above MSL. It is bounded by Nagaland in the north, Imphal district in the south and Senapati district in the west. In the East, it lies on the international border of Myanmar. The mean minimum and mean maximum temperature vary between 3ºC and 33ºC and with an average rainfall of 1449.3 mm. Ukhrul District occupies an area of 4,544 sq. km (20.37% of the total geographical area of Manipur). The Tangkhul tribe constitute the 90% of the Ukhrul District’s population. They are one of the major Naga tribes. The Kukis also co-exist in some parts of the District, but their population against the Tangkhul is small.

2.2 Data collection

The study was carried out in the community forest land managed by two neighbouring village - Matiyang and Chamu village situated on the eastern side of Ukhrul District, which is located near the Indo-Myanmar frontier. The soil samples were collected from the primary and secondary forests area. Most of the forests in the study area are secondary forest with few patches of undisturbed primary forest. The secondary forests have undergone repeated cycles of shifting cultivation, which is the main source of livelihood for the people living in this region. Based on the interaction with the locals the secondary forest, where the present study was carried out, has been left fallow after shifting cultivation for ~25-30 years.

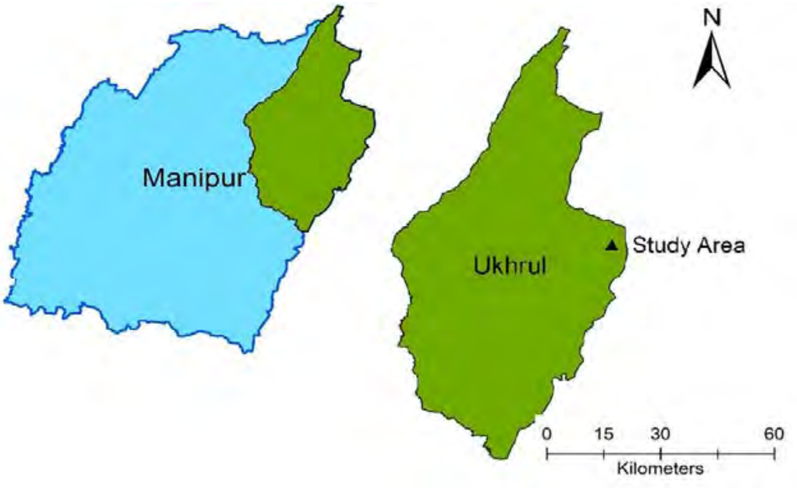

Fig. 1 Location of the study area.

A reconnaissance survey of the study area was carried out in January 2012 for secondary forest and January 2014 for the primary forest. The soil samples were collected randomly in the month of January-February 2013 and January -February 2015 respectively for the two sites. The soil samples were collected from 20 pits of 30cm x 30cm x 30cm at 0-15 cm (top) and 15-30 cm (bottom) depth and a total 40 samples were obtained from each site. Each sample pit was marked using Trimble Juno 3B Global Positioning System. 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).

2.3 Data Analysis

All the statistical analysis was carried out using IBM SPSS 19, statistical software. An independent samples t-test was conducted to compare and determine whether the mean percentage of soil organic carbon content in the top and bottom layer of each site were significantly different with depth. The same t-test was also conducted to compare the means of the SOC percentage between the top layers of the two sites and between the bottom layers of the same, to find out which of the mean percentages of SOC were significantly different from each other.

3 Results and Discussion

The estimates of mean SOC was found to be much higher in the primary forest (5.25%) than the secondary forest (2.97%). There is a decrease in the SOC percentage from the upper layer to the sub-surface layer in both primary and secondary forests (Table 1). The mean of SOC percentage shows a significant difference between the top and bottom layers in both the sites with $p < 0.05$ as shown in Table 1 indicating that depth has an effect on the amount of organic carbon content in the soil.

The Independent sample t-test between the mean SOC percentage in the top layers of the primary and secondary forest soil and bottom layers of the two sites also indicates a significantly different mean with $p < 0.05$ (Table 2). This result implies that the type of land use system has a significant effect on the SOC concentration.

Table 1 Independent sample T-test between top and bottom layers of primary and secondary forest soils.

Forest type	Layer	SOC % (Mean)	Range SOC %		Std. Deviation	Std. Error Mean	t	Df	Sig. (2-tailed)P
			Min.	Max.					
Primary	Top	5.25	2.65	8.36	1.47	0.33		38	0.000
	Bottom	3.12	0.18	5.10	1.15	0.26	5.105		
Secondary	Top	2.97	0.84	4.30	0.77	0.17		38	0.000
	Bottom	1.88	0.69	4.14	0.72	0.16	4.602		

Top = 0 - 15 cm depth; Bottom = 15 - 30 cm depth

Table 2 Independent samples T-test between the top layers of primary and secondary forest soils and between the bottom layers of the same.

Layer	Forest type	SOC % (Mean)	Range SOC %		Std. Deviation	Std. Error Mean	t	Df	Sig. (2-tailed)P
			Min.	Max.					
Top	Primary	5.25	2.65	8.36	1.47	0.33			
	Secondary	2.97	0.84	4.30	0.77	0.17	6.127	28.667	0.000
Bottom	Primary	3.12	0.18	5.10	1.15	0.26			
	Secondary	1.88	0.69	4.14	0.72	0.16	4.063	38	0.000

Top = 0 - 15 cm depth; Bottom = 15 - 30 cm depth

The outcome of our study indicated that the soil in the top layer and in the primary forest has more potential to sequester and hold carbon in it. The mean SOC percentage in the top layer of the two sites has higher values than the sub-surface layer, which is also observed in other studies (Table 3). The higher SOC concentration in the top layer could be due to organic carbon inputs from the forest canopy as litterfall and partially or completely decomposed vegetations on the surface layer. Land use changes or disturbances have also known to have a significant effect on the carbon sequestering potential of soil (Don et al., 2011). In the present study, the higher SOC content in the soil of primary forest can be attributed to years of carbon sequestered and stored as the area remained untouched by man.

The SOC percentage in the primary forest of the present study area is higher than most of the forest areas mentioned in Table 3, except that of secondary forest in Sumatra and forest in Brazil. Although the soil in the secondary forest has lower SOC percentage than the primary forest, it still contains a good percentage of organic carbon when compared to other forest soils (Table 3).

Table 3 SOC percentage in various forest soils from different sources.

Site	Depth (cm) of the soil	SOC (%)	Source
North-east India, Himalayan ranges	--	4.82	Jenny and Raychaudhuri (1960)
Secondary forest (20 yrs fallow), Mizoram, Northeast Region India	0-10	2.65±0.20	Tawnenga et al. (1997)
	10-20	2.22±0.18	
Secondary forest, Sumatra	--	6.66	Noordwijk et al. (1997)
Natural forest, Meghalaya, Northeast region India	--	1.92	Majumdar et al. (2004)
Kolli hills, Tamil Nadu	0-30	1.4	Ramachandran et al. (2007)
	30-60	0.86	
	60-90	0.66	
Senapati District, Manipur	0-10	1.20	Binarani & Yadava (2010)
Natural forest, Terai Zone, West Bengal	0-10	1.77	Koul et al. (2011)
	10-20	1.53	
	20-30	1.38	
	30-40	1.16	
Oak forest, Kumaun Divison, Uttarakhand, Central Himalaya	--	1.82	Bora & Singh (2012)
Forest, Southern Brazil	0-5	5.98±0.22	Tivet et al. (2012)
	5-10	2.78±0.23	
	10-20	1.99±0.23	
	20-40	1.85±0.12	
	40-60	1.58±0.11	
	60-80	1.29±0.19	
	80-100	1.08±0.10	
Gharwal Himalaya, Uttarakhand*	0-10	4.44	Gairola et al. (2012)
	11-30	2.55	
	31-60	2.16	
Chittagong Hill Tracts, Bangladesh	--	1.55	Biswas et al. (2012)
Nanmangalam Reserve Forest, Tamil Nadu	0-15	0.14 - 0.87	Radhapriya et al. (2014)
	15-30	0.12 - 0.41	
Narmada Forest Division, Gujarat	0-15*	1.3 ±0.1	Yadav et al. (2015)
	15-30*	1.2 ±0.2	
	0-15#	1.6 ±0.7	
	15-30#	1.3 ±0.5	
Forest soil, Kadapa District, Andhra Pradesh	0-10	1.156 ±0.47	Mastan et al. (2015)
	10-30	0.874 ±0.41	
Primary forest	0-15	5.25	Present study Ukhrul District, Manipur
	15-30	3.12	
Secondary forest	0-15	2.97	
	15-30	1.88	

*Dry deciduous forest; #Moist deciduous forest

4 Conclusions

The SOC content in the primary forest indicates the potential of the forest soil to sequester carbon, if it remained undisturbed from anthropological disturbances, in this case shifting cultivation. Even though the secondary forest in the present study has been subjected to many cycles of shifting cultivation, the forest soil still holds a fairly good amount of SOC, which implies the recuperating capacity of the soil. The study, thus, implies that the soil in these forests, with proper land use management like maintaining or improving tree cover and proper forestry management, can sequester and store the carbon in the soil reducing the amount in the atmosphere thereby playing an important role in the mitigation and adaptation to climate change.

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