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Assessment of tree species composition and tree carbon stock of Nongkhyllem Wildlife Sanctuary and Nongkhyllem Reserve Forest in Ri-Bhoi District, Meghalaya, India

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Abstract

Climate change has emerged as one of the leading Environmental issues in the recent past, the major contributors to climate change are greenhouse gases such as carbon dioxide (CO_2) and methane (CH_4), of these, carbon dioxide is more prevalent in the atmosphere. Forests are one of the major carbon sinks of the world, assessment of carbon stock offorests is essential to obtain the baseline of carbon stored in the forests and for projection of temporal carbon sequestration potential of the forests for the conservation of biodiversity. The rapid changes in patterns of land use have resulted into forest degradation and its adverse impact on global climate due to the emissions of greenhouse gases (GHGs) from terrestrial and aquatic systems. The present study aims at assessing the above ground biomass (AGB) and below ground biomass (BGB) using allometric models, it also aims at determining the species composition, frequency, diversity and carbon density of the forests. The study was conducted in the thick dense sub-tropical forests of Ri-Bhoi district. The forests chosen for this study were Nongkhyllem Wildlife Sanctuary and Nongkhyllem Reserve forest, these forests represented an adequate representation of the phytodiversity prevalent in the district and presented as adequate study sites as they were highly undisturbed.

Keywords: Carbon stock, carbon density, remote sensing, phytodiversity, biomass, Nongkhyllem Wildlife Sanctuary, Nongkhyllem reserve forest.

Introduction

Forests have a major impact on the carbon cycle whether it is localised, regionalised or even at a global scale. Forests sequester enormous amounts of carbon in the form of vegetation as well as in the soil, the carbon cycle in forests is regulated with the atmosphere through the process of photosynthesis, where carbon is assimilated and respiration[1]. The carbon reservoir in the terrestrial biota and soil biota are important sources as well as sinks of atmospheric carbon[2]. Forest ecosystems provide a number of provisioning, regulatory, supporting, and cultural services that are important to the lives and livelihoods of humans, and they also play an important role in maintaining habitats that support important global biodiversity[3,4]. Compared to other terrestrial ecosystems, forests store the most carbon[5], with the majority of sequestered carbon held in woody biomass. Trees lock atmospheric carbon dioxide in the form of carbon, and hence reduce atmospheric greenhouse gas (GHG) accumulation. Because of this, forests have a huge impact in mitigating climate change globally[6]. Deforestation and forest degradation influence the amount of carbon in the atmosphere, with deforestation and forest degradation contributing an estimated 18% of total global anthropogenic greenhouse gas emissions[6]. However, recent estimates of global carbon emissions from 2011 to 2015 point to a 25% reduction in emissions resulting from deforestation and forest degradation (i.e., from an annual average of 3.9 billion tonnes of CO_2 in 2011 to 2.9 billion tonnes in 2015). This drop is linked to net growth in planted forest[7]. Sequestration of carbon in forests differs and depends on spatial as well as temporal factors which include age, size, stand structure, forest types, vegetation and ecological zones[3,4]. Understanding these differences, and how they affect the degree to which the effects of greenhouse gas (GHG) emissions can be offset through afforestation and improved forest management, is important to informing forestry management programmes[8,9].

It has been estimated that 44% of the world’s total forested areas is comprised of Tropical forests[10], Forests are of great importance and act as major sources of food, biodiversity and are the largest terrestrial carbon pool. Tropical forests have an important on the global climate and have a significant contribution to one of the biogeochemical cycles, i.e. the carbon cycle. Quantitative estimation of organic carbon in forests has shown that 80% of the total organic carbon is above ground while 40% is below-ground. Global emissions of carbon as a result of forest degradation and deforestation have been estimated to be around 15%–20% where tropical regions contribute the most to these emissions. A study determined deforestation of tropical forests release an annual rate of 1.5Gt of carbon back into the atmosphere[11]. One of the main indicator of carbon sequestration is forest biomass.

According to Brown forests sequester approximately 50% of forest dry biomass[12]. In forest ecosystem, enormous carbon is stored which is classified in five pools, the living portion of biomass is classified into two pools; the above ground biomass (AGB) and below ground biomass (BGB) which are stores of significant amount of carbon. The dead organic matter is also classified into two pools: dead wood, which comprises mostly of fallen trees and forest litter. Soil Organic Matter (SOM) comprises the fifth pool where a significant amount of organic carbon is present. Estimation of above-ground forest biomass helps in determining the available carbon stock including the seasonal fluxes of carbon sequestration and emissions, this quantification of carbon can assess the contribution that forests have on the carbon cycle globally. The prediction of root biomass (BGB) is done through the estimation of the above ground (AGB) which is taken to be 20% of the total AGB[13], whereas the carbon stored in dead wood or forest litter contribute 10%–20% of the carbon and are also added to the total above-ground carbon stock in maturedforests[14]. Traditional field measurements of biomass have proven to be the most accurate methods, although they are prolonged, tedious, expensive, and labour intensive[15]. Progressively, applications of remote-sensing (RS) techniques have yielded greater results in lieu of the traditional methods for natural resources management.

Methodology

Study area: The present study was conducted in Nongkhyllem Wildlife Sanctuary, The sanctuary lies between 25°45' - 26°00' N latitude and 91°45' - 92°00'E longitude. The Nongkhyllem wildlife sanctuary and Nongkhyllem reserve forest are continuous. The Nongkhyllem reserve forest was constituted in the year 1910 with 96.91km area. The Nongkhyllem wildlife sanctuary was carved out of Nongkhyllem reserve forest in the year 1981 for adequate protection of the floral and faunal species of the area and covers an area of 29km^{2}on steep hill slopes (20° to > 65°) with an elevation ranging from 205 to 297 m. The Umtrew river is the major river in the study area and it marks the western boundary of the Sanctuary and the Reserve Forest. The river Umran forms the dividing boundary between the sanctuary and the reserve forest in the east and joins river Umtrew through the northern half of the sanctuary. The river Umling forms the northern boundary of the reserve forest and joins river Umtrew near the office of the sanctuary.

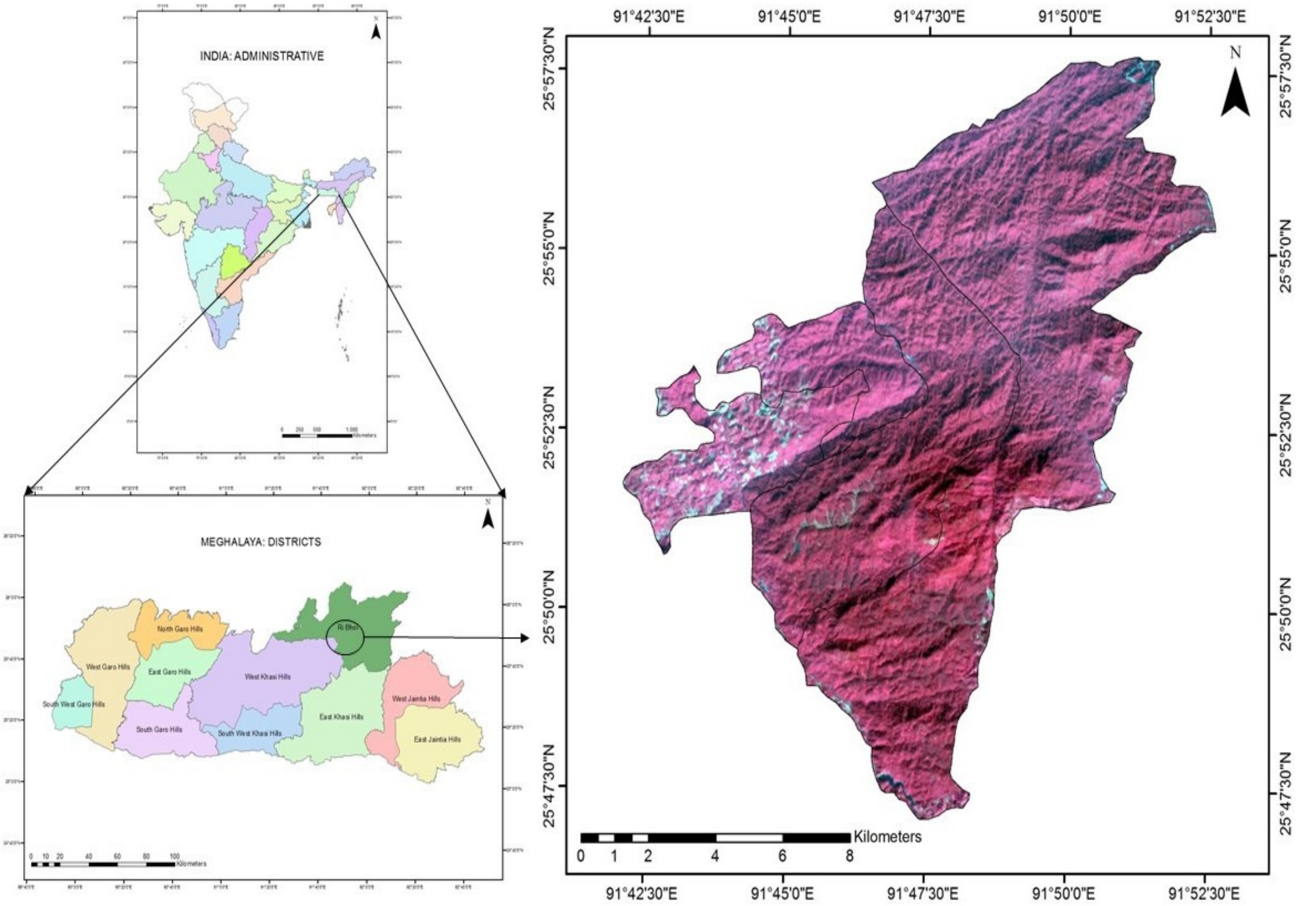

Figure-1: Location and Map of study area.

Sampling design: Stratified random sampling was employed for tree inventorying in which 8 plots were established in different sites depending on the ease of access as well as the elevation of the locations. The layout of all the sampling plots were 31.6×31.6m. The field data collected was the Girth at breast height (GBH) and tree height, all tree species were identified and recorded on the basis of their domesticity and origin.

Data processing and analysis: All the collected data and information were reviewed, sorted and analysed carefully and systematically according to the objectives of the study. The biomass of trees was calculated by using allometric equations[16], in which the biomass is related to the diameter at breast height (DBH)[17]. The DBH of tree species was obtained by dividing the GBH with a factor of 3.14 (pi).

The biomass of each tree was calculated by computing the exponential of the different tree constants while adding and subtracting with the natural logarithm of the DBH of the individual trees as shown in the equation.

$$AGB= EXP\ [-0.307 + 0.333 \ln (DBH) + 0.933 \ln (DBH)^2 - 0.122 \ln (DBH)^3]$$

The definition of below-ground biomass encompasses the entirety of all live roots, with the exception of fine roots having a diameter of less than 2mm, these cannot be empirically differentiated with soil organic matter. Below-ground biomass accounts for about 20% of the total biomass[17] to 26%[18]. AGB and BGB is an important carbon pool of many land-use systems and vegetation types. The dynamics of biomass accumulation for above ground and below ground are interlinked.

According to Bohm[19] and Jackson et al.[20], the highest concentration of root biomass is present at depths of 30cm from the soil. Perturbation of topsoil yields losses of below-ground biomass whereas afforestation of degraded land brings about continued accumulation of below-ground biomass. The below ground biomass of tree species was obtained by using a different allometric model based on the ratio between the root and shoot[21].

The estimation of below-ground biomass is as important as the estimation of AGB as this carbon pool contributes a major portion to the total biomass (20– 26%). The allometric model used for the estimation of BGB is given as:

$$BGB=EXP\ (-1.0587+0.8836*AGB)$$

Frequency and relative frequency of plant species were estimated by two recognized formulae[22].

The carbon stock of the tree species is estimated to be around 47% of the total biomass[23], therefore the biomass obtained from the allometric models is multiplied by a factor of 0.47 for both AGB and BGB models. The cumulative carbon stock of the tree species per plot was then calculated by addition of the carbon stock of the individual species, the carbon density is represented in tonnes per hectare (Mg hectare^{-1}). The data is then computed in ArcMap and the raster calculator is employed to generate a carbon density map of the study site.

Table-1: Frequency, Relative Frequency, Density and Abundance.

Frequency	$\frac{\text{No. of samples in which the species occurred}}{\text{Total no. of samples studied}} \text{X } 100$
Relative Frequency	$\frac{\text{No. of Occurrences of the species}}{\text{Total no. of occurrences of all the species}} \text{X } 100$
Density	$\frac{\text{Total no. of individual of the species}}{\text{No . of quadrat per units studied}} \text{X } 100$
Abundance	$\frac{\text{Total no. of individual of the species}}{\text{No . of quadrate per units in which they occur}} \text{X } 100$

Results and discussion

Tree species composition: The total number of tree species found cumulatively in all the plots was 17 species, the dominant species were *Tectona grandis, Shorea robusta* and *Castanopsis sp*., the least dominant species were *Albizia odoratissima, Semecarpus anacardium, Schima wallichii, Garuga pumata, Artocarpus chaplasha, Bischofia javanica, Mallatus nepalensis, Exoecaria oppositifolia*. With the exception of a few, the tree species were identified along with their vernacular names, the frequency, density, abundance and relative frequency of the recorded species were then computed.

Frequency and relative frequency of tree species: The study revealed that only *Tectona grandis* and *Shorea robusta* were the only frequently distributed species with relative frequencies of 53.87% and 11.97%. Other species like *Castonopsis sp., Toona ciliate, Albizia odoratissima, Schima wallichii, Garuga pumata, Artocarpus chaplasha, Bischofia javanica, Mallatus nepalensis, Exoecaria oppositifolia* were sparsely distributed with low relative frequencies.

Given below is a summary of the tree species composition of Nongkhyllem Reserve and Wildlife Sanctuary.

Biomass and carbon stock: After correlation of the Biomass along with NDVI, the equation thus obtained was then computed on the raster layer to obtain a Biomass layer, a Carbon stock layer was then executed from the Biomass layer. Given below is the generated map as a result of this study.

Table-2: Frequency (F), Relative Frequency (RF), Density and Abundance.

Botanical name	Vernacular name	Frequency (%)	Density	Abundance	Relative frequency (%)
Tectona grandis	Dieng Teak	100	19.13	19.13	53.87
Castonopsis sp.	Dieng Sohot	50	1.88	3.75	5.28
Shorea robusta	Dieng Blei	63	4.25	6.80	11.97
Toona ciliata (Meliaceae)	Dieng Sali	13	0.75	6.00	2.11
Minusops alangi	Dieng Shyiap	50	0.75	1.50	2.11
Albizia odoratissima	Dieng Kriat	13	0.25	2.00	0.70
Semecarpusana cardium Linn. F.	Dieng Sohbhala	13	0.13	1.00	0.35
Schima Wallichii	Dieng Ngan	13	0.75	6.00	2.11
Garuga pumata	Dieng Khniang	13	0.25	2.00	0.70
Artocarpus chaplasha	Dieng Laram	13	0.25	2.00	0.70
Artocarpus sp	Dieng Soh phan khlaw	13	0.38	3.00	1.06
Drimy carpus	Dieng Sali	25	0.25	1.00	0.70
Bischofia javanica	Dieng Sohtung	13	0.38	3.00	1.06
Mallatus nepalensis	Dieng Lakhor	13	0.25	2.00	0.70
Exoecaria oppositifolia	Dieng Soh jam	13	0.50	4.00	1.41
Ficus sp.	Dieng Soh Jri	13	0.13	1.00	0.35
Stereospermum sp.	Dieng Sir	13	0.13	1.00	0.35

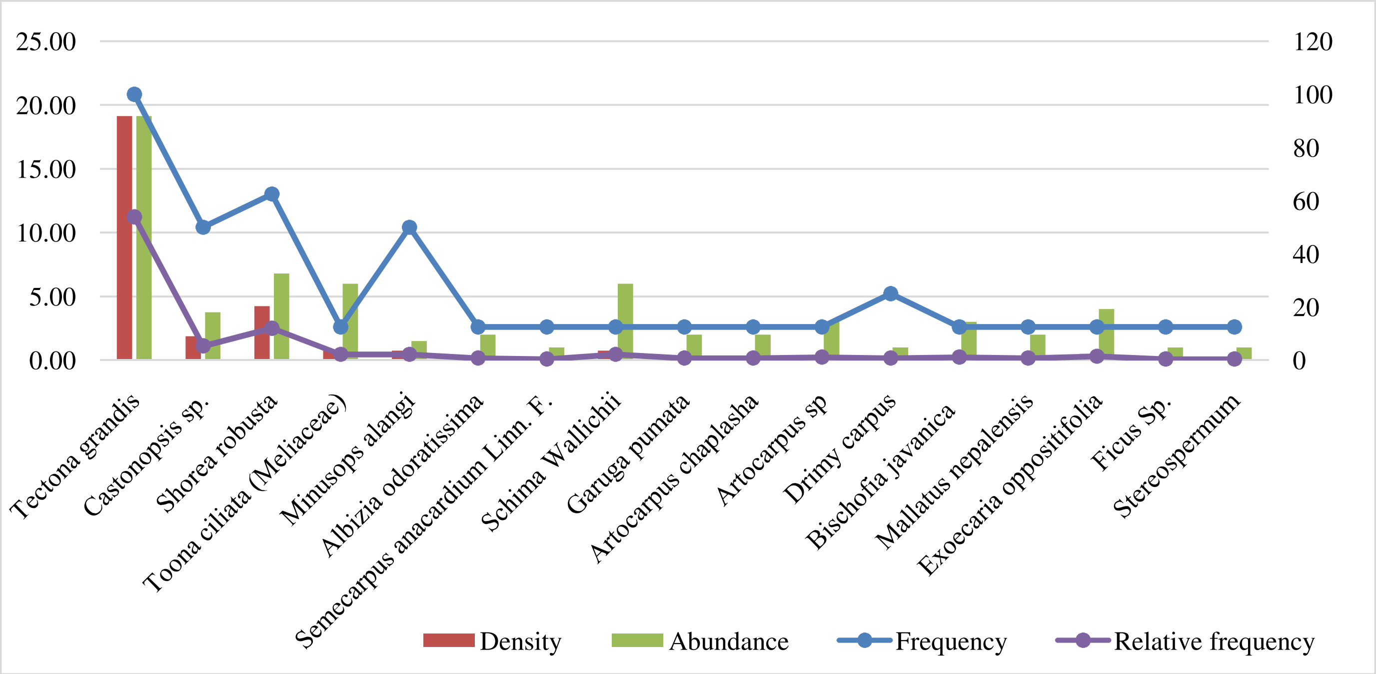

Figure-2: Importance values of different tree species of Nongkhyllem Reserve and Wildlife Sanctuary.

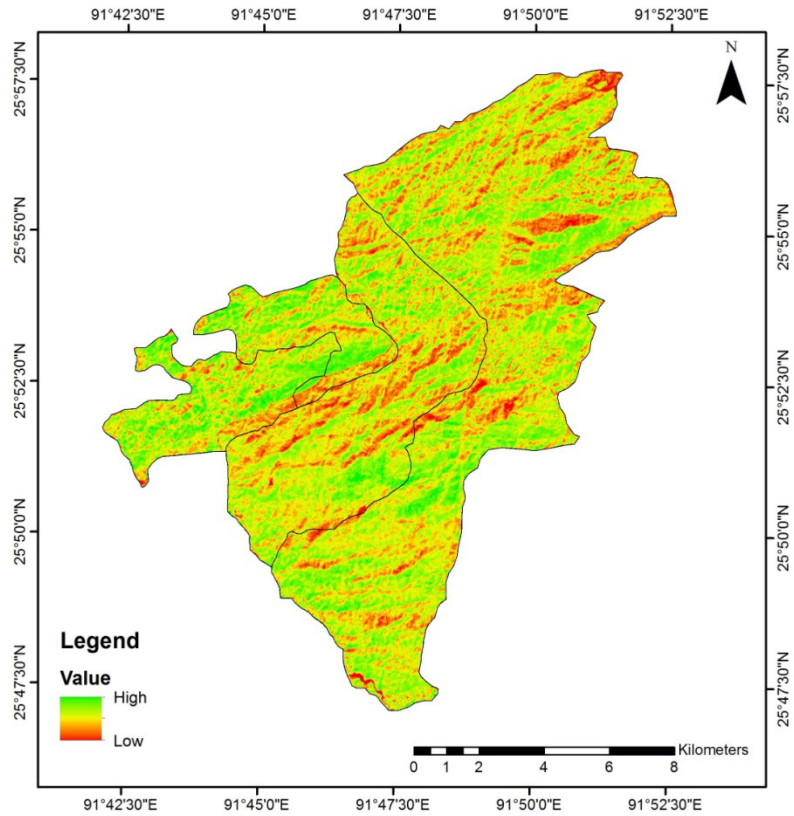

Figure-3: Carbon stock of Nongkhyllem Reserve and Wildlife Sanctuary.

Conclusion

In the assessment of biomass, the novel technique through employment of remote sensing methods provide a faster, more efficient and less time consuming alternative as compared to the traditional field based measurements which are cumbersome and time consuming for scientific management of forest resources. The quantification of forest carbon stocks enables us to assess the amount of carbon loss during deforestation or for the generation of prediction models to calculate the amount of carbon that a forest can store when such forests are regenerated. The estimation of biomass is the principal element for the estimation of forests' carbon stocks. The result of this research is the generation of a carbon stock map of Nongkhyllem Reserve and Wildlife Sanctuary, which can be highly useful in the management of this Reserve and Wildlife Sanctuary. Further, the same can be applied to other studies relating to biomass and carbon.

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