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Carbon Sequestration Scenario's From World's Forests To Indian Forest Ecosystem-A Review Study On Approaches In Nature Conservation

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Abstract:
Photosynthesis is the unique mechanism through which carbon transforms in various parts of the plant body and store by a biochemical process in the plant's body in the form of organic matter which is called as biomass. These biomass are mainly compartmentalized in above ground biomass (AGB) and below ground biomass (BGB) in all existing flora species in the ecosystem. AGB includes tree parts above the land/surface like trunk, leaves, main or secondary branches, fruits and flowers etc. while BGB includes roots. Soils are largest carbon reservoir in the forest ecosystem, which supports the plant growth. Today, human inducing activities have been upgraded the concentration of atmospheric carbon in the form of carbon dioxide which resulted in Global warming. Our main objective of present review study is to explore innovative ideas for nature and biodiversity conservation and enlighten on the possible approaches made by Scientists and Researchers of various fields. The present study is a small assortment of different biomass methods, which will cooperate to estimate the carbon budget in the ecosystem. The study is also giving exposure on the role of Indian Forests in carbon sequestration in International arena.

Keywords: *Above and Below ground biomass (AGB/BGB), Carbon, SOC.*

1. Introduction

Carbon is the major component of all cellular life forms such as plants and animals; they utilize carbon and store it, in different parts of plants viz. Trunks, branches, leaves, reproductive parts (flowers & fruits) and roots (Kiran et al., **2011**). The carbon exists in all surviving organisms in the ecosystem or has ever survived. Macromolecules like De-oxiribo nucleic acid (DNA), Ribonucleic acid (RNA) or Proteins are structurally bound with carbon. Carbon is transported in complex form i.e. CO_2 in an ecosystem; it flows and sinks in the form of biomass by photosynthesis and the electron transport chain in plant system. Carbon (C) sequestration refers to the storage of carbon into a stable form. This act of sequestering carbon is dependent upon the nature of the **carbon sink** and can be achieved by several ways: directly by inorganic chemical reactions that cause carbon dioxide (CO_2) in the form of carbonates/bicarbonates to bond with dissolved minerals and salts to form compounds such as calcium and magnesium carbonates; by plant photosynthesis, which uses sunlight to combine CO_2 from the atmosphere and water to form glucose ($C_6H_{12}O_6$), a simple sugar that is stored within the tissue of living plants; and indirectly, by the microbial decomposition of the biomass of plant and animal tissue into other compounds like carbohydrates, amino-acids/proteins, organic acids, wax, coal, oil, and natural gas, etc (Atkin et al.,2012).

1.1.Carbon-Sink, Storage And Sequestration

The C cycle of any forest ecosystem is recognized by a number of ‘pools’ and ‘fluxes’. Pools are the top locations of carbon in the forest, i.e. AGB and BGB, litter layer, dead twigs and foliages and soil. Each pool possesses an amount of C that is referred to as the ‘stock’. Carbon relocated and shifts between the various pools by photosynthesis, respiration and combustion mechanisms are known as ‘fluxes’. The net switching of carbon between a forest ecosystem and the atmosphere is determined by two large fluxes. The first of these is C transformed as a result of photosynthesis. The second is the self utilization of C as a result of respiration by trees, in the form of biomass, and decomposition of soil organic matter in soil. If C transformation exceeds loss, the forest is a ‘sink’. Conversely, if the loss or utilization exceeds uptake the forest is a ‘source’ (Byrne and Black, 2003). Carbon sequestration is a nature balancing process of removing of the carbon from the atmosphere (Source) by storing it in the biosphere (Chavan et al., 2012) i.e. green plants (Sink). These sinks are aboveground biomass (trees/AGB) or living biomass and below ground (BGB) in soil (root-system and microorganisms) or in the deeper subsurface environments (Jina et al., 2008).

1.2.Carbon And Forest Ecosystem Relationship

The term ecosystem was suggested by an English Ecologist, Tansley in the year 1935. He defined it as including "not only the organism-complex, but the whole complex of physical factors forming what we the environment." There are several alternative definitions, all proposed by American ecologists. Lindeman in 1942 proposed that "an ecosystem is any system composed of physical, chemical and biological process active within any space-time unit." Whittaker in 1975 suggested that "an ecosystem is a functional system that includes an assemblage of interacting organisms (plants, animals and saprobes) and their environment, which acts on them and on which they act". Odum in 1971 proposed a longer but more explicit definition:

"Any unit that includes all of the organisms (i.e., the community) in a given area interacting with the physical environment so that a flow of energy leads to a clearly defined tropic structure, biotic diversity and material cycles (i.e. Exchange of materials between living and non-living parts within the system) is an ecological system or ecosystem." An ecosystem dominated by trees, in which the microclimate, soils, hydrology, nutrient cycling, biomass creation, storage and turnover, and food chain processes reflect the dominance by large, long lived wood plants is called as forest ecosystem (Kimmins, 1997).

In nature, the forest ecosystem is one of the most important carbon sinks and acts as a reservoir of the carbon and regulates the carbon cycle by exchange of $CO_2$from the atmosphere by photosynthesis. It stores the carbon in the plant tissues, forest litter and soils. Thus, forest ecosystem plays important role in the global carbon cycle by sequestering a substantial amount of carbon dioxide from the atmosphere (Vashum et al.,2012).

Forests are bio-scrubber, they absorb CO_2 from the atmosphere and moving into the physiological system and biomass of the plants, and finally into the soil and transport the carbon into the biological system. Thus, the carbon is sequestered in the plants and then from the plants to the animals by food chain. Eventually, after the death of the animals, the detritus decomposes into the soil organic carbon by microbial enzymatic activities. These sequestered carbons finally act as 'sinks' in the forest lands (Ramchandran et al.,2007). It is estimated that the world's forests store 283Gt of carbon in their biomass alone and 638Gt of carbon in the ecosystem as a whole (to a soil depth of 30 cm). Thus, forests contain more carbon than the entire atmosphere accounting for 77% biomass carbon storage of global terrestrial ecosystems. Worldwide, 50% of the aboveground carbon is stored in tropical forests and the minimum storage is proved in polar forests (Liu et al., 2012).

Ecological Forest Zone	**Area (10^9**	**Carbon**
Tropical	1.91	142.50
Tropical rainforest	1.03	73.20
Tropical moist deciduous forest	0.47	38.40
Tropical dry forest	0.22	11.00
Tropical mountain system	0.15	16.90
Tropical shrubland	0.04	3.00
Tropical Desert	0.00	0.00
Subtropical	0.41	34.30
Subtropical humid forest	0.19	15.90
Subtropical Mountain system	0.12	9.10
Subtropical steppe	0.04	5.20
Subtropical dry forest	0.04	2.30
Subtropical desert	0.02	1.80
Temperate	0.63	53.70
Temperate continental forest	0.28	16.40
Temperate mountain system	0.24	25.70
Temperate oceanic forest	0.05	6.10
Temperate steppe	0.03	3.10
Temperate desert	0.01	2.40
Boreal	1.22	55.90
Boreal coniferous forest	0.65	28.00
Boreal Mountain system	0.39	18.50
Boreal tundra woodland	0.19	9.40
Polar	0.03	1.30
World Forests	**4.19**	**287.70**

Table1: Aboveground Biomass Carbon Storage Potential of World Forests

2.Literature Survey

A review of earlier works is very significant for any type of research which is related to the theme. It helps to decide the objectives of the any study and selecting the methodology and to analyze data with proofs. Here, some previous works already done by the Biological and Environmental Scientists in last two years and have been reviewed by me, which will support to the Reviewers and Researchers in future studies in same research. Biomass is an organic matter of any existing plant creature, which is a complex form of organic carbon. Destructive and Non-destructive two methods have been adopted for Phyto-mass and organic carbon determinations in the forest ecosystem, some of the scientific approaches are followed:

Ilyas, (2013); Tree biomass in A. Mangium were estimated by destructive sampling technique in 3 quadrats of size 20m x 30m. Diameter and height of the trees were measured with vernier calipers and Ultrasonic hypsometer respectively. Total 12 sample trees were uprooted according to age criteria. Tree samples stem, branch and leaves were collected and Oven dried at 105^0C to gain constant weight. Regression equations were used to estimate the biomass. Total biomass was calculated from the sum of above and below ground biomass. The relationship between diameter and biomass shows the 67%, 19% and 14% biomass contribution for stem, branch and leaf. Pandya et al., (2013); 25 heritage plant species were taken under consideration for biophysical monitoring. The data's of relevant GBH (Girth at Breast height, 1.32 above the ground or surface) and height were taken from forest inventories of the Gujarat Forest Department. The diameter was calculated by assuming the tree trunks to be cylindrical. Bio-volume was multiplied with $600Kg/m^3$ as standard average wood density to estimate the biomass. 50% of biomass were made in consideration for carbon.

Sreejesh et al., (2013); 181tC/ha carbon storage potential was estimated in Tectona grandis by destructive sampling applied on various age stands plantation forest. Regression function was used to assess the carbon content. The carbon content 46%, 32%, 40% and 45% was estimated for the wood; bark, branches and roots parts respectively, on the CHNS elemental analyzer.

Joshi et al., (2013); Carbon sink potential of Dalbergia sissoo and Eucalyptus hybrid was estimated by plot method. Plots were randomly set up in plantation areas and Phyto-sociological study was done by measurement of ideal girth class trees. Forest floor and herbaceous vegetation were sampled and oven dried at 60^0C for 72 hrs or constant weight till samples get de-moisturized. Soil samples collected up to the depth 70cm. The young

Eucalyptus hybrid is sequestrating carbon at 7.89 $tha^{-1}yr^{-1}$ and Dalbergia sissoo stores 6.47 $tha^{-1}yr^{-1}$ carbon.

Qing Qing et al., (2012), Biomass carbon accumulation rates increase continuously until the forest canopy closes; after that, it tends to decrease. In one of the study carried out in South China shows the significance of forest types for carbon storage. The four forest types were covered in study which are Pinus massoniana forest, Cunninghamia lanceolata forest, hard broad-leaved evergreen forest and soft broad-leaved evergreen forest. AGB and net carbon accumulation (TNEP) was analyzed in 5stand ages (initiation, young, medium, mature and old). The 5stand ages were analyzed by bio-static tools one way ANOVA in SAS (Version8.0) and regression were curved in built-in statistical program Origin (Version8.0). In each period, correlations in all four forest types were all statistically significant ($P<0.01$) with $R2 > 0.95$. TABC was therefore predicted by these regression functions from 2000 to 2050 and the mean TNEP during the predicted period was estimated to be about 41.14, 31.53, 75.50 and 75.68 g $Cm^{-2}a^{-1}$ in Pinus massoniana forest, Cunninghamia lanceolata forest, hard broad-leaved forest and soft broad-leaved forest, respectively.The study suggested that broad-leaved forests are better solutions for afforestation and reforestation in south China in light of their greater potential carbon accumulation ability compared with needle-leaved forests.

Chavan et al.,(2012); Biomass analysis in Annona squamosa and Annona retiaculata tree species is estimated by destructive methods followed by the ash content method. Plants separated into stem, leaves, bark and sub branches and oven dried at 80^0C for 24 hours and after then placed in a muffle furnace for carbon ignition process. Carbon content in Annona retiaculata and Annona squamosa was 83.1 Kg Cha^{-1} and 73.5 Kg Cha^{-1} estimated respectively. Carbon is estimated by following equation:

Carbon = Biomass x Carbon%

Miria and Khan (2012); Ornamental trees sequester more carbon than timber species; Common lawn grass Zoysia japonica has higher carbon density then other wild grasses. The study was done by a non-destructive method for trees. For grass samples quadrates of 1m x 1m were placed and litter samples for above ground biomass estimation were collected. Samples were oven dried at 95^0C for 72 hrs and heated in a muffle furnace to calculate the carbon percentage. Peltophorum pterocarpum indicated highest total biomass carbon density (496Kg/t) and Azadirachta indica has the lowest value (462Kg/t).

Hangarge et al., (2012), 31 tree species having 4000 individuals were recorded in 25 x 25 sq. meter in 80 quadrates at Somjaichi Rai (Sacred grove) of Pune district. Carbon sequestration in trees was estimated by non-destructive method. Above ground biomass (AGB) of species were calculated by multiplying the tree volume with wood density (Kg/m^3) while; below ground biomass (BGB) was measured by multiplying the AGB to factor 0.26 (root: shoot ratio). Terminalia bellirica species were found to be dominant having 180 trees and sequestrated 327.78 tonnes of carbon followed by Ficus amplissima (221 tonnes).

Terakunpisut et al., (2012); Carbon sequestration study was carried out in Thong Pha Phum National Forest, Thailand. Girth and Height were measured, by SILVIC program. Quadrate method applied for biomass estimation. AGB was estimated by destructive sampling and regression allometric equations were used to evaluate the carbon. The conversion factor 0.5 was applied to convert the AGB into carbon content. Tropical Rainforests < Dry evergreen forests < Mixed deciduous forests carbon stock order was estimated.

Kaewkrom et.al, (2011); Primary mixed deciduous forests (PMDF) sequesters more carbon dioxide than Secondary mixed deciduous forests (SMDF) in Thailand. One study quadrate 50m x 50m laid in both the forest sites by preparing five 10m x 10m sub-quadrates for trees and Shrub enumeration respectively. Soil organic carbon was estimated by standard Walkley-Black method. Data analyzed by ANOVA as statistics tool. Relative density, Relative dominance, Relative frequency, and Importance Value Index (IVI) were calculated as ecological parameters. Species composition was made up of 36 identified tree species and 36 identified shrub species in PMDF whereas SMDF had 36 identified tree species and 22 shrub species. The dominant species having a high carbon concentration included Canarium subulatum, Pterocarpus macrocarpus, Dalbergia cultrate, Largerstroemia tomentosa, and Xylia xylocarpa.

Aticho, (2013) Suggested; Soil sample depth, bulk density and organic carbon concentration are important indicators of soil organic carbon (SOC) storage capacity. Soil samples were collected from the upper, middle, lower and a toe Slope zone from the forests of Bita district. SOC storage was estimated from wet oxidation method and bulk density was determined by dividing the oven dry at 110^0C for 24hrs weight (gm) of soil to the volume of the core (cm^3). Multiple regression function was used in SPSS version 16. The quantity of organic carbon stored in the soil was 639.64 ± 286.10t ha^{-1}.

Atkin et al., (2012); The higher the content of SOC, the greater the fertility and productivity of the soil. Soil bulk density (g/cm3) is the dry weight (g) of one cubic centimeter (cm^3) of soil. The higher the bulk density the more compact the soil. Generally, soils of low bulk density are well structured and have more space than stuffing`. The lower the bulk density the more room for air and water and the better the conditions for soil life and nutrient cycling. Bulk density usually increases with soil depth, unless acidified with the present method to open up the soil pores. SOC content was raised by acidifying the land by applying the water with pH adjusted Sulfur dioxide (SO_2) to open up the soil pores at greater depths of soil and supplemented to plants and soil bacteria's, due to which assimilation of high CO_2 produces and resulted the high SOC in soil. A 1% increase in organic carbon in the top 20 cm of soil with a bulk density of 1.2 g/cm3 represents a 24 t/ha increases in SOC which equates to 88 t/ha of CO_2 sequestered.

3. Carbon Sequestration in Indian Forests

Sheikh et al., (2011); The total estimated carbon stock in Indian Forest biomass varied from 3325Mt to 3161Mt during the years 2003 to 2007 respectively. The data of growing stock, biomass, forest floor and carbon stock were collected in 14 physiographies zones of India. The forests AGB in this study was estimated by multiplying the growing stock to mean density and biomass expansion factors. The BGB was evaluated by multiplying the AGB to root: shoot ratio. Total biomasses were calculated from summation of AGB and BGB. To estimate the total amount of carbon stock in Indian forests dry weight of biomass was converted into carbon by multiplying by a factor 0.45. Any biomass study of carbon estimation is incomplete without estimating the carbon stocks of forest soils. Because soils of any forest land are major terrestrial carbon reservoirs in form of Soil organic carbon (SOC). Out of 14 Physiographic zones of India, Western Himalaya Zone has reserved maximum carbon stock in their ecosystem than remaining 13 Zones (Table-1.2).

	Year-2003		Year-2005		Year-2007	
P-Zone	**TFB(Mt)**	**CS (Mt)**	**TFB (Mt)**	**CS (Mt)**	**TFB (Mt)**	**CS(Mt)**
Western Himalayas	1336.346	601.35	1348.518	606.83	1397.583	628.91
Eastern Himalayas	632.932	284.82	654.225	294.4	625.094	281.30
North East	560.823	252.37	580.109	261.05	511.54	230.19
North Plains	328.344	147.75	326.344	146.85	284.429	127.99
Eastern Plains	449.63	202.33	446.16	200.77	389.378	175.22
Western Plains	120.576	54.26	101.997	45.89	94.81	42.66
Central highlands	277.82	125.02	233.75	105.19	253.737	114.18
North Decan	429.738	193.38	390.715	175.82	420.002	189.00
East Decan	829.063	373.07	879.758	395.9	945.817	425.62
South Decan	530.92	238.91	461.027	207.46	413.273	185.97
Western Ghats	640.656	288.39	659.703	296.9	668.771	300.95
Eastern Ghats	663.94	298.77	578.887	260.5	502.23	226.00
West Coast	300.066	135.03	280.151	126.07	292.737	131.73
East Coast	288.692	129.9	222.998	100.3	226.614	101.98
Total-14	**7389.546**	**3325.36**	**7164.342**	**3224**	**7026.015**	**3161.7**

Table 2: Physiographic Zone wise Carbon Stock in Indian Forests (Mehraj et al., 2011)

As per the NATCOM project (2001) sponsored by the Ministry of Environment and Forests, India with the assist of Forest Survey of India reported about the state wise total biomass of the standing forests and carbon stocks in the country. This study predicted that Madhya Pradesh State has highly conserved the biomass and sequestered a huge quantity of carbon in their standing bio-volumes. During the study, Gujarat State has shown increment in carbon storage in their biomass for both the years. The values of the total biomass (TB) and carbon storage potential in tones are mentioned for the Year 1989 and 1997; the details are in Table 1.3.

	Year-1989		**Year-1997**	
State/UT	**TB tons**	**CS tons**	**TB tons**	**CS tons**
Andhra Pradesh	219010.98	98433.53	199009.01	89434.15
Arunachal Pradesh	184145.78	83386.96	180673.44	81820.37
Assam	168264.15	75757.31	165652.81	74580.8
Bihar	81530.34	37182.39	71805.32	32765.22
Goa, Daman & Due	6046.55	2720.95	6375.36	2868.91
Gujarat	**29538.1**	**13137.57**	**44735.27**	**19924.12**
Haryana	254.19	114.76	464.85	210.2
Himachal Pradesh	86386.2	39671.46	106442.18	48909.11
Jammu & Kashmir	179648.81	82635.73	180931.27	83225.78
Karnataka	146907.03	66054.84	147861.54	66484.14
Kerala	47801.75	21466.62	47959.28	21537.31
Madhya Pradesh	447667.36	202057.94	439853.33	198427.67
Maharashtra	126821.51	56489.43	125582.63	55954.62
Manipur	43415.68	19588.16	44046.03	19868.31
Meghalaya	67897.26	30477.01	73216.88	32857.56
Mizoram	34144.86	15331.92	35765.64	16058.45
Nagaland	57026.41	25665.85	51701.86	23272.92
Orissa	175575.19	80136.82	171486.83	78264.95
Punjab	466.91	210.78	648.40	291.83
Rajasthan	7317.90	3304.16	7863.78	3550.03
Sikkim	18895.47	8524.96	19481.35	8789.05
Tamilnadu	43010.75	19353.78	41844.81	18829.17

Uttar Pradesh	169264.50	77498.27	172032.75	78773.06
West Bengal	40162.51	18204.90	42339.55	19200.71
Tripura	8236.33	3698.52	8564.13	3846.41
Dadar & Nagar Haveli	913.99	410.14	937.02	420.73
A&N Islands	8108.47	3648.81	8098.13	3644.16
Total	**2398459**	**1085163.6**	**2395373.5**	**1083809.7**

Table 3: State wise biomass (TB) and carbon Stocks (CS) in Indian Forests

4.Discussion and Conclusion

A key point of our study is that, Results from all aforementioned approaches are varied because different methods are applied in the carbon sequestration study. Quantitative analysis by destructive sampling is more accurate in biomass studies because it provides accuracy in data's and minimizes the errors, but it's very cost-effective method and requires more human resource power. Non-destructive sampling is applicable for small populations, where fewer occurrences of the trees are found. Also non-destructive can be used because it's less time consuming and we need not to sacrifice entire living standing bio-volumes i.e. Trees (Chavan et al., 2012). Carbon sequestration among the species and among the different forest ecosystem will significantly always vary due to their Bio-geographical locations. Bio-physical parameters of trees are not constant, their growth is dependent on the ecosystem in which they are growing and developing. Carbon sequestration of the same species in their individuals can vary or varies in entire communities of forests. Tree's growth, large diameters and increasing height are itself an indicator of their large biomass contents and terrestrial carbon reservoir, i.e. Carbon Stock. Plantation forest stores more carbon than mature forests, due to their rapid carbon sequestration rate. As per previous researches of our literature survey, we can conclude that species which sinks more carbon in their organic biomass should be planted more. Mature trees are the terrestrial carbon reservoir, should be cultured by plant tissue culture, protect and planted towards biodiversity and nature conservation.

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