Research Journal of Agriculture and Forestry Sciences ISSN 2320 – 6063
Vol. **6(12),** 7-14, December **(2018)** *Res. J. Agriculture and Forestry Sci.*

Conversion of forests into shifting cultivation and its impact on Soil organic carbon budget of Nagaland

Dhruba J. Das, Ejaful Ahmed*, Sumita Duara, Abhinab Borah, Satabdi Hazarika and Abhijit Medhi
Rain Forest Research Institute, P.B NO 136, Sotai, Jorhat 785001, Assam, India
ahmedejaful@gmail.com

Available online at: www.isca.in
Received 27th August 2018, revised 25th November 2018, accepted 3rd December 2018

Abstract

Nagaland of North East India falls within the Eastern Himalayan Biodiversity region. This region falls within the lowland highland transition, manifesting one of the richest diversity of biomes and ecological communities. Nagaland is thus manifested with one of the richest biological values but has been undergoing tremendous land use change of late. A major driver of this land use change from forest to non forest in the region is the traditional practice of shifting cultivation locally known as Jhum. This age old practice has persisted despite its contribution to accelerated soil erosion and runoff from the agricultural fields. Land use changes in such a highly diverse region not only affect the overall biodiversity but also alter the carbon budget of the ecosystem. The shortening of the jhum cycle from 10-15 years to 3-5 years has worsened the situation in terms of productivity and ecological stability. An important component of an ecosystem carbon budget is the soil organic carbon. This study attempts to estimate the changes in carbon stock in two contrasting land uses viz. 'forest' and 'shifting cultivation' following standard methods. 220 soil samples from both the land uses were collected from three depths 0-15, 15-30 and 30- 45cm depth and SOC was estimated following the Walkley and Black method. The carbon stock in the forest was found to be 75.09 t C ha^{-1} whereas in the shifting cultivation it was estimated to be 42.03 t C ha^{-1}. Shifting cultivation in Nagaland is found to have increased over the years, most of these are reportedly at the cost of primary forest cover, these land use dynamic has serious implications in the overall carbon budget in Nagaland and needs to be addressed effectively to prevent further loss of this rich, immense natural resource.

Keywords: Land use change, shifting cultivation, soil organic carbon, forest cover, carbon stock, natural resource.

Introduction

The forests function as carbon sink of the terrestrial ecosystem thus playing an important part in the global carbon cycle. Forests ecosystems have both an ecological and economical importance and the forest soil is an important component of the carbon cycle owing to the large areas involved at regional as well as global scale[1]. Forest vegetation and soils contain about 1240Pg of C[2] and the carbon stored in the trees of this ecosystem is termed as the biomass of the forest. More than 40% of the total organic C in terrestrial ecosystems is stored in the forest soil[3]. Land use change and more particularly conversion to agricultural lands, depletes the soil carbon[1], an important component of the overall carbon budget in an ecosystem. Converting natural forests to agricultural land results in the mineralization of soil organic C (SOC), thus reducing SOC stocks and increasing atmospheric CO_2 concentrations[3]. Land use change driven SOC reduction are difficult to predict, owing to variations in the factors that drive SOC mineralization, e.g., forest type, climate, and soil properties[3]. Across the globe non forest activities are rapidly spreading at the expense of natural forests and at a much faster rate in the environmentally fragile mountainous areas. Shifting cultivation is one of the predominant agricultural systems in the tropics and is considered to be the principle driving force behind deforestation in Tropical Asia[4]. The North-Eastern state of Nagaland a part of the Eastern Himalayan Biodiversity hot spot region is endowed with a rich diversity of species, flora and fauna; resulting in one of the richest biological values. However, the state has been undergoing tremendous land use change of late.

A major driver of this land use change from forest to non forest in the region is the traditional practice of shifting cultivation locally known as *Jhum*. Shifting cultivation as a system of land use and agriculture is widespread in the mountainous areas of the North eastern region of India[5]. The shortening of the jhum cycle from 10-15 years to 3-5 years has worsened the situation in terms of productivity and ecological stability. The India State of Forest Report, 2017[6] revealed that Nagaland has lost over 2.5 percent of forest area measuring 450 sq km since 2015. This report has revealed that maximum decline of green cover in the state pertained to 'Open Forest' (OF) which declined by 342 sq km since 2015. Medium Dense Forests (MDF) has declined by 103 sq km while Very Dense Forests (VDF) declined by 5 sq km in the state (SFR, FSI 2017). From the FSI (Forest Survey of India) report, the declining trend of forest area of Nagaland are mentioned in Figure-1.

According to state land records, the net area under Jhum cultivation of Nagaland is mentioned in Figure-2.

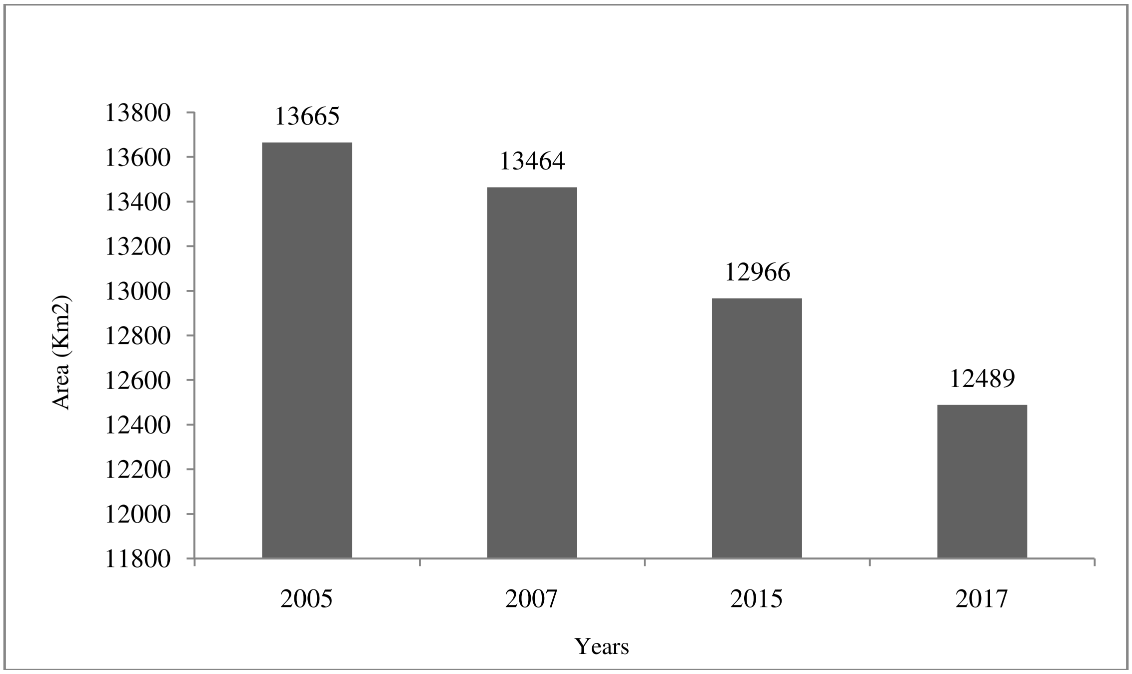

Figure-1: Year wise forest area of Nagaland.

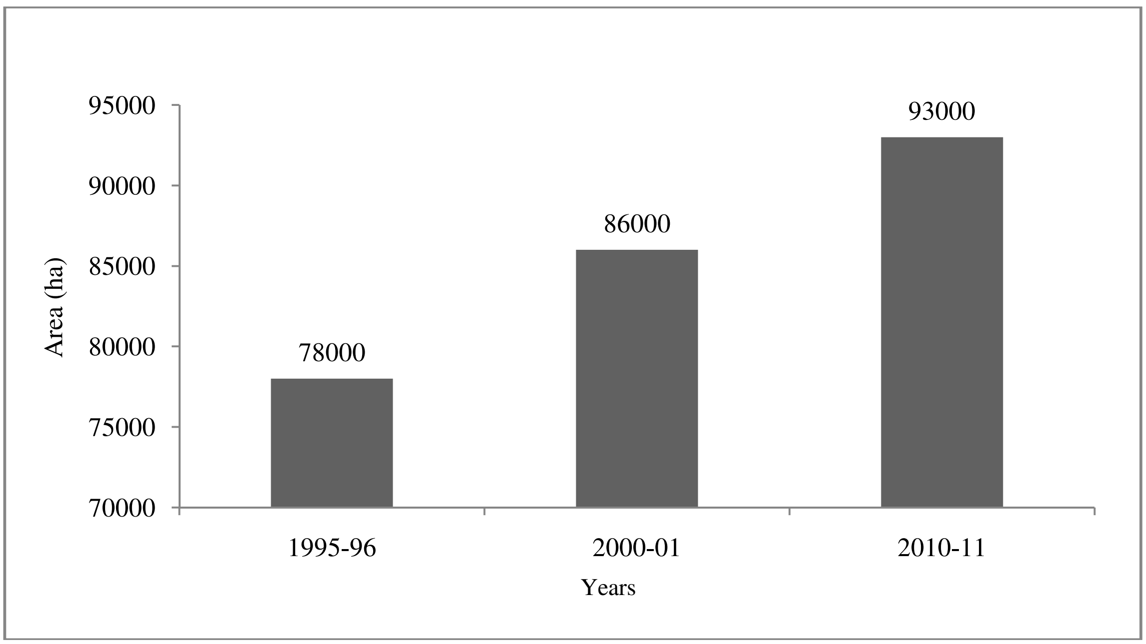

Figure-2: Year wise Jhum land of Nagaland.

This age old practice has persisted despite its contribution to an accelerated soil erosion and runoff from the agricultural fields. Land use changes in such a highly diverse region not only affect the overall biodiversity but also alter the carbon budget of the ecosystem. This study attempted to estimate the changes in carbon stock in two contrasting land uses viz. 'forest' and 'shifting cultivation'.

Study areas: Nagaland stretches from 93°20'E-95°11'E longitude to 25°06-27°04' N latitude encompassing an area of 16,579 square kilometres. Myanmar borders it on the east, the state of Assam to its west, while Arunachal Pradesh along with a part of Assam and Manipur lie to its north and south respectively. Nagaland is characterised by an undulating terrain amounting to a severe topography devoid of plateau or tableland with altitudes ranging from 194 meters to 3,048 meters. As a result most of the thousand and odd village's stands at 1 to 2000 meters, which is typical of the Nagas to build their houses on the hill and at higher elevations.

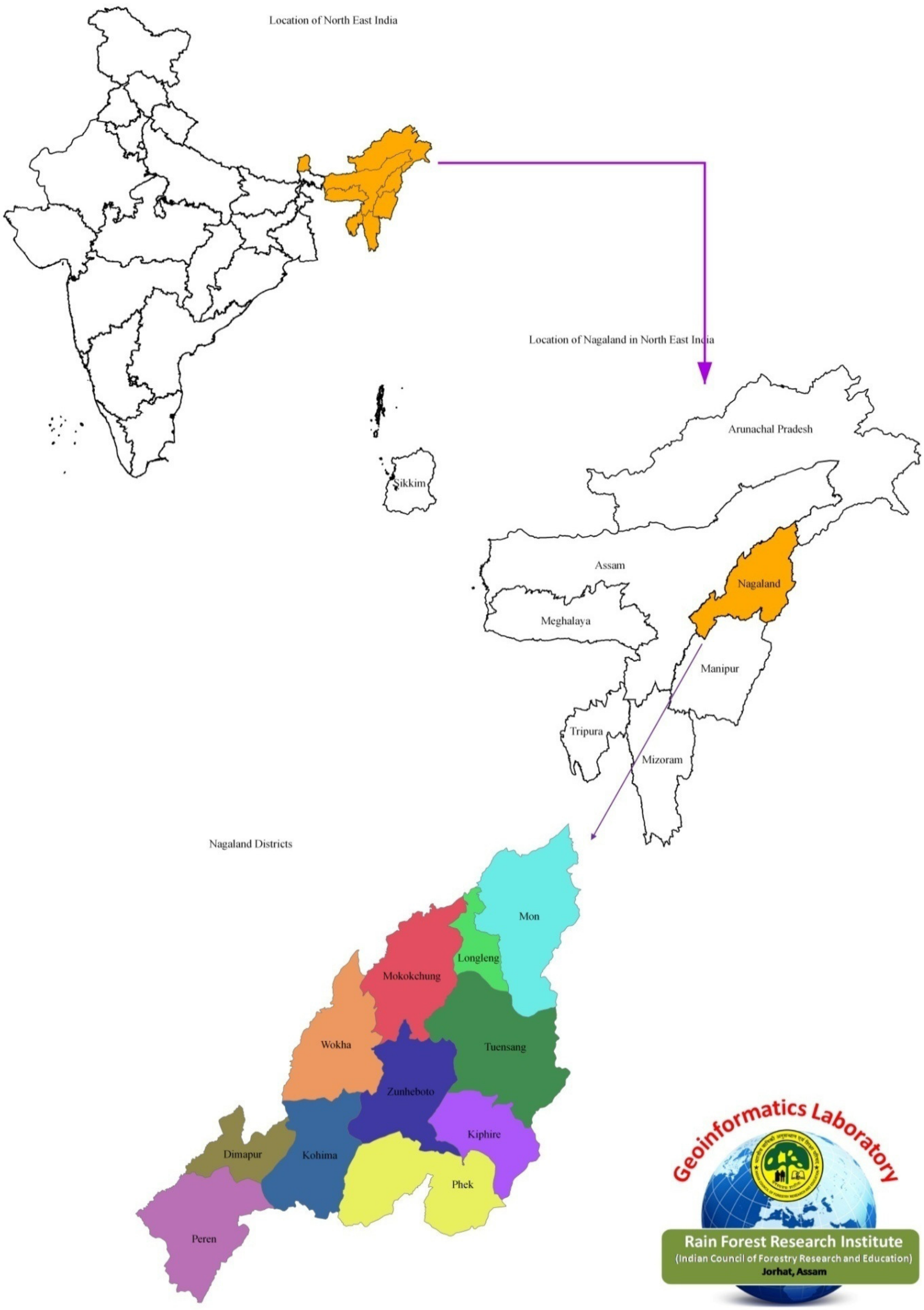

Figure-3: The location of the study area.

Climate: Nagaland has a sub tropical to sub temperate climate influenced by the hilly and undulating topography. The recorded average annual rainfall in the area ranges from 200-2500 mm with torrential rains in the months of June to September due to the influence of south west monsoon. The summer temperature ranges from 16°C to 31°C whereas it drops as low as 4°C in the winters. The maximum average temperature recorded in the winter season is 24°C with occurrence of snow in the high altitude areas. Strong North West winds blow across the state in the months of February and March.

Methodology

The study was conducted in 6 districts of Nagaland. 345 soil samples from the three land uses were collected, 21 samples from Fallow, 36 samples from Current and 60 samples from the Forest strata (Fig 3). Plant Community analysis was carried out by the Nested quadrat method. For carrying out detailed inventory of trees, plots of 0.1 Hectare (31.62×31.62 m^2) were taken as sampling units. For enumeration of shrubs and herbs nested quadrates of (5m x 5m) and (1m x 1m) respectively were laid (Figure-4).

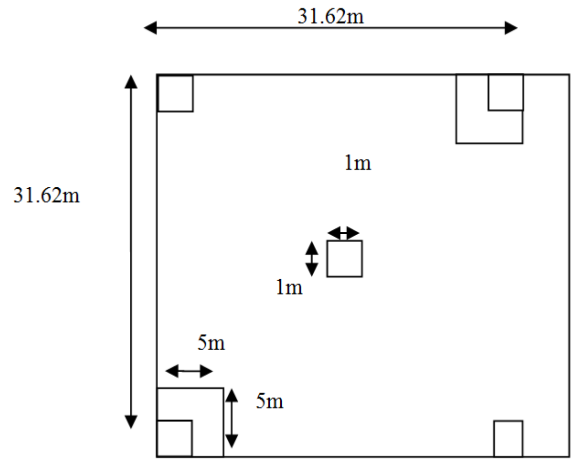

Figure-4: Diagram showing Nested Quadrate sampling method.

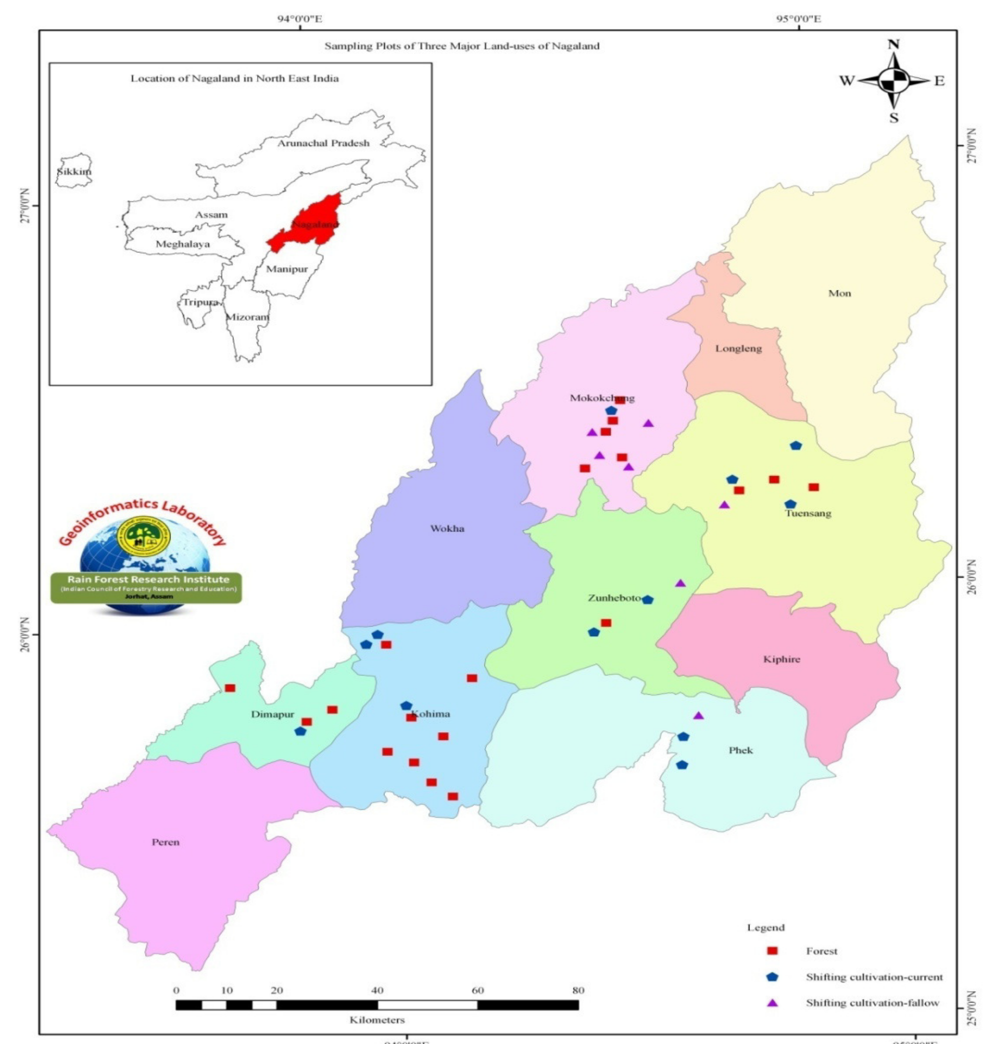

Figure-5: The location map of the plots in the study area.

The Soil Moisture Content was estimated by the Gravimetric Method[7]. pH was analysed by the Glass electrode method[8].The Rapid titration method[9] was used to analyze Soil Organic Carbon. To characterize the data, statistics as mean, minimum, maximum, median, standard deviation (SD), range, skewness and kurtosis were inferred using SPSS 16.0 software.

Results and discussion

Soil parameters comprising of MC, pH, BD, SOC and SOM were studied and analysed in the three land use systems *viz* Forest, Jhum Fallow and Current Jhum. The results showed variation in all the three land use systems for all the parameters. For all the variables studied the skewness values indicated a normal distribution with a range from -1 to +1.

It has been found that the highest soil moisture content has been recorded in Fallow jhum followed by Forest and current jhum. The soils of the three study sites are acidic with a mean pH of 4.66. The acidic soil of the study area can be attributed to decomposition of SOM thereby releasing organic acids which lead to leaching of bases under the high rainfall and hilly topography regime. The pH in the different land use follows the order of Forest >Current Jhum > Fallow Jhum.

The SOM and SOC is found to be higher in the Forest plots than in the other land use types (Table-1 and Figure-6) . The percent SOC content was higher in Forest (2.23%), followed by Fallow Jhum (1.85%) and the least in soils of Current Jhum (1.80%).

The average SOM value ranged from (1.78 to 6.51) % in Forest> (1.67 to 5.57) % in Fallow Jhum > (1.73 to 4.26) % in Current Jhum. The SOM for Natural Forest has a higher value in comparison to that of the Jhum Fallow and Current Fallow plots. This can be attributed to the least disturbance and exposure of the forest soils, less erosion owing to closed canopy and accumulation of leaf litter that provides substantial amount of ground cover. Current jhum plots has the least amount of SOM, as these are intensively cultivated accompanied by harvesting and burning of the biomass. An increased temperature increases the rate of SOM decomposition[16] thus leading to an increased SOM decomposition and mineralization in these jhum plots. Thus this calls for proper management of the SOC regime to prevent degradation of land uses. The fallow jhum plots have a layer of herbaceous cover which reduces soil erosion and consequently leads to production of biomass and this can be credited for a higher SOM values than the current jhum plots.

Table-1: Summary of statistics for the various soil parameters in three land uses of Nagaland.

Variables	Unit	Land uses	Mean	Min	Max	Median	SD	Skewness	Kurtosis
MC	%	Forest	26.55	15.93	37.15	25.82	7.62	0.06	-1.58
		Fallow	29.43	24.30	35.70	28.60	4.30	0.64	-1.05
		Current	24.31	16.20	34.70	29.05	5.79	-0.69	-0.45
PH		Forest	5.01	4.01	6.27	4.88	0.77	0.49	-1.24
		Fallow	4.60	4.03	5.02	4.79	0.35	0.55	-1.93
		Current	4.30	3.92	4.87	4.19	0.33	-1.40	1.60
BD	g/cm3	Forest	0.83	0.48	1.23	0.87	0.20	0.98	2.45
		Fallow	0.69	0.50	0.91	0.70	0.14	0.34	-1.32
		Current	0.68	0.43	1.15	0.59	0.18	-0.66	1.37
SOC	%	Forest	2.23	1.04	3.79	2.32	0.77	0.14	-0.63
		Fallow	1.85	0.97	3.24	2.01	0.81	0.45	-1.06
		Current	1.80	1.01	2.48	1.87	0.55	-0.12	-1.69
SOM	%	Forest	3.83	1.78	6.51	3.99	1.32	0.14	-0.63
		Fallow	3.19	1.67	5.57	3.46	1.39	0.45	-1.06
		Current	3.10	1.73	4.26	3.22	0.94	-0.12	-1.69

Soil Carbon stock of three different land uses in Nagaland: It is evident from Figure-5 that the soil carbon stock in Forest land is highest (75.09C t ha^{-1}) followed by Fallow Jhum (44.13C t ha^{-1}) and Current Jhum (39.93 C t ha^{-1}). The carbon stock obtained from Nagaland forest was comparatively lower than other study areas.

Tropical forests are the major source/sink of C[11] due to their strong (46%) impact on the global terrestrial C cycle[12]. And in Nagaland, the biodiversity rich forests are under the control of the communities. The SOC stock in the studied forests is much lower than the SOC stocks of Tropical forests in India as well as the Barak Valley area. Also, the value of SOC stock obtained is even lower than the values obtained for degraded forest in Barak Valley area by Brahma *et. al*[13]. This signifies the poor state of the forests in the study area. This state can be attributed to the deforestation prevalent in the forests of Nagaland which is also one of the main factors for the global net release of carbon dioxide from soil to atmosphere.

Guo and Gifford[14] states that an almost 42% decline in soil organic C (SOC) stocks occurs with land use changes from native forest to crop. The Carbon stock of the jhum lands-current as well as fallow is way less than the Carbon stock of natural forests, however it is comparable to the values of stock of Fallow and Current shifting cultivation as reported by Melgoza *et al*.[15] in Mexico.

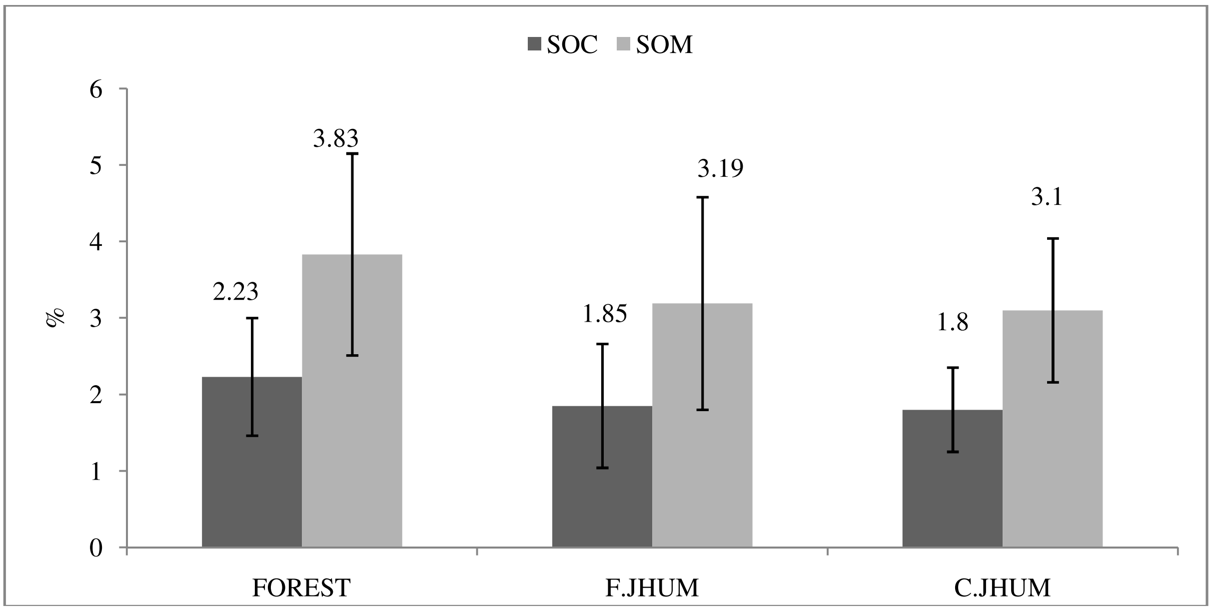

Figure-6: SOC and SOM in three different land uses in Nagaland.

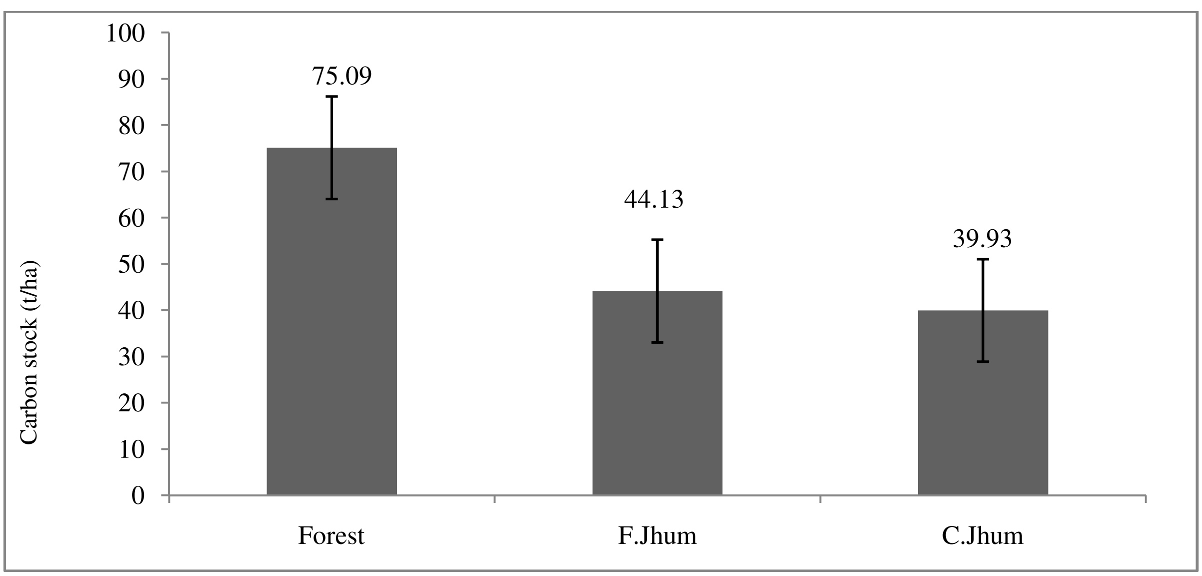

Figure-7: Soil Carbon stock of three different land uses in Nagaland.

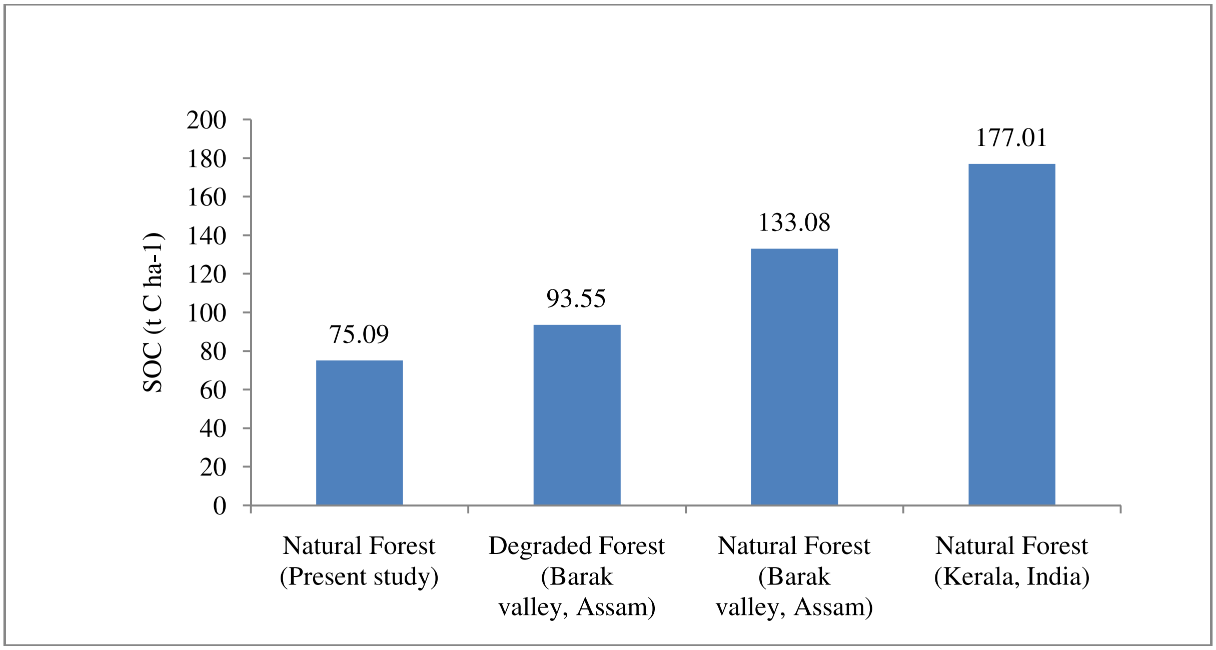

Figure-8: Comparison of SOC stock of Forest from different areas.

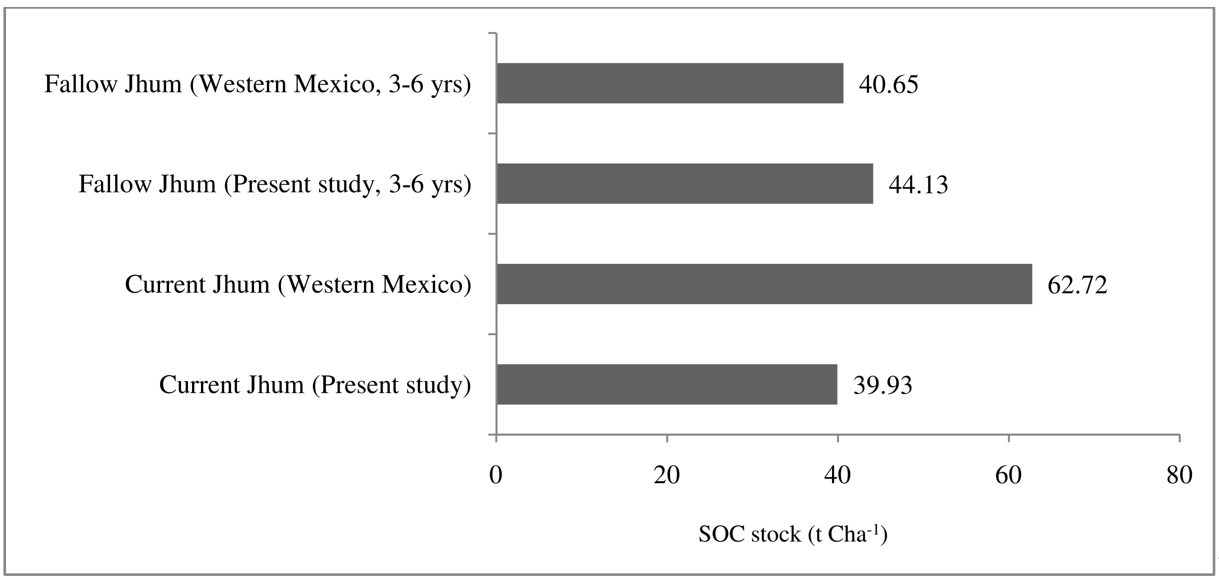

Figure-9: Comparison of SOC stock of shifting cultivation from different areas.

Carbon stock in the fallow jhum land is lower than the Natural forest (around 10%) values and higher than the current jhum values, this can be explained by the recovery of above ground biomass in the form of a herbaceous layer. The carbon stock in the Current jhum lands is around 10% lower than that in the Fallow jhum and this can be attributed to the increase in soil carbon due to charcoal and ash produced by burning.

Conclusion

The soil organic carbon (SOC) was found to be highest in the Forest, followed by the Fallow Jhum and Current Jhum in the 0-15, 15-30 and 30-45 cm layers. The trend of SOC in our study of Forest (2.23 %) > Fallow Jhum land (1.85 %)> Current Jhum land (1.80 %) and is in conformation with the findings of Chase et al.[16] and Melgoza et al[15]. SOC stock in the studied areas was found to be highest in the forest strata. The lowest SOC was recorded in the Current Jhum fields, this is primarily attributed to rapid oxidation of SOM, washing away of the nutrient rich top soil, rapid decomposition and intensive cultivation without the scope for nutrient replenishment and depletion of the above ground carbon stocks in the form of tree cover loss . Intensive cultivation has led to the least amount of carbon stock in the current Jhum fields and an increase in the carbon stock in

Fallow Jhum fields signifies the necessity of fallow periods for replenishment of soil nutrients and soil structure. The fallow lands studied were all in the bracket of 3-6 years of fallow period. A difference of 12.73 t C/ha in SOC stock has been observed upon conversion of forest to current shifting cultivation. Thus, losing a substantial amount of carbon which will lead to imbalance in the soil carbon budget of Nagaland. However, this can be remedied with introduction of fallow period as the difference in SOC stocks between forest and fallow jhum lands is 6.71 Mg C/ha. An increase in the fallow period to more than 20 years can lead to return of carbon stock levels to that of old growth forests as has been found by Melgoza et al[15].

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