Carbon Stock Estimation in Man Made Forest of SFRTI Campus in Raipur, Chhattigarh

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Key words: Green House Gases (GHGs), Carbon stock assessment, Manmade forest, Afforestation.

Introduction

Globally, deforestation, forest degradation, forest fires and burning of fossil fuel are playing a significant role in producing the Green House Gases (GHGs) [1]. Hence, deforestation and forest degradation, caused by increasing population and land degradation, are major problems in developing countries; whereas burning of fossil fuel from industries is major problem mainly in developed countries. The conversion of forest area into non-forest area, which leads to the additional GHGs in the atmosphere, was recorded as 12.3 million ha between 1990 and 2000 in the tropical. In fact, carbon is held in the terrestrial ecosystems as vegetation and in soils. In addition oceans hold a large volume of carbon so does atmosphere. Carbon sequestration is the process of removing additional carbon from the atmosphere and depositing it in other reservoir principally through changes in land use. The terrestrial carbon sequestration is the net removal of CO2 from the atmosphere and storing it in terrestrial ecosystem. Forestry is only the major option for carbon sequestration in the terrestrial ecosystem among agricultural systems and agroforestry systems (Singh, 2005) and has concluded that the total carbon was found highest in the naturally grown forest. . In practical terms carbon sequestration occurs mostly through the expansion of the forests (Houghton, 1996). Forest has a prime role in sequestering carbon from the atmosphere. In reality, the forest is a reservoir, a component or components of the climate system where a green house gas is stored, as well as sink, any process which removes a green house gas from the atmosphere (Pearce et al., 2003). Thus the forest is the complement of carbon sequestration. So, the forest expansions and sustainable forests, as mitigation measure, have a significant contribution to the environmental benefit but any shrinkage of forests, as emission, has a long term influence and impact. Therefore, the sustainable forest, as a carbon sinks, is the key factor to balance the GHGs emission[2].

The increasing amounts of GHGs adversely affect the global environment. These effects are climate change, global warming, rising of mean sea level, alteration of weather and they threaten the life of living beings. Hence, the relationship between the increasing amount of GHGs in the atmosphere and climate change was taken seriously in 1990 and many efforts were made to create awareness globally. A Recent IPCC Report, 2013 reveal that concentrations of CO2, CH4, and N2O have now substantially exceeded the highest concentrations recorded during the past 800,000 years[3].

Forests and climate change are intimately intertwined. Forests regulate the climate, rain, groundwater, and soil. Integral to the movement of the carbon cycle, forests are instrumental in the storing and releasing of carbon. While a growing forest captures carbon from the atmosphere, a mature forest is a repository of carbon. The world’s forests and forest soils currently store more than one trillion tones of carbon—twice the amount found floating free in the atmosphere. Estimates made for FRA 2010 show that the world's forests store 289 gigatonnes (Gt) of carbon in their biomass alone. While sustainable management, planting and rehabilitation of forests can conserve or increase forest carbon stocks, deforestation, degradation and poor forest management reduce them. For the world as a whole, carbon stocks in forest biomass decreased by an estimated 0.5 Gt annually during the period 2005–2010, mainly because of a reduction in the global forest area[4].

All development is now taking place in a world shaped by climate. Climate change is happening now and impacting countries and people, with the poor the hardest hit. Potsdam Institute for Climate Impact Research shows, globally warming of close to 1.5°C above pre-industrial times – up from 0.8°C warming today – is already locked into Earth's atmospheric system by past and predicted greenhouse gas emissions. Immediate global action is needed to slow the growth in greenhouse gas emissions this decade and to help countries prepare for a warmer world and adapt to changes that are already locked in. Getting there will require economic transformations and a path to net zero emissions before the end of the century[5].

Present study was carried out to estimate carbon stock of the campus of Chhattisgarh State Centre for Climate Change, SFRTI, Raipur. This is a 31.42ha campus which was a barrel and at the time of taking in the account in the year 2003. Total 22 plots of different sizes were identified for plantation of different species for research purpose. With the journey of time these plantation sites has became a classical example of manmade forest. Looking in to the importance & role of this plantation in carbon sequestration, a study on carbon assessment were carried out during the year with following objectives –

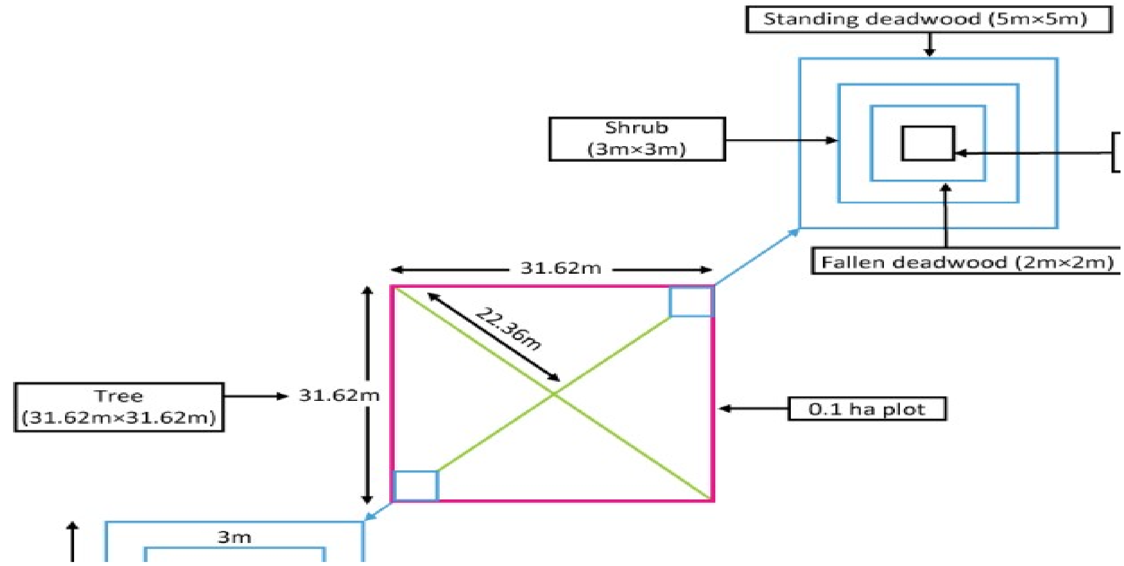
- To assess the amount of carbon is stored in SFRTI campus.
- To calculate CO_2 - tCERs of this stock at present.

Location of the study site

Chhattisgarh State Centre for Climate Change is in housed with the State Forest Research and Training Institute which is situated at Zero point, Near Legislative Assembly, Balodabazar Road, Raipur. The geo-coordinates of the site is lies between 21^{o}17'42.95" N to 81^{o}43'53.33"E.

Methodology

Present study were carried out in 32 ha man made forest at SFRTI. Total 22 permanent sample plots of 0.1 ha were laid out in the study site & assessment of carbon stock in deferent strata of the plantation sites were carried out. Diameter at Breast height (1.37m) & height of each tree in plot has been measured with the help of measuring tape & range finder. Detail description of sample plots is as under-



Permanent square plot size of different strata

Lying of Permanent Sample Plots:-

The plots are square and 31.62 m X 31.62 m in size, for standing forest tree and plantation sites. Centre points of all plots must be marked permanently in the field using marks, such as concrete pillars, metal rods, pipes, or stone poles. No matter what object is used for marking the centre, there is always a risk that it needs to be moved or removed. Therefore, the distances and bearing between the center and at least 3–4 permanent reference points (stones or trees) is recorded. The references should be distributed around the centre. A sketch of the plot centre references, their distances, and bearings to the centre is recorded and shown on the inventory form. Trees greater than or equal to 5 cm DBH are measured in each permanent square plot of a 1,000m2 plot that is 17.84 m in radius. This measurement is done using a diameter tape, clinometers, and a linear tape, starting from the edge and working inwards, and in the process of marking each tree to prevent accidentally counting it twice.

Biomass of shrubs and herbs is estimated by laying quadrates' within the main plot. Two quadrats each 3 m x 3 m in size are to be laid in each of the main plot for the measurement of shrubs. For the measurement of herbs, two quadrats each 2 m x 2 m in size are to be laid in each of the main plot for the measurement of Dead wood and two quadrats each 1 m x 1 m are to be laid within the main plot for all the litter and soil sample (dead leaves, and twigs) within the 1 m 2 subplots are collected and weighed.

Data Analysis

Date were collected for all five carbon pools i.e. Above ground biomass (AGB), Below ground biomass (BGB), Leaf litter, Dead wood carbon & Soil carbon. After collection of samples, analysis of data has been done with the help of following formulas -

1. **Above-ground Biomass:-**

   Above-ground biomass (AGB) = Volume X Wood density (WD) X Biomass Expansion Factor (BEF)

   BEF Value

Open forest – 1.14
Moderately dense forest – 2.5
Dense forest – 3.4

2. **Below-ground biomass:-**

BGB = AGB X 0.27 (IPCC default value)

Where:
BGB = below-ground biomass
AGB = above-ground biomass

3. **Deadwood:-**

DW= Dry biomass weight X 0.47 (IPCC default value)

4. **Leaf litter:-**

L = wfield/A * wdry /wwet * 1/1,000

Where,
L = biomass of LL and DW
Wfield = weight of fresh field sample
A = Size of the area
Wdry = Weight of the oven-dried sample
Wwet = Weight of fresh sample taken to the laboratory to determine moisture content

5. **Soil organic carbon:-**

SOC = rb * d * %C
Where,
SOC = soil organic carbon stock per unit area (t/ha)
rb = soil bulk density (g/cm3) – Default value is 1.2
d = total depth at which the sample is taken (cm)
%C = carbon concentration

Reference Range			
Nutrient	Low	Medium	High
Soil Organic Carbon (in carbon concentration %C)	Below 0.5%	0.5% to 0.75	Above 0.75%

6. **Total Carbon Stock Density:-**

The carbon stock density is calculated by summing the carbon stock densities of the individual carbon pools of that stratum using the below-mentioned formula. It should be noted that any individual carbon pool of the given formula can be ignored if it does not contribute significantly to the total carbon stock.

$$\Delta C = \Delta CAGB + \Delta CBGB + \Delta CLL + \Delta CDW + \Delta SOC$$

Where,
C = carbon stock density
C(AGB) = carbon in above-ground biomass
C(BGB) = carbon in below-ground biomass
C(LL) = carbon in leaf litter
C(DW) = carbon in deadwood
SOC = soil organic carbon
The total carbon stock is then converted to tonnes of CO2 equivalent by multiplying it by 44/12, or 3.67 (Pearson et al. 2007)[16-17].

Carbon stock estimation

FSI made the first tentative estimate of woody growing stock of the country forests in 1995 using its first inventory data collected during 1965 to 1990 using thematic maps and forest cover information (SFR-1995). This information has been the main input for estimating forest Carbon stock by different institutions. During 2001-03, FSI has been major contributor on forest biomass estimation and Carbon stock changes (during 1984-1994) process the FSI estimate forest carbon woody growing stock. This study estimate carbon stock in different plantation strata of woody growing stock as well as five carbon pool also through using FSI tentative. The growing stock (Volume) data was first converted in to biomass by using species- wise wood density. Thereafter Biomass Expansion Factors (BEF) were used to convert woody biomass to total above ground biomass (AGB) which includes all others like foliage of tree, shrubs, herbs etc. same as below ground biomass (BGB) was computed using default value root shoot ration from GPG. The total biomass obtained which was converted in to Carbon by using conversion factor. Estimations of individual tree biomass were done using volume equation and wood density of each species ex. Teak *Tectona grandis* Volume Equations: - 0.00855 + 0.4432*D^2 + 0.28813*D^2*H (Volume Equations for Forest of India, Nepal and Bhutan, FSI.1996), and Wood density is 0.50 tonnes /m^3 (FAO). After taking the sum of all the individual weights (in kg) of a sampling plot and dividing it by the area of a sampling plot (1,000 m2), the biomass stock density is attained in kg/m2. These values were converted to tha-1 by multiplying it by 10. Since the pilot areas are part of the tropical and subtropical region, the biomass stock density of a sampling plot were converted to carbon stock densities after multiplication with the IPCC (2006) default carbon fraction of 0.47.

Result and Analysis

This study reveals the carbon stock of the sequestration period of 15 years of development and establishment of a man made forest area. Total land available for the different forestry options and multi forest tree species is 31.42 Ha. 18 important tree species were identified in all 22 strata. Major important trees species are present which are identified Sissoo (Dalbergia sissoo), Arjun (Terminalia arjuna), Saja
(Terminalia tomentosa), Subabul (Leucaena leucocephala), Eucalyptus (Eucalyptus globules), Khamhar (Gmelina arborea), Aonla (Emblica officinalis), Kasahi (Bridelia retusa), Safed Siris (Albizia procera), Kachnar (Bauhinia variegate), Plash (Butea monosperma), Katha (Acacia

catechu), Tendu (Diospyros melanoxylo), Amaltas (Cassia fistula), Bheda (Terminalia beleriea), Kala siris (Albizia lebbeck), Teak (Tectona grandis), Neem (Azadirachta indica).

After collection of respective data and there analysis following observation is presented below in tables. Table-1 is showing the plot wise carbon stock of the study site.

Table:1- Plot wise carbon stock of the study site

Plot no	Area of Plot	Above Ground level (In	Below Ground (In	Leaf Litter (In	Dead Wood (In	Soil carbon (In	Total Carbon Stock	C_{TREE} (t.CO2e)
1	0.44	32.24	8.70	0.59	0.22	0.0086	41.76	153.26
2	0.46	39.52	10.67	8.05	0.54	0.0169	58.80	215.79
3	1.20	269.33	72.72	9.54	0.49	0.0101	352.09	1292.18
4	0.44	27.35	7.39	3.69	0.07	0.0133	38.51	141.33
5	0.80	21.39	5.77	2.39	0.29	0.0112	29.85	109.56
6	2.82	87.38	23.59	0.15	0.20	0.0365	111.36	408.70
7	0.46	92.58	25.00	1.90	1.45	0.0084	120.94	443.85
8	0.60	42.35	11.43	1.86	1.20	0.0050	56.84	208.61
9	0.8	106.94	28.87	0.90	1.89	0.0050	138.61	508.69
10	3.08	78.95	21.32	0.39	0.38	0.0310	101.07	370.92
11	0.40	36.27	9.79	1.41	2.59	0.0076	50.06	183.73
4	0.40	53.24	14.37	2.07	1.47	0.0050	71.16	261.14
13	0.40	33.64	9.08	0.18	0.69	0.0113	43.60	160.02
14	5.06	197.39	53.30	0.07	0.20	0.0219	250.98	921.11
15	7.00	485.80	131.17	0.03	0.16	0.1058	617.27	2265.37
16	0.30	5.85	1.58	0.94	5.03	0.0013	13.39	49.16
17	0.10	1.67	0.45	2.35	9.87	0.0004	14.35	52.65
18	0.40	0.11	0.03	1.05	1.79	0.0020	2.98	10.93
19	2.34	97.34	26.28	0.23	0.29	0.0303	124.17	455.71
20	0.40	3.39	0.92	0.13	0.06	0.0060	4.50	16.52
21	0.40	4.33	1.17	0.09	0.04	0.0052	5.64	20.69
22	3.10	81.51	22.01	0.06	0.03	0.0398	103.66	380.43
Total	**31.40**	**1798.59**	**485.62**	**38.05**	**28.96**	**0.38**	**2351.59**	**8630.35**

Whereas species wise carbon stock of the site is presented in table -02.

Table:2- Species wise carbon stock of the study site

S.N.	Major Species in Plots	Carbon Stock in 0.1Ha sample plot (in tones)	Area of Plantation Sites (In Ha.)	Total Carbon Stock (in tones)	C_{TREE} (t.CO2e)
1	*Dalbergia sissoo*	9.49	0.44	41.76	153.26
2	*Terminalia arjuna*	12.78	0.46	58.80	215.79
3	*Eucalyptus globulus*	27.09	1.20	352.09	1292.18
4	*Gmelina arborea*	3.73	0.80	29.85	109.55
5	*Tectona grandis*	7.46	10.28	767.14	2815.40
6	*Cleistanthus collineus*	12.52	0.40	50.06	183.72
7	*Terminalia bellirica*	17.79	0.40	71.16	261.16
8	*Shorea robusta*	6.93	0.40	27.74	101.81
9	*Santalum album*	4.96	5.06	250.98	921.10
10	*Aegle marmelos*	0.75	0.40	2.98	10.94
11	Triphala plantation	5.31	2.34	124.17	455.70
12	*Dendrocalamus strictus*	2.92	3.90	113.80	417.65
13	*Acacia Catechu*	9.41	0.60	56.84	208.60
14	*Emblica officinalis*	17.33	0.80	138.61	508.70
15	*Azadirachta indica*	3.28	3.08	101.07	370.93
16	Mix Plantation	10.9	0.40	43.60	160.01
17	*Terminalia tomentosa*	26.29	0.46	120.94	443.85
Total		**178.94**	**31.42**	**2351.59**	**8630.34**

Total Carbon Stock Density

The carbon stock density is calculated by summing the carbon stock densities of the individual carbon pools of that stratum using the below-mentioned formula. It should be noted that any individual carbon pool of the given formula can be ignored if it does not contribute significantly to the total carbon stock.

$$\Delta C = \Delta CAGB + \Delta CBGB + \Delta CLL + \Delta CDW + \Delta SOC$$

$$\Delta C = 1798.59t + 485.62t + 38.05t + 28.96t + 0.3830t = 2351.56 \text{ Tones}$$

To assess the financial value of the stock , total carbon stock is then converted in to tones of CO2 equivalent by multiplying it by 44/12, or 3.67t. (Pearson et al. 2007).

To calculate CO_2 - tCERs of this 2351.56 carbon stock and there total CER in C_{TREE} (t.CO2e) is 8630.36 t. at present value in rupees as compared to one US dollar. At present value of one US dollar in Indian currency equals to 73.86 rupee following data given below:-

One CER	3.67
1 CER	5US $
1US $ = 73.86/-rs	73.86

so, 1 CER= 5*65	369.30
Total CER amount	**3187189.47**

*Conversion rate - 1 US dollar = 73.86 INR

Conclusion

Climate Change is one of the most burning global issues now days. It is causing a deep concern all over the world climate change is not only concern with developed countries but also affecting the developing countries as well. Climate change related events including hurricanes, droughts and floods have brought the attention of the public and policy-makers towards climate change impacts, and the need for adaptation and mitigation. SFRTI campus area has utilized under various plantations. The major species planted are Sal, Sandal, Teak, Amla, Sisso, Neem, Kahua, Nilgiri, Khamhar, Karra, Saja, Karanj, Baheda, Guava, Aam, Bamboo, Bael, khair, Mahua. This plantation is not only ensuring greenery but also playing an important role in storage of the carbon as well. These plants are serving habitat to different faunal and reptile species as well as contributing in climate change mitigation. Assessment total carbon stock of different stratum in different sample plot in SFRTI campus area showing that great value of the carbon has stored in the campus with the help of this plantation. The campus area is classic example of manmade forest & carbon sequestration. Process adapted in the study is total in replicable manner & it is recommended that this kind of study has to carry out in other same sites of the country.

Acknowledgement

The author is thankful to the research team of Chhattisgarh State Centre for Climate Change for their enormous dedication and support during the study.

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Note: This paper is under publication with Indian Forester, Research Journal.