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Soil organic carbon and carbon stock in community forests with varying altitude and slope aspect in Meghalaya, India

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Abstract

The contribution of forest ecosystems to the global climate change mitigation by storing carbon in the soil and their vegetation in nature is significant. Soil contain three times more carbon than that stored in the vegetation of an area. Altitude is one of the important factors influencing various parameters of the soil including carbon stock. Present study was conducted to understand variation in the soil carbon and carbon stock with respect to altitude and aspect in community forests of three agro ecological regions of Khasi Hills, Meghalaya. The study concluded that, Central upland region with highest elevation has highest level of carbon stock (47.27±2.12t/ha), followed by the Northern undulating region (28.09 ±1.25t/ha) and lowest in the South Precipitous low elevation region (24.24±.60t/ha). The result leads to the conclusion that the areas with higher altitude has higher carbon stock as compared to lower elevation areas which may be attributed to decreasing temperature with increasing altitude which inhibits the decay rate of soil organic matter which in turn induces higher carbon content in the soil. The study also record a strong positively relationship between altitude and other soil parameters like soil organic carbon, nitrogen and carbon stock. However it is negatively correlated with soil bulk density.

Keywords: Soil organic carbon, carbon stock, altitude, aspect, climate change.

Introduction

During the past few decade the world has observed serious rise in the carbon dioxide level in the atmosphere[1]. Burning of fossils fuel alone contributes to nearly two-third of the total rise. While the rest is due to the release of carbon from the soil due to changing of land use system[1]. This phenomena has gain the attention of many innovative community to reduce the rising level of atmospheric carbon dioxide with the concept of capturing and storing it in the soil and vegetation in the terrestrial ecosystem so as to prevent the green house emission thus ultimately preventing or mitigating climate change. The uptake of Carbon by the vegetation and soil of terrestrial ecosystems playa tremendous role in determining the accumulation of carbon dioxide level in the atmosphere and also the rate of change in global climate. Besides the other land use, in the terrestrial biosphere, forest has gain more importance in the context of soil carbon storage.

Carbon from the atmosphere mostly gets absorbed into the terrestrial ecosystem mainly through photosynthesis by the vegetation. Leaf and litter fall in the forest is decomposed in the detritus path way thereby introducing carbon into the soil. The concentration of carbon stored in soils of the terrestrial ecosystems is as much as thrice to that which is being stored in the vegetation[2] which is roughly twice to that in the atmosphere[3]. For this reason, soil carbon stock has gain importance as even a small changes or fluctuation in organic carbon in the soils may have serious influence on the universal carbon cycle[4]. The organic carbon in the soil has also been considered as an important pool among the other major natural carbon pools in the Land Use Land Use Change in Forestry sector as described by the IPCC (Intergovernmental Panel on Climate Change)[5].

The amount of carbon stored in the soil is very much significant for the global terrestrial ecosystem carbon stock which is also strongly influenced by the altitude of the area. However there is no concise conclusion on the relationship between altitude and SOC (soil organic carbon) and SOC stock area. Various researchers have reported a positive relationship between SOC and altitude[6-8], although not always[9,10]. With this concept, the present research was conducted with the aim of understanding carbon stock variations along the different altitudinal and slope facing direction or aspect in the community forests of the different agro-ecological regions of Khasi Hills, Meghalaya.

Study area: The study was conducted in three agro-ecological zones of Khasi hills, Meghalaya, a north eastern state of India from March 2016 to February 2017. The state of Meghalaya is a hilly area with varying degree of elevation, slope and aspects. The state also has a diverse pattern of distribution of rainfall. Meghalaya has been divided in to four broad agro ecological regions[11]. The Central Upland Region (CUR) comprising of majority of the Khasi and Jaintia Hills Districts is characterised by high elevation and medium rainfall. The highest plateau point of the state is the Shillong peak which is locate in this region with an elevation of upto 1961M. The South Precipitous

Regions (SPR) mainly includes the South areas of mainly the Khasi and Jaintia Hills Districts and some parts of Garo hills Districts and it stretches to the border of the neighbouring country of Bangladesh. The region is characterised by gorges and steep slopes. This region receives the highest rainfall in the state. Mawsynram and Cherrapunjee areas with highest record of rainfall globally are located in this region. The Northern Undulating Hills (NUH) is the region bordering the neighbouring state of Assam. This region is characterised by low elevation with gentle slope and low rainfall. Lastly the Western region with low elevation and low rainfall includes the majority of the Garo Hills Districts of the state. Meghalaya is divided into eleven districts which can be broadly grouped into three categories viz. Khasi Hills (East, West, South West khasi hills, and Ri-bhoi), Jaintia Hills (East and West Jaintia Hills) and Garo hills (East, West, North and South Garo Hills)[12]. However, for the present study only the Khasi Hills are taken as study area. From the DEM (Digital Elevation model) of the state, it is clear that the districts of Khasi hills are diverse in the agro- ecological Zones and most of the zones described for the state are found in this area.

Forests in Meghalaya are very important. They cover approximately about seventy seven percent out of the total geographical area of the state. Besides the forest cover of the state, one attention drawing facts of the state's forests is that majority of the forest area in the state (approximately 94%) are owned and controlled by the tribal people, whose rights are being protected by the sixth scheduled of our country[13]. Commonly these forests are collectively known as community forests which are further classified into different forest types based on their ownership, belief and degree of protection like Raid forests, Clan Forest, Village forests, Restricted Forest, Prohibited Forests, Sacred forests etc[14]. These forests form an important part of the livelihood of the people of the state. They also are home or repository to the floral and faunal diversity of the state. Apart from diversity and other environmental services provided to the tribal people of the area, these forests also house a large amount of carbon in their vegetation and soil. However the high dependence of the people on these forests has placed a huge threat and stress on them. Destruction or conversion of these forests to other form of land use can mean direct releasing of the carbon back into the atmosphere.

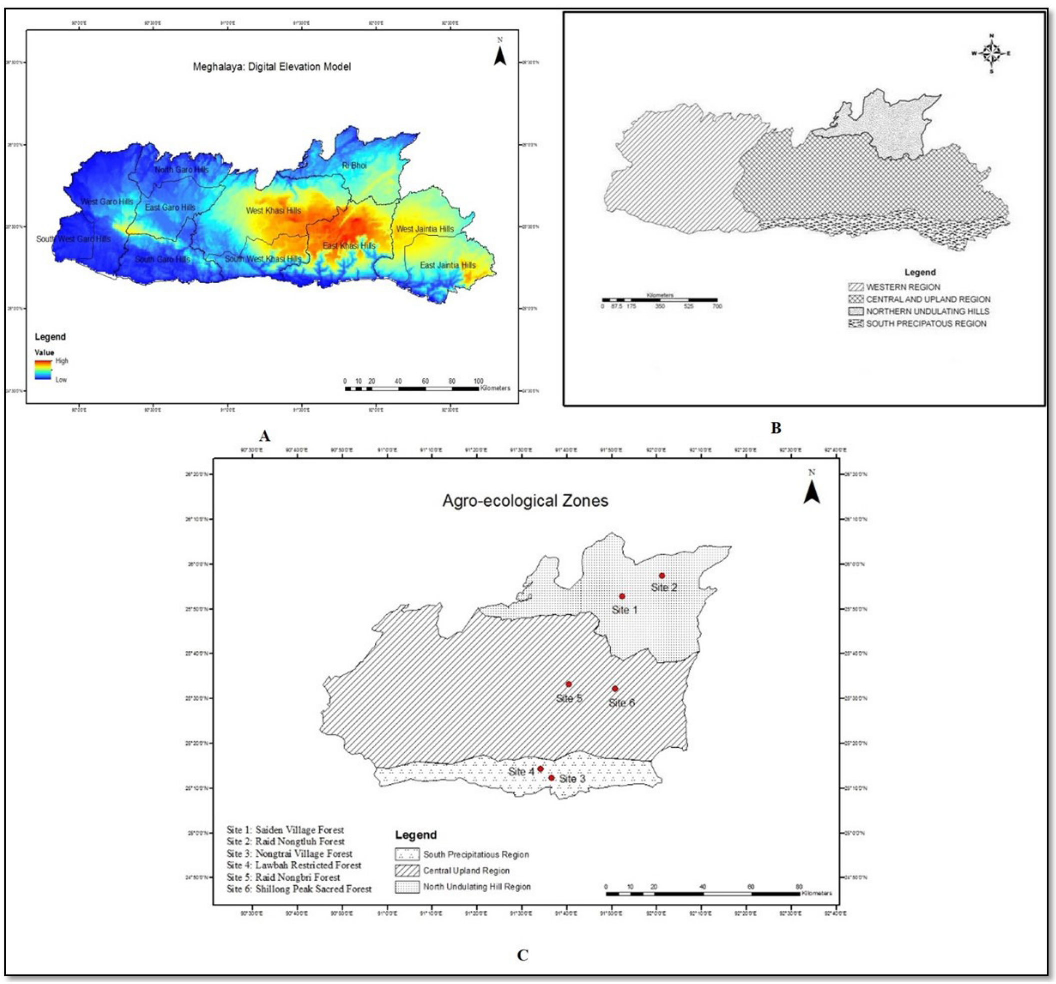

Figure-1: Study area map **A**: Meghalaya DEM with District Administrative Boundary, **B**: Agro-Ecological Zones of Meghalaya[11], **C**: Agro-Ecological Zones of Khasi Hills Extracted from Tynsong et al[11].

Methodology

Two community managed forests from each zone (CUR, NUH & SPR) were selected based on elevation of the sites. Composite soil sampling method was followed in each of the forests considering a depth of 0-30cm. The soil samples collected were then air dried and then made to pass through a 0.1mm sieve and then stored in air tight plastic bag for further laboratory analysis. SOC(%) was analysed following the modified walkely black method, Total Nitrogen (TN)(%) by Macro Kjeldahl digestion analyser[15,16]. Bulk density was determined by gravimetric method[17] and Soil carbon stock (CS) was calculated using the following formula[18].

$$Bulk\ Density\ \left(\frac{gm}{cm3}\right) = \frac{Oven\ Dry\ weight\ of\ Soil(gm)}{Volume\ of\ Soil(cm3)}$$

$$CS\left(\frac{t}{ha}\right) = [(soil\ bulk\ density(g/cm3) \times soil\ depth(cm) \times \%\ C)] \times 100$$

Different statistical test were also applied in this study. Significant variation between different parameters like CS, SOC, TN, Bulk Density and altitude was analysed using ANOVA, Tukey HSD post-hoc test was then used to find out the statistical significant variation between the groups. The correlation coefficient between different parameters was established using Pearson Correlation coefficient. The different statistical tests are performed at p≤ 0.01level (unless specified). IBM SPSS 20 version software was used to carry the statistical analysis.

Results and discussion

SOC and SOC Stock: One way ANOVA (Table-1) signify that the various parameters showed a significant difference across the three regions (p<0.01). It is clear that there is a marked difference in their level with the increase in altitude. SOC stock and bulk density significantly vary in different agro-ecological regions (Table-2). The results revealed that highest overall mean SOC stock of 47.27±2.12 t/ha was recorded in the Central Upland Region, followed by 28.09±1.25t/ha in the North Undulating Regions. Lowest SOC stock of 24.24±.60t/ha was recorded in the South Precipitous Region. Central upland region SOC stock was found to be significantly different from both the Northern and the Southern Regions however there is no significant different between the North and the South regions as per Tukey HSD test even at p≤0.05 (table.2). Similarly, Highest SOC (4.53±0.16%) was also found in Central Upland Region followed by Northern Undulating Region (2.04±0.09%) and lowest in South Precipitous Region with (1.63±0.03%). All the three areas shows a significant different from one another according to Tukey HSD post hoc test (Table-2). Altitude was found to be positively correlated with SOC stock (r=.845), SOC(r=.912), N (r=.802), (Table-3). Furthermore, the carbon stock was found to be positively correlated with SOC (r=.871), however it was negatively correlated to the bulk density (r= -.465).

Soil Bulk Density: The Bulk Density of the soil was found to be highest in the South Precipitous Region (1.00±.03g/cm^3) followed by Northern Undulating Regions (.92±.02g/cm^3) and least in the Central region (.71±.04g/cm^3). Tukey HSD test showed significant variation in the central region than the other two regions, however there is no marked significant variation between the Northern and Southern regions (Table-2). According to Pearson Correlation Coeffecient (Table-3), bulk density was found to be negatively correlated with Altitude (r= -.630) as well as with the SOC (r=-.808).

Table-1: One Way ANOVA showing significant variation of test parameters with altitude.

Parameters	F value	Sig. level
BD(g/cm^3)	18.15	0.000
SOC (%)	19.70	0.000
CS(t/ha)	70.75	0.000
TN(%)	24.44	0.000

Table-2: Variation of CS, SOC and TN in the different agro-ecological zones.

Aspect	BD(g/cm^3)	SOC(%)	CS(t/ha)	TN(%)
Central	.71 ± .04^a	4.53 ±.16^a	47.27 ±2.12^a	.45 ±.02^a
North	.92 ±.02^b	2.04 ±.09^b	28.09 ±1.25^b	.22 ±.01^b
South	1.00 ±.03^b	1.63 ±.03^c	24.24 ±.60^b	.23 ±.02^b

Values are Mean ±Standard error.

Table-3: Pearson Correlation Coefficient between various test parameters.

	CS(t/ha)	SOC(%)	ALT (m)	TN(%)
BD(g/cm^3)	-.465**	-.808**	-.630**	-.805**
CS(t/ha)	1	.871**	.845**	.634**
SOC(%)		1	.912**	.849**
ALT (m)			1	.802**
TN(%)				1

**Correlation is significant at the 99% level of confidence (2-tailed).

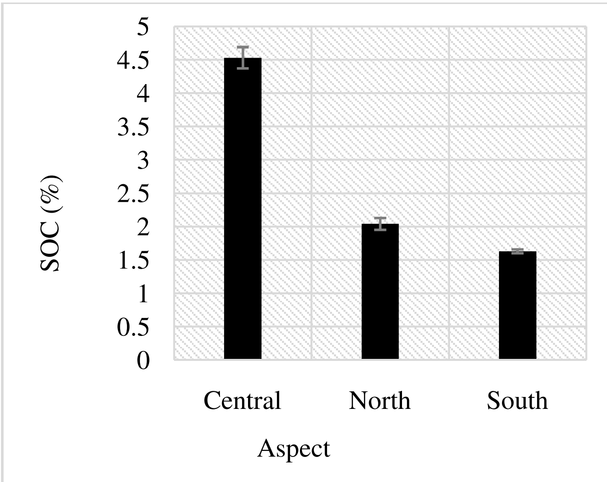

Figure-2: Aspect with SOC (%).

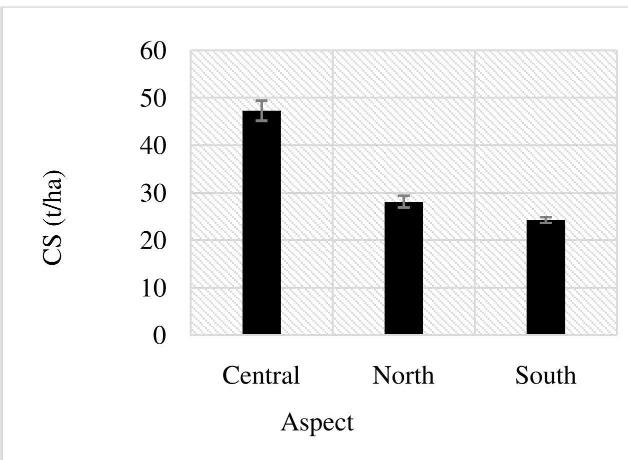

Figure-3: Aspect with CS (t/ha).

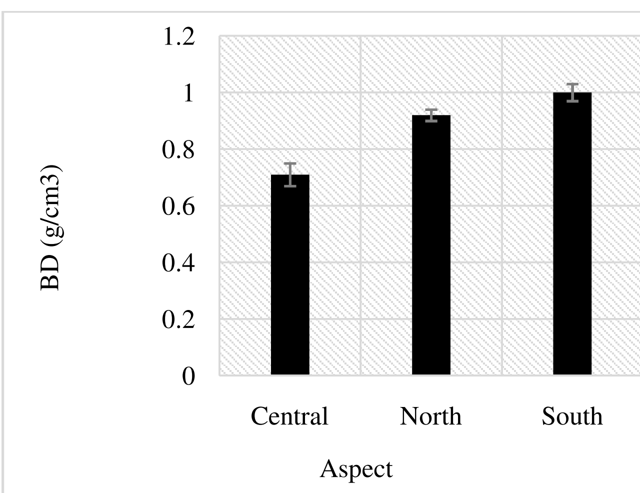

Figure-4: Aspect with BD (g/cm3).

Discussion: Almost sixty percent of the global terrestrial carbon is captured in the Forests ecosystem[19]. Out of the total terrestrial carbon budget, about eighty percent of the above ground and seventy percent of the soil organic carbon is stored in the forests ecosystem[20,21]. Present study found that both the SOC, CS and bulk density vary significantly in the different agro-ecological regions with different altitude and slope aspect. The increase in SOC level with the increase in altitude may be attribute to the decreasing temperature and increasing precipitation in the north to South Direction. Low temperature and high precipitation inhibit the rate of decomposition of forest litter thus allowing Soil organic matter (SOM) accumulation and this explains the high SOC and SOC stock in the central Upland Region. Similar results have been recorded from other low temperature and high rainfall areas[22,23].

In this present study, it was observed that soil bulk density decreases with the increase in the altitude of the areas. In nature, temperature tend to decrease with the increasing altitude. Low temperature usually does not favour the decomposition of leaf litter which reduce the mineralization rate of organic matter thus allowing them to accumulate as organic matter and organic carbon mostly in the top soil layer. Soil with high organic matter are more porous in nature than those with low organic matter as they have more pore space in between the soil particles which ultimately leads in reducing the soil density of an area. Thus this explains the low soil bulk density in the higher elevated area of the present study. Similar result was also recorded by various authors[24-26]. A positive correlation is also being recorded between the altitude and the SOC in the present study which is also recorded by number of similar studies[27,28].

The study also found that SOC stock in northern slope direction was slightly greater than that of the southern slope siding direction. The lower value of SOC stock in the south facing slopes may be due to high rate of decomposition (due to high temperature) accompanied by leaching of nutrients and SOC from the soil due to heavy rainfall in the area[29,30].

Conclusion

The study concludes that, the SOC stock, SOC, TN and Bulk Density showed a significant variations in the various aspect of the study area. Altitude behave as an important determining factor to the carbon content and carbon stock potential of the soil. For a sustainable environment, continuous lowering of carbon dioxide level in atmosphere and enhancing its accumulation in forests soil, it is also suggested that forest degradation should be avoided as they houses large quantity of carbon in their vegetation and soil which may contribute to global climate issues if the accumulating carbon is released back into the atmosphere due to such activities.

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