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Appraisal of fixed CO_2 in varying tree formations of tropical forest

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ABSTRACT

Tropical forests have been experienced lot of anthropogenic effects and which enforce natural forest degradation and transformation of their formation. This attempt was to evaluate the different tree formations' capability to fix the atmospheric CO_2 to biomass of tropical forest by estimating their biomass carbon. Tree formations were identified from IRS LISS 4 satellite images and biomass carbon and its equivalent CO_2 of varying formations were estimated from field samples. Tree vegetations such as thick evergreen, evergreen, thick semi-evergreen, semi-evergreen, moist deciduous and degraded were identified. These formations were again categorized in elevation wise as high elevations, medium elevations and low elevations. Amount of CO_2 fixed in unit area of all tree formations was ranged between 540.23 t ha^{-1} of low elevation degraded and 1595.57 t ha^{-1} of high elevation thick evergreen. In evergreen and thick semi-evergreen, CO_2 fixed rate of medium elevation was less than low elevation formations whereas in remaining formations such as thick evergreen, semi-evergreen, moist deciduous, and degraded the CO_2 fixed rate in medium elevation was higher than low elevation.

Key words: Sequestered, CO_2, tree formation, biomass, carbon, tropical forest, atmosphere.

INTRODUCTION

Global warming is one of the major threats facing in the development of modern world. Its dangerous effect noted by Bhadwal and Singh [1] that 1^{o} C rise in temperature will displace the limits of tolerance of land species some 125 km towards the poles. Over the last three decades, GHG emissions have increased by an average of 1.6% per year with CO_2 emissions from the use of fossil fuels growing at a rate of 1.9% per year, and these emission trends are expected to continue in the absence of additional policy actions [2]. It is clearly illustrated in the synthesis report of IPCC [3] that the CO_2 is the most important anthropogenic GHG. Matthews and Caldeira [4] reported that human-caused warming linked to CO_2 is nearly irreversible for more than 1,000 years, even if emissions of the gas were to cease entirely. Mohamed et al. [5] stated that, even the increasing emission of CO_2 is parallel with the economic growth, the world economic growth is impossible to decrease. In this context, identify the possible ways for reduce the atmospheric CO_2 concentration is crucial.

Carbon sequestration involves either the capture and secure storage of power plant CO_2 emissions in geologic formations or deep oceans, or the removal of CO_2 from the atmosphere by terrestrial or marine photosynthesis and the subsequent long-term storage of the carbon-rich biomass [6]. These uptake and storage processes—referred to hereafter as carbon "sinks"—play a significant role in the global CO_2 cycle, so that only about one-half of the CO_2 emitted from fossil fuels accumulates in the atmosphere. The other half is absorbed by the oceans and terrestrial ecosystems [7]. Thus, terrestrial ecosystem is a major biological scrubber of atmospheric CO_2 that can be significantly increased by careful management. Absorbing CO_2 from atmosphere and moving into the physiological system and biomass of the plants, and finally into the soil is the practical way of removing large volumes of the major GHG [8]. Moreover, since the Kyoto protocol on greenhouse gas emission reduction, vegetations have been targeted for reducing carbon emissions and this carbon finally stored in soil [9]. In fact, about half of the dry mass of all living things is composed of carbon. Plants take carbon from the atmosphere in the form of CO_2 and use the water and sun's energy to make a new compound, glucose ($C_6H_{12}O_6$), composed of carbon, hydrogen, and oxygen. Some of the glucose is converted by the plant to cellulose and ends up as one of the main structural compounds in wood in the case of trees. Through this process, called photosynthesis, carbon is removed from the atmospheric pool. About half the carbon absorbed through photosynthesis is later released by plants as they use their own energy to grow. The rest is either stored in the plant, transferred to the soil where it may persist for a very long time in the form of organic matter, or transported through the food chain to support other forms of terrestrial life [10,11].

Since the variations in topography, climate, wind, and water potential, nutrients, chemical and physical structure of soil in tropical forests are drive to the heterogeneity in the natural species composition. According to this species variation, different formations are formed and hence their density and physiological activities like rate of photosynthesis are also varied. Beyond these natural influences, anthropogenic disturbances are obvious in tropical forests. Very recently many reports are highlighted consequences of disturbance on natural resources like deforestation [12-16]. The Western Ghats, one of the 'biodiversity hotspots' and the region of high population pressure in the world, is a chain of mountains spread over an area of about 54,000km^2. It is unique in terms of its endemic flora, fauna as well as the biological affinities it shares with tropical forests in south-east Asia. Among the other regions of the Western Ghats, the southern Western Ghats is one of the richest abodes of tropical moist forests in the country. A large portion of the southern Western Ghats falls within Kerala State, with a few significant spur hills extending into the neighboring Tamil Nadu State [17]. Lot of studies highlighted the ecological importance and in a recent study, Karunakaran et al. [18] reported urgent need of protection with community participation of this region. So far, detailed study about the potential of different formations of these tropical vegetations to mitigate global warming is not present. In the context of heterogeneity in vegetation and degradation influenced by anthropogenic pressure, a detail comparative study of varying vegetation formations is essential. This attempt was to evaluate the different tree formations' capability to fix the atmospheric CO_2 to biomass of tropical forest by estimating their biomass carbon.

MATERIALS AND METHODS

Study area

The study was conducted in Shenduruny Wildlife Sanctuary, located between $77^0$4 and $77^0$17 East longitude and $8^0$48 and $8^0$58 North latitude, belonging to Agasthyamalai Biosphere Reserve, southern Western Ghats, India. The Shenduruny Wildlife Sanctuary has an area of 17100 ha including a reservoir and plantations. Vegetation of the sanctuary has been classified into West Coast Tropical Evergreen, Southern Hill Top Tropical Evergreen, West Coast Semi Evergreen and Southern Moist Mixed Deciduous Forest [19, 20].

Forest Classification

Indian Remote Sensing P6 LISS 4 satellite images (January and February 2007) with 5.8 m spatial resolution and software such as ArcGIS 9.3 and ERDAS IMAGIN 8.3 were used for this study. Standard FCC imagery generated by combining band 3, 2, and 1. In the FCC image, the forests would appear in dark red to light red tone. The richness of the red indicated the vigor of the leaves and their sizes. Patches of light red tones represented degraded formation. The light greenish to white tones indicated barren lands. Water bodies were indicated in blue and black tones. Shuttle Radar Thematic Map (SRTM) was used for elevation wise classification.

Radiometric correction of images was performed for abolishing unwanted artifacts like additive effects due to atmospheric scattering by a set of preprocessing or cleaning up routines. First order corrections were done by dark pixel subtraction technique. This technique assumes that there is a high probability of at least a few pixels within an image, which should be black, i.e. with zero reflectance. However, because of atmospheric scattering, the image system records a non-zero DN value at the supposedly dark-shadowed pixel location. This represents the DN value that must be subtracted from the particular spectral band to remove the first order scattering component [21]. For geometric correction ground control points from Survey of India Toposheets (1:50000) and GPS were used and given Universal Transverse Mercator (UTM) projection.

Digital image classification technique was performed for forest type classification from satellite images. Since the ground truths were available supervised classification with maximum likelihood classifier algorithm was preferred in the present study. Supervised classification in which the analyst 'supervises' the pixel categorization process by specifying, to the computer algorithm, numerical descriptors of the various cover type present in a scene [22]. As considered only tree vegetation of forest, input training sites were focused from tree vegetations such as thick evergreen, evergreen, thick semi-evergreen, semi-evergreen, moist deciduous and degraded. Since the forest physiognomy is varied as per the altitude difference, satellite images of the study area were categorized as elevation wise into three such as low elevation, medium elevation and higher elevation. The interval of each elevation class was adapted from Pascal et al. [23] and hence altitude of lower elevation was < 800 m, medium elevation was 800 – 1450 m and for higher elevation was >1450 m. All formations of tree vegetation from the classified image were checked in the field by taking GPS points from corresponding forest regions. As per the identified errors, necessary corrections were done and finalized the forest formation maps.

Biomass carbon and fixed CO_2

Non-destructive method was followed for estimate tree biomass in natural forest whereas plantations were excluded in this study. Plot sampling technique adapted from Ramachandran et al. [8] was used from pre-determined regions from classified maps. The 20 m × 20 m plots were laid and girth at breast height (GBH) measurement (in cm) of all trees (GBH > 30 cm) was collected from different tree formations. GBH measurement was taken from 130 cm above from the soil surface in normal trees and 130 cm above from the buttress region in buttressed trees. The aboveground biomass (AGB) of each tree was worked out using the allometric equation prepared for tropical trees, Biomass = exp{-2.134+2.530*ln(D)} [24]. The below ground biomass (BGB) was estimated from the AGB using standard conversion ratio 0.26 [2]. Amount of carbon present in the biomass was estimated by multiplying 0.5 with biomass value and fixed CO_2 in biomass was calculated by multiply the molecular weight of CO_2 and divide by the atomic weight of carbon with biomass carbon.

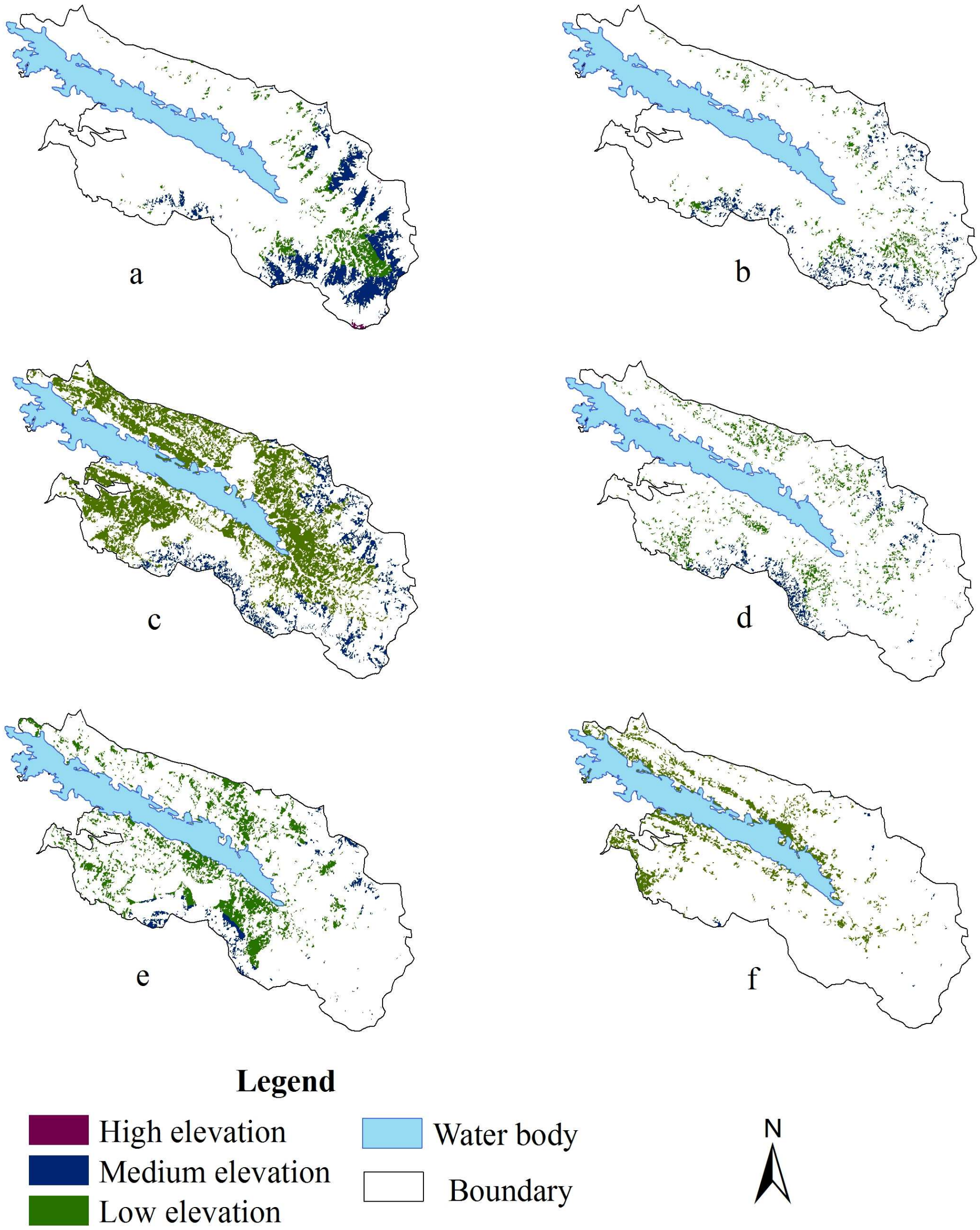
RESULTS AND DISCUSSION

Tree formations

Different formations of tree vegetation namely thick evergreen, evergreen, thick semi-evergreen, semi-evergreen, moist deciduous and degraded were identified from Shenduruny Wildlife Sanctuary of southern Western Ghats of India (Figure i). Thick evergreen was confined in three elevation classes such as high elevation (> 1450 m), Medium elevation (800 – 1450 m) and low elevation (< 800 m) whereas the evergreen, thick semi-evergreen, semi-evergreen, moist deciduous and degraded were confined up to medium elevation level. Area wise distribution of each forest type was varied from low to high elevation. Of 2000.21 ha of thick evergreen, 33.66% (673.30 ha) was in low elevation, 64.35% (1287.09 ha) was in medium elevation and remaining 1.99% (39.82 ha) was in high elevation. In 884.48 ha of evergreen type, 45.29% (400.57 ha) was in low elevation and 54.71% (483.91 ha) was in medium elevation were estimated. Most of the thick semi-evergreen, semi-evergreen, moist deciduous and degraded were in low elevation with shared 79.69%, 65.70%, 75.37% and 98.70% respectively and remaining 20.31% of thick semi-evergreen, 34.30% of semi-evergreen, 24.63% of moist deciduous and 1.30% of degraded were in medium elevation. In percentage wise allocation of each formation from medium to low elevation, a gradual reduction obvious from thick evergreen to degraded formations.

Pascal et al. [23] identified, by the presence of common species combinations, two types evergreen formations of both in low elevation (*Dipteriocarpus indicus – Kingiodendron pinnatum – Strombosia ceylanica* and *Diptericarpus indicus – Dipteriocarpus bourdilloni – Strombosia ceylanica*) and in medium elevation (*Cullenia exarillata – Mesua ferrea – Palaquium ellipticum – Gluta travancorica* and *Cullenia exarillata – Mesua ferrea – Palaquium ellipticum*) in forest map of south India classification. In a revised survey of the forest types of India, Champian and Seth [20] identified two types of wet evergreen forest in southern Western Ghats, i.e. west coast tropical evergreen forest (1A/C4) and southern hill top tropical evergreen forest (1A/C3). Pascal et al. [23] identified low elevation evergreen type and Champian and Seth [20] identified west coast tropical evergreen forest type represents the low elevation formations of thick evergreen and evergreen of present study. Mean time Medium elevation type of Pascal et al. [23] represents the respective formation of present study. Champian and Seth [20] identified southern hill top tropical evergreen forest represents the medium elevation formations of thick evergreen, evergreen and high elevation thick evergreen of present study. Pascal et al. [23] identified with common species composition, *Bhesa indica – Gomphandra coriacea – Litsea* spp., was also represented the high elevation thick evergreen formation of present study. In medium elevation and low elevation, thick semi-evergreen and semi-evergreen formations were identified in this study. The same types were commonly grouped under same type, west coast semi-evergreen forest by Champian and Seth [20]. Pascal [25] explained the semi-evergreen forest formations apparent in between evergreen and moist deciduous types. In present study, moist deciduous type was most in low and was less in medium elevation regions. According to the illustration of Western Ghats forest [25], moist deciduous formation was occupied in between the formations of semi-evergreen and tree savanna and the tree savanna was considered as degraded formation in present study. The same pattern was obvious in present study and the most of degraded formation was in low elevation regions where experienced most of anthropogenic influences. Many authors [26-28] agreed the tree savanna was anthropogenic origin and it was obvious in degraded formation of present study since most of degraded formation was in human approachable areas. These early studies illustrated allocation trends of semi-evergreen, moist deciduous and degraded was apparent in the present study.

Figure i Different tree formations of Shenduruy Wildlife Sanctuary



a – thick evergreen, b – evergreen, c – thick semi-evergreen, d – semi-evergreen, e – moist deciduous, and e – degraded.

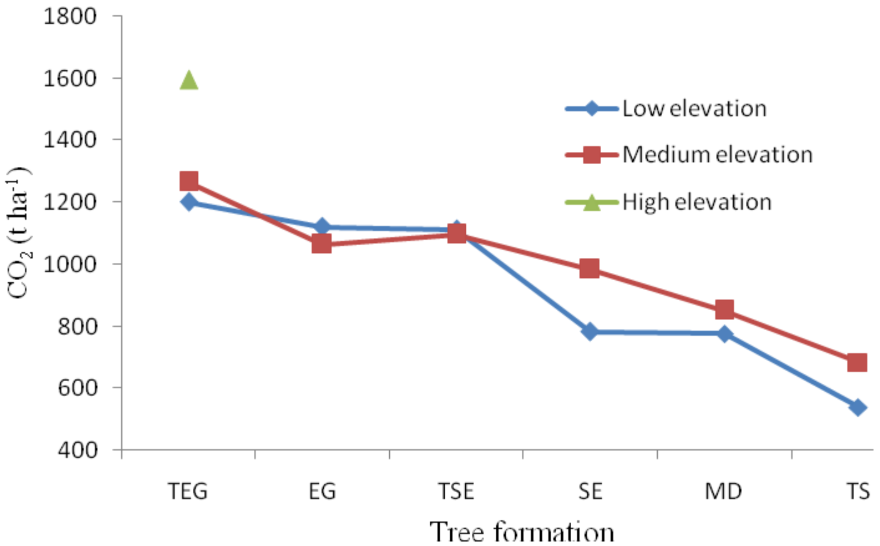
Biomass

Estimated biomass (sum of above ground and below ground) in unit area (1 ha) was varied from 294.67 to 870.31 t ha^{-1} in different tree formations of Shenduruny Wildlife Sanctuary (table i). Thick evergreen forest type in high elevation class showed highest biomass amount whereas least amount was estimated from degraded in low elevation. Medium and low elevation thick evergreen (689.59 and 654.92 t ha^{-1} respectively), low elevation evergreen (610.57 t ha^{-1}) and thick semi-evergreen (606.71 t ha^{-1}) were showed > 60 t ha^{-1} of biomass after the highest value of high elevation thick evergreen. Remaining formations such as medium elevation evergreen and thick semi-evergreen, medium and low elevation semi-evergreen, moist deciduous and medium

Table i Biomass and biomass carbon of different tree formations in unit area (t ha^{-1})

Tree formation	Biomass	Biomass carbon	Tree formation	Biomass	Biomass carbon	Tree formation	Biomass	Biomass carbon
LE-TEG	654.93	327.46	**LE-TSE**	606.71	303.36	**LE-MD**	423.31	211.66
ME-TEG	689.59	344.8	**ME-TSE**	598.2	299.1	**ME-MD**	464.59	232.3
HE-TEG	870.32	435.16	**LE-SE**	427.15	213.57	**LE-DG**	294.67	147.34
LE-EG	610.58	305.29	**ME-SE**	536.42	268.21	**ME-DG**	373.38	186.69
ME-EG	579.81	289.91						

Figure ii Rate of fixed CO_2 in different tree formations



HE – high elevation, ME – medium elevation, LE – low elevation, TEG – thick evergreen, EG – evergreen, TSE – thick semi-evergreen, SE – semi-evergreen, MD – moist deciduous, DG – degraded

HE – high elevation, ME – medium elevation, LE – low elevation, TEG – thick evergreen, EG – evergreen, TSE – thick semi-evergreen, SE – semi-evergreen, MD – moist deciduous, DG – degraded elevation degraded were showed 579.81, 598.19, 536.41, 427.14, 464.59, 423.31 and 373.38 t ha^{-1} respectively. Biomass studies in the tropical forests of India were rare and available studies were conducted in national or large area scale [1, 29-31]. Since the Indian tropical forests especially Western Ghats had heterogeneous nature in topography, rainfall, temperature, evapo-transpiration, soil and water availability, distinctive divergence on vegetation parameters was obvious in place to place. In present approach, the total biomass in t ha^{-1} (sum of above ground and below ground) range of all tree formations was 294.67 - 870.31 t ha^{-1}. From the tropical forest of French Guiana Chave et al. [32] reported the above-ground biomass ranged from 356 to 398 t ha^{-1} it was equal to 448.56 – 501.48 t ha^{-1} of total biomass. Zheng et al. [33] reported 362.1 to 692.6 t ha^{-1} biomass from the tropical forest of southwest China. From the tropical forest of Madagascar, Eckert [34] estimated above ground biomass was varied from 323.30 - 1048.08 t ha^{-1} (its equivalent total biomass was 407.36 – 1320.58 t ha^{-1}) in non-degraded forest and 217.16 - 572.22 t ha^{-1} (its equivalent total biomass was 273.62 – 721.0 t ha^{-1}) in degraded forest. From the southern Western Ghats (Karnataka State of India), Rai and Proctor [35] estimated above ground biomass was ranged 420 – 649 t ha^{-1} and it was equivalent to 529.2 – 817.74 t ha^{-1} range of total biomass. The biomass range of present study can comparable with the range of early reports of tropical forests in other regions and southern Western Ghats.

Fixed CO_2

Tree vegetations sequestered carbon in the form of biomass was converted to equivalent CO_2 reduced from atmosphere and given in figure ii. Amount of CO_2 sequestered in unit area of all tree formations was ranged between 540.23 t ha^{-1} of low elevation degraded and 1595.57 t ha^{-1} of high elevation thick evergreen. The rate of sequestered CO_2 was gradually reduced in the way of thick evergreen > thick semi-evergreen > evergreen > semi evergreen > moist deciduous > degraded. In evergreen and thick semi-evergreen, CO_2 fixed rate of medium elevation was less than low elevation formations whereas in remaining formations such as thick evergreen, semi-evergreen, moist deciduous, and degraded the CO_2 fixed rate in medium elevation was higher than low elevation formations. Since the scarcity of previous studies about CO_2 estimation from sequestered carbon of vegetations, unable to compare the fixed CO_2 values of present study with early studies. Also, since estimated biomass carbon and fixed CO_2 were directly proportional to biomass, more comparative explanation of biomass carbon and CO_2 with previous studies is not relevant.

CONCLUSION

Highlighting the possible mitigation options of global warming is the need of present time in the context gradual elevating trend of atmosphere heat in day by day. Even if the green house gasses have been produced as the part of modern development, we have limitations to avoid this development. Same time focuses on the eco-friendly solutions like conversion of atmospheric CO_2 to biomass carbon by vegetations and then to as soil organic carbon is the feasible way. Capability of different tree formations to fix atmosphere CO_2 is not uniform and it is obvious in the present study. In Shenduruni Wildlife Sanctuary, amount of CO_2 fixed in unit area of tree formations was ranged between 540.23 t ha^{-1} of low elevation degraded and 1595.57 t ha^{-1} of high elevation thick evergreen. In evergreen and thick semi-evergreen, CO_2 fixed rate of medium elevation was less than low elevation formations whereas in remaining formations such as thick evergreen, semi-evergreen, moist deciduous, and degraded the CO_2 fixed rate in medium elevation was higher than low elevation formations.

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