

Original Research Article

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Carbon Stock of Prevailing Land Use Systems under East Siang District, Arunachal Pradesh, India

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ABSTRACT

The present investigation were carried out in split plot design using six land use system, natural grassland (T₁), natural forest (T₂), agriculture field (T₃), rubber plantation (T₄), teak plantation (T₅) and tea plantation (T₆) at three soil layers and replicated thrice under Pasighat Forest Division of East Siang District, (Arunachal Pradesh). The results have revealed higher total biomass production level (770.78 t ha⁻¹) by teak plantation followed by natural forest (424.54 t ha⁻¹), which affect the carbon stock and carbon sequestration potential. While minimum of total biomass production was found in natural grassland. Soil organic carbon and soil organic stock was higher in natural forest and teak plantation, enhances belowground carbon storage. As a result, the maximum total carbon stock was recorded in teak plantation (405.13 t ha⁻¹) followed by natural forest, rubber plantation, tea plantation and agriculture field while minimum total carbon stock was recorded in natural grassland (8.44 t ha⁻¹). The study highlights the opportunity to increase carbon storage potential through trees.

Keywords

Land use, Carbon stock, Carbon sequestration, Biomass and organic carbon

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Introduction

Carbon sequestration through sink enhancement by way of integration of trees into landscapes is one of the cost-effective mitigation strategies in the terrestrial ecosystem may be categorized into vegetative carbon and soil carbon components. The capacity of terrestrial ecosystems to sequester

carbon varies based on its land use patterns. Land use, land use change and forestry (LULUCF), an approach that became popular in the context of the Kyoto protocol, allows afforestation and reforestation as greenhouse gas offset activities (Nair *et al.*, 2011).

Decisions about terrestrial carbon sequestration need a deliberate exploration for

adjustments among multiple resources for ecosystem benefits. Agricultural lands are believed to be a major potential sink and could observe large quantities of carbon if trees are introduced to these systems and judiciously manage together with crops, trees accumulating carbon in wood as they grow and acting as stable carbon stores upon maturity. By promoting different tree based land use system with higher carbon contents, a net gain in the existing carbon stock can be realized. The most significant increase in carbon storage can be achieved by moving from lower biomass to higher biomass land use system such as teak plantation, rubber plantation, etc. Teak plantation provide as high as 635.33 t ha^{-1} of above ground biomass in hilly zone as reported by Reddy, *et al.*, (2014).

Soils are also an effective sink for carbon. However, soil carbon stocks vary as a function of different land management practices, landscape position and vegetation productivity. Findings estimate that the global potential of soil carbon sequestration is 0.4 to 1.2 Gt C yr^{-1} , or an amount equal to roughly 5 to 15% of total man-made CO_2 emissions. The soil organic carbon concentration is considered to be the highest in forestry, followed by horticulture; while the least efficient is agriculture (Sharma *et al.*, 2014). To be most effective, CO_2 must be fixed into long-lived pools (or “sinks”) by transfer of atmospheric CO_2 into the soil, plays an important role in the global C cycle (GCC).

In Arunachal Pradesh, land use pattern under tropical ecosystem lying between 100 m to 200 m above sea level has under gone a significant change upon the introduction of tea, rubber, etc. as cash crops. Although these changes in the land use will greatly revolutionize the economy of the people but no study has been carried out to know the carbon stock and sequestration potential of

these changed land uses. A realistic estimate of carbon stock at any given time is crucial for indicating the potential of vegetation to released or absorbed carbon and can be used to constrain other methods such as inversed modelling in estimating net carbon flux (Goodale *et al.*, 2002). Therefore, an attempt with the present investigation was undertaken to determine the carbon stock of prevailing land use systems under East Siang District, Arunachal Pradesh.

Materials and Methods

The study was conducted in Pasighat Forest Division of East Siang District, Arunachal Pradesh, India ($94^\circ 42'$ to $95^\circ 35'$ E and $27^\circ 43'$ to $29^\circ 20'$ N) with an elevation of 155 m (a.s.l). The climate characteristics of this area is generally humid sub-tropical, receives more than 4000 mm average rainfall. The annual mean maximum temperature is $31 \pm 1.1^\circ\text{C}$ and the mean minimum temperature is $18 \pm 1.2^\circ\text{C}$ with soil type of entisols, inceptisols. The research method laid out in split plot design focused on six land use system (T), three soil layers (L) and replicated thrice. The six land use system were: natural grassland (T_1), natural forest (T_2), agriculture field (T_3), rubber plantation (T_4), teak plantation (T_5) and tea plantation (T_6). The soil sample collected from sampling sites using random sampling technique from three depth of soil layers extracted at: 0-15cm (L_1), 15-30cm (L_2), and 30-45cm (L_3). The plot size of each land use system was 50m x 10m except for natural grassland and agriculture field where the plot size was 1m x 1m quadrates. The observations of the tree species were recorded during September-October, 2017. The tree height and form height were measured using Spiegel Relaskop. The girth at breast height (GBH) measured with the help of measuring tape was converted to diameter at breast height by DBH ; form factor and volume were calculated using the formula given by

Bitterlich (1984) and Pressler (1865) respectively. The above-ground biomass ($t\ ha^{-1}$) has been calculated by multiplying volume with specific gravity. Estimation of wood specific gravity followed by Gupta *et al.*, (2017) and Williamson and Wiemann (2010). The sample branches and leaves of tree were taken for total dry biomass estimation. The biomass value for the three tree component (stem, branch and leaf) were obtained by summing up all the three values.

The root system weight about 20 per cent, as much as the above ground weight of the tree. Therefore, 20% of the total above ground biomass were considered as root biomass (below-ground biomass) as given by Achard *et al.*, (2002) and Ramankutty *et al.*, (2007). The crop and grass biomass were estimated by collection of samples (harvested at ground level) of the quadrat and oven-dried to estimate the weight. Biomass estimated for different strata were summed to calculate total above-ground biomass and carbon stock by multiplying estimated dry biomass weight with 0.47 as suggested by IPCC (2000) and IPCC methodologies default 0.47 carbon percent (Mc Groddy *et al.*, 2004). The bulk density was calculated as method described by Singh *et al.*, (1986). Organic carbon was determined by Walkley and Black (1934) and the soil organic carbon was computed by using the formulae of Nelson and Sommers (1996).

Soil Carbon stock ($t\ ha^{-1}$) = [soil bulk density ($g\ cm^{-3}$)] x soil depth (cm) x soil carbon (%)

Total carbon stock = plant carbon stock + soil carbon stock

The data obtained were subjected to statistical analysis using split plot of experimentation as per the procedure suggest by Gomez and Gomez (1984).

Results and Discussion

Biomass production: The biomass production level and carbon stock depends upon the land use systems, structure, and intensity of management. The maximum above ground ($642.32\ t\ ha^{-1}$) biomass production level was demonstrated by teak plantation (table 1) followed by natural forest ($353.79\ t\ ha^{-1}$), rubber plantation ($130.59\ t\ ha^{-1}$), tea plantation ($41.37\ t\ ha^{-1}$) and agriculture field ($7.83\ t\ ha^{-1}$), and minimum above ground biomass production was found in natural grassland ($2.98\ t\ ha^{-1}$). Similar significant trend was observed in below ground biomass production and total biomass production.

Biomass carbon stock: Above ground biomass carbon stock ($301.89\ t\ ha^{-1}$) was higher in teak plantation followed by natural forest ($166.28\ t\ ha^{-1}$), rubber plantation ($61.38\ t\ ha^{-1}$), tea plantation ($19.45\ t\ ha^{-1}$) and agriculture field ($3.68\ t\ ha^{-1}$) and was found lower ($1.40\ t\ ha^{-1}$) in natural grassland. Similar trend was observed in below ground biomass carbon stock and total biomass carbon stock (table 1).

Bulk density: A gradual increase in bulk density with increase in depth of soil for all the land use systems was observed in all the land use systems under the investigation. A significant difference in bulk density was seen at three depths (Table 2). Highest bulk density was recorded in natural grassland ($1.36\ g\ cm^{-3}$) and agriculture field ($0.96\ g\ cm^{-3}$) was recorded the lowest.

Soil organic carbon and soil carbon stock : The results revealed highest soil organic carbon in natural forest (1.42 %) and natural grassland (0.20 %) was exhibited lowest (Table 2). Similarly soil carbon stock had highest in natural forest ($49.21\ t\ ha^{-1}$) followed by teak plantation ($42.86\ t\ ha^{-1}$) and natural grassland ($6.76\ t\ ha^{-1}$) was recorded

lowest. While in order of soil layers, the soil organic carbon decreased with increase in depth, while soil carbon stock increases with increase in depth of soil in general in all the land use systems.

Total carbon stock: The estimation of the total carbon stock in six land use system are

shown in Figure. 1. The significantly higher total carbon stock was recorded in teak plantation (405.13 t ha⁻¹) followed by natural forest (248.75 t ha⁻¹), rubber plantation (106.75 t ha⁻¹), tea plantation (55.25 t ha⁻¹) and agriculture field (22.90 t ha⁻¹), while natural grassland (8.44 t ha⁻¹) was recorded lowest.

Table.1 Biomass production levels and biomass carbon stock of above ground biomass (ABG), below ground biomass (BG) and total biomass (T. Bio) in different land use systems

| Land use systems | Characters | Biomass production levels (t ha ⁻¹) | Biomass carbon stock (t ha ⁻¹) |
|--|------------|---|--|
| T₁=Natural grassland | ABG | 2.98 | 1.4 |
| | BG | 0.6 | 0.28 |
| | T. Bio | 3.58 | 1.68 |
| T₂=Natural forest | ABG | 353.79 | 166.28 |
| | BG | 70.76 | 33.26 |
| | T. Bio | 424.54 | 199.54 |
| T₃=Agriculture field | ABG | 7.83 | 3.68 |
| | BG | 1.57 | 0.74 |
| | T. Bio | 9.4 | 4.42 |
| T₄=Rubber plantation | ABG | 130.59 | 61.38 |
| | BG | 26.12 | 12.28 |
| | T. Bio | 156.71 | 73.65 |
| T₅=Teak plantation | ABG | 642.32 | 301.89 |
| | BG | 128.46 | 60.38 |
| | T. Bio | 770.78 | 362.27 |
| T₆=Tea plantation | ABG | 41.37 | 19.45 |
| | BG | 8.27 | 3.89 |
| | T. Bio | 49.65 | 23.33 |
| Factors | | CD _{0.05} | CD _{0.05} |
| Factor(T) | | 11.46* | 5.38* |
| Factor(C) | | 2.82* | 1.33* |
| Factor(C)at same level of T | | 7.38* | 3.47* |
| Factor(T)at same level of C | | 12.77* | 6.00* |

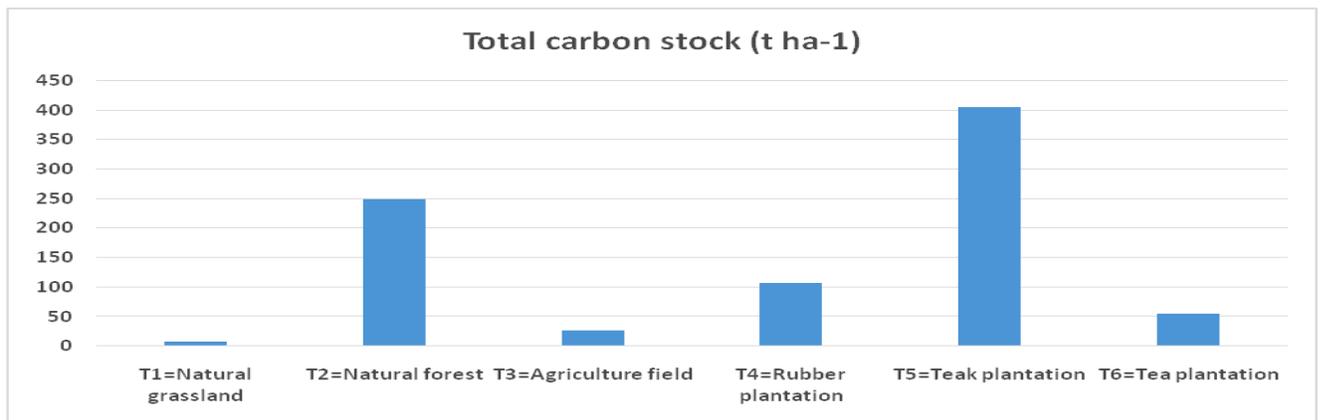
* Significant at the 0.05 *p* level.

Table.2 Bulk density, soil organic carbon and soil carbon stock

| Landuse systems | Soil layers (cm) | Bulk density (g cm ⁻³) | | Soil organic carbon (%) | | Soil carbon stock (t ha ⁻¹) | |
|---|------------------------|------------------------------------|------|-------------------------|------|---|-------|
| | | Actual | mean | Actual | mean | Actual | mean |
| T₁=Natural grassland | L ₁ (0-15) | 1.16 | 1.36 | 0.3 | 0.2 | 5.3 | 6.76 |
| | L ₂ (15-30) | 1.37 | | 0.22 | | 8.91 | |
| | L ₃ (30-45) | 1.56 | | 0.09 | | 6.07 | |
| T₂=Natural forest | L ₁ (0-15) | 1.15 | 1.18 | 1.54 | 1.42 | 26.43 | 49.21 |
| | L ₂ (15-30) | 1.18 | | 1.44 | | 51.13 | |
| | L ₃ (30-45) | 1.22 | | 1.28 | | 70.09 | |
| T₃= Agriculture field | L ₁ (0-15) | 0.89 | 0.96 | 1.1 | 0.86 | 14.74 | 22.9 |
| | L ₂ (15-30) | 0.96 | | 0.83 | | 24.08 | |
| | L ₃ (30-45) | 1.02 | | 0.65 | | 29.89 | |
| T₄=Rubber plantation | L ₁ (0-15) | 1.02 | 1.06 | 1.32 | 1.12 | 20.31 | 33.1 |
| | L ₂ (15-30) | 1.06 | | 1.21 | | 38.35 | |
| | L ₃ (30-45) | 1.1 | | 0.82 | | 40.64 | |
| T₅=Teak plantation | L ₁ (0-15) | 1.07 | 1.11 | 1.51 | 1.34 | 24.21 | 42.86 |
| | L ₂ (15-30) | 1.1 | | 1.33 | | 43.64 | |
| | L ₃ (30-45) | 1.15 | | 1.17 | | 60.73 | |
| T₆=Tea plantation | L ₁ (0-15) | 1.12 | 1.15 | 1.11 | 0.96 | 18.7 | 31.91 |
| | L ₂ (15-30) | 1.15 | | 0.95 | | 32.66 | |
| | L ₃ (30-45) | 1.18 | | 0.83 | | 44.39 | |
| Factors | | CD _{0.05} | | CD _{0.05} | | CD _{0.05} | |
| Factor(T) | | 0.022* | | 0.03* | | 1.04* | |
| Factor(C) | | 0.015* | | 0.03* | | 0.91* | |
| Factor(C)at same level of T | | 0.037* | | 0.06* | | 2.29* | |
| Factor(T)at same level of C | | 0.037* | | 0.06* | | 2.11* | |

* Significant at the 0.05 *p* level.

Fig.1 Total carbon stock (t ha⁻¹) in different land use system



It is evident from the present study that there is highly significant influence of prevailing land use change and management effects on biomass production levels and are relatively well known. The total biomass production level (770.78 t ha^{-1}) was demonstrated by teak plantation followed by natural forest (424.54 t ha^{-1}) while highest soil organic carbon in natural forest (1.42 %) and teak plantation (1.34 %) reveals that trees and wooded areas may store carbon by sequestering atmospheric carbon which are potential natural carbon sink and increase soil organic carbon (Brown and Pearcel, 1994). The results are in line with the findings of Singh *et al.*, (2009) and Haripriya (2000). Chhetri (2007) reported that soil with high organic carbon content is of high quality and higher soil carbon stock is a pathway of input of new soil organic carbon into the soil. As the tree roots enhances belowground carbon storage (Howlett *et al.*, 2011), the present investigation undertaken for soil carbon stock in natural forest (49.21 t ha^{-1}) and teak plantation (42.86 t ha^{-1}) were relatively higher as compared to natural grassland (6.76 t ha^{-1}) which contributed low soil organic carbon stock due to the removal of grass due to grazing and fodder collection. Similar findings were reported by Dhruw *et al.*, (2009); Negi *et al.*, (2003) and Chimdi *et al.*, (2012). However, carbon stock has tremendous impacts on improving soil productivity and reducing green house gases emission, total carbon stock was recorded higher in teak plantation (T_5) followed by natural forest (T_2) as compared to the rest of four land use system studied, the findings indicate an opportunity to increase carbon storage via trees, that accumulate more carbon content in stem and roots. Similar results were reported by Reddy *et al.*, (2014) and Arya *et al.*, (2018).

In conclusion, teak plantation and natural forest which represents maximum biomass carbon production and carbon stock among

the six prevailing land use system. In conclusion, the results of this study inferred that teak plantation has the potential to sequester carbon from the atmosphere, and further the natural forest should not be disturbed, and other tree based land use system should be encouraged, where ever any opportunity in areas of agriculture field, Tree outside Forests (ToF) or agroforestry based land use system should be followed to increase the carbon sequestration potential of the region.

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