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Carbon Sequestration in Plantation of Forest Trees In Garhwa Social Forestry Division, Jharkhand

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Abstract: *The continuous depredation of the ecosystem, the major component of which is plants, has resulted in Global warming , breakdown and melting of glaciers, pollution of atmospheric air, rising pollution of sea water, decrease in soil fertility and decrease of quality fresh water which has impacted the human population with regard to various health indices. The State of Forest in India , published by the Forest Survey of India, reported in 2017 that the forests of Jharkhand has grown by 317 sq. km. raising the forests vs. land ratio by more than two percent of the artificial regeneration activities taken up by the State. To assess the carbon sequestration in artificially regenerated forest, this study has been taken up in the driest part of Jharkhand i.e. Garhwa district which experiences daily summer temperature of 47^0 C. or even more. This also is a part of rain shadow zone. The present study area covers plantations of tree species in various administrative blocks / forest ranges taken for a period of successive ten years. The growth of biomass and carbon sequestration over each year has been calculated on a purposive sample basis. The amount of AGC and BGC has been estimated. The result of the study shows that 205 t C / ha has been sequestered in these plantations.*

Key words: *Biomass, Carbon Sequestration, Quantification, Valuation, Ecosystem Services*.

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I. Introduction

The ever increasing global temperature resulting in gradual extinction of sensitive plant and animal species , rising level of sea water level due to liquefaction of polar glaciers , danger faced by the ever increasing human population requiring more ecosystem services for their basic needs, increasing varieties of bacteria and viruses posing constant danger to human health , growing infertility of soils, severe decline in supply of natural fertilizers and overall decrease in quality pure water supply and high level of air pollution are all the negative factors of depletion of level of quality forest and hence the carbon stock.

Kumar, M., 2011 has cited that "The global forests cover 3870m. Hectare according to Global Forest Resource Assessment 2000, and contain a total standing volume of 386 billion m^3 of wood. In terms of mass of the woody vegetation the stock is estimated at 422 billion tonnes dry matter in the above ground biomass including stems, branches, tops and foliage (Anon, 2001). The average standing stock is thus estimated at 10.9 kg per m^2 in terms of dry biomass and 5.45 kg per m^2 in terms of carbon (Kauppi, 2003)." The Stockholm Convention, 1972 may be taken as the first significant international convention to discuss the global environmental situation. The second major international conference at Rio de Janeiro, Brazil in 1992, Agenda-21 programme of Actions were declared. The last global summit at Paris, 2017 an agreement on climate change lays out commitments for nations to limit their greenhouse-gas emissions and contain the impact of global warming.

Though all the plant species having photosynthesis absorb a part of carbon from the atmosphere, trees are considered as the largest individual carbon sinks. Theoretically, the carbon absorbing capacity is high in the initial stages of plant growth because metabolism is comparatively high. One half of a tree's dry weight is carbon (Nowak, 1994). Kumar M. Has stated that "Thus carbon storage is directly related to size. Annual carbon sequestration is related to tree size and growth rates." According to the India State of Forest Report,2017 total carbon stock in forests of India in 2017 is 7082 million tonnes. It has also reported that the annual increase in carbon stock is 19 million tonnes. The total carbon stock of Jharkhand is 222882000 tonnes and per hectare carbon stock is 94.6 tonnes. This gives average carbon stock taking in to account the natural and small amount of artificial forests.

Geo-climatic factors always affect the growth of plants and this also varies from species to species. The present study has been carried out in Garhwa district to calculate the annual increase in carbon stock per hectare

from the very first year of plantation till the tenth year. The study shows that in a mixed plantation with 1666 plants planted per hectare sequestered 205 t C / hectare.

II. Materials and Methods

Study Area: The Garhwa district is situated on south-west corner of Palamau Division which lies between $23^0$60' and $24^0$39' N latitude and $83^0$22' and $84^0$00' longitude. The district is surrounded by Sone river in the north and Sarguja district of Chhatisgarh and Sonebhadra district of Uttar Pradesh.

Configuration of the ground: The average elevation of Garhwa district is about 1200 feet above the MSL. The hill of Gulgulpath is the highest with 3819 ft. high. The general line of drainage is from south to north towards the river Koyal and Sone. There are a host of smaller streams, most of which are from mountain currents with rock stream beds.

Climate and Rain fall: The climate of this district is dry and bracing. The average annual rainfall for the district as a whole is 52.55 inches. Temperature can be as high 47^0 C on individual days in summer. It lies partially under the rain shadow zone and often haunted by drought.

Rock and Soil: The granite gneiss and associated migmatites are the most predominant rock types in the area. They are generally leucocratic, well foliated and have gneissose fabric. They contain enclaves of schists, crystalline lime stones amphibolites. The perphyritic granites appear to be younger than the granite gneiss. The Gondwana is represented dominantly by its lower members and consists of boulder beds and sand stones. Boulders of limestone and horn blends schist are seen in it. The gneisses and granites show a greater diversity of texture than a mineral composition.

The soil is laterite clay or clayey loam on the plateau formations and hill slopes on the south. Elsewhere shallow loam mixed with quartz pebbles and sand or coarse sandy loam originating from quartzite or gneiss or granite gneiss is present. The alluvial soil is limited to the flat valleys of Koel, Kanhar, Tahle and Danro.

Methods: The plantation areas taken up for this study is block plantation that extends from 30 hectare to 50 hectares depending on the availability of blank areas and depending on the fund received by the forest division. Each block is fenced by digging trench along the boundary in order to prevent cattle grazing. However these plantations always face risks of being damaged by cattle, goats and wild animals. The vulnerability from wild animals like Nilgais along with wild boars is also present to a great extent.

Sampling Method:

Objective: The objective of survey is to measure a sample in each year of plantation beginning from the first year to the tenth year planted at different sites in the same district. Measuring the whole area of plantations is very difficult and both time and money consuming. Moreover, it is also not required since it is assumed that the growth pattern of same variety of trees shall not differ much, since the general climate and soil pattern is almost same throughout the district. Intentionally such areas have been taken for study so as to derive easier correlation in annual biomass pattern.

Population: In this study the population is selected according to the year of plantation in order to achieve successive annual biomass pattern. It is assumed that a mixed plantation population shall show equal growth pattern.

Sample size: Keeping in mind that an individual block plantation area is on an average forty hectares and the whole area of plantation is similar in its mixed pattern, the sample size has been determined. One sample unit in each year plantation has been taken as 150ft. * 150ft. or 47m * 47m.

Sampling design: Cross-sectional study method has been chosen so that a sample is drawn from the relevant population and studied once. This study had described the characteristics of a population attaining same year of growth. In this design purposive sampling has been taken so that the samples are selected deliberately so as to constitute a sample on the basis that the small mass that has been selected out of a large one is representative of the mixed population planted for the same year. At peripheral areas more damage to the plantations are generally done so the sample in each block plantation area is chosen generally towards the centre so that availability of survived plants are more.

Biomass study: In the sample area all the available plants has been measured physically. In first two year plantations the girth measurement is very difficult since the plants are of very little size. Still as far as possible, measurements have been taken. Girth measurements were done through tape. Height of the plants for first two year plantations has been measured through tape. Beyond second year growth, tree heights were measured basing on shadow and similar triangles method. At places where growth is better, heights were calculated using tangent formula by using spirit level app. Girth measurements have been taken at 4.5ft. and in smaller plants at 2.00 ft. ht.

The trees which are forked below 4.5ft. have been taken as two trees.

The AGB and BGB have been calculated by using the formula. Soil organic carbon along with other soil characteristics have been measured in State certified laboratory in order to have authentic data. Biomass

calculations have also been done by using similar formula as is used in Kumar M.'s study in his work " Assessment of carbon sequestration potential in trees of Jnanabharathi campus – Bangalore University, Karnataka, India" published by LAP LAMBERT Academic Publishing in 2011.

Parameters: The basal area is calculated from GBH. The volume of above Ground Biomass (AGB) is then converted in to tonnes using the wood density values. The volume of Below Ground Biomass (BGB) has been taken as a default conversion factor of 0.26 of AGB (IPCC, 2003). Then AGC (Above Ground Carbon) was derived by using a value of 0.5 of dry biomass as carbon content as per the IPCC (1996) guidelines.

Formula used for calculating biomass and carbon are:

Basal Area = $(GBH)^2 / 4\pi = (GBH)^2 / 12.56$.

Stem volume = $\pi r^2 h$.

Biomass = stem volume * density factor. In this study density factor has been taken as 0.45.

Biomass dry weight= 0.6 of live Biomass taken as default factor.

Carbon = 0.5* dry biomass.

Carbon dioxide used was calculated on the basis of formula used by Ajay Kumar & Singh, 2003:

Quantum of carbon dioxide = Quantum of carbon * 44 / 12

Where 44 is the molecular weight of CO_2

& atomic weight of carbon is 12.

The quantification of Oxygen has been done as per international standardization which is 1 kg. carbon = 32/12 = 2.66 kg. of O_2

i.e. 38 Kg. of Carbon is equivalent to 100 Kg. of Oxygen.

Statistical analysis has not been used because the study is carried out in artificially choosen area in a particular type of rock and soil composition along with same climatic pattern. More so, the seedlings have been planted at a uniform spacing pattern so inter specific competition for light, water and soil fertility is common throughout the planted area. To some extent there is little variation in land pattern since some areas cover hilly region so that the representative types of land pattern of the district is taken in to account.

Limitations of the study: Grasses, herbs and shrubs have not been taken in to account because of minor variations in its extent and growth. The amount of herbs, grasses and shrubs in these planted areas are also very less because purely indigenous varieties of tree species specific to the natural forests existing in Garhwa district have not been taken in to account in these plantation activities.

For test, soil has been taken up to six inches depth after properly mixing. The carbon calculations have been done for AGB and BGB. But since the amount is very less so it has not been included for this study.

III. Results

As per the survival level of number of trees in the sample plots the AGC = 33987 Kg. & BGC = 8837 Kg.

Since due to human intervention for their economic needs some trees has been taken away, so calculations per Hectare has been done by normalizing the calculation to one hectare plantation (1666 trees / Hectare) in ratio of corresponding survival rate. According to the normalized data the total carbon sequestered per hectare is: AGC = 162503 Kg. / hectare and BGC = 42251 Kg. / hectare. So total carbon sequestered is 205 tonnes / hectare.

Result of quantification of carbon dioxide used is: 205 t / ha * 44/12 = 205* 3.7 = 758 tonnes CO_2/ hectare i.e. 758 tonnes of carbon dioxide from the atmosphere has been used in this process. The value of sequestered carbon per hectare plantation worked out to be (Kumar M. 2011) 205 t / ha * $ 20 = $ 4100 * 64.94 = INR 2,66,254 / per hectare. So valuation of sequestered carbon / ha / yr = INR 2,66,254.

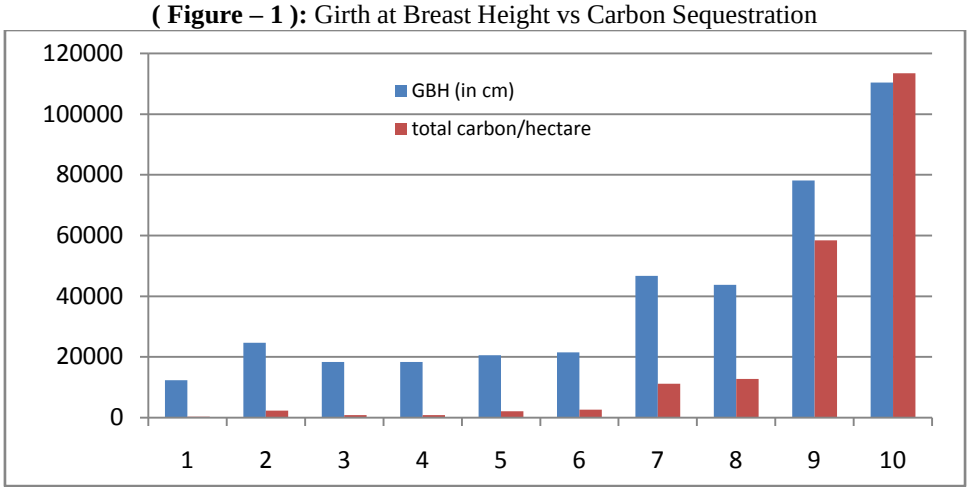
Result of quantification of Oxygen produced in this process is: 205 t C / ha * 32/12 = 546 t O_2 / ha i.e. 54.6 t O_2 / ha / yr. The cost of medical oxygen in India is INR 650 for 6 litres of oxygen (data from website) or 7.5 Kg. of Oxygen. For calculation purposes the cost of 10 Kg. of Oxygen has been taken as INR 650 due to varying prices. So total cost of Oxygen produced / ha /yr = 54.6 t / 10 = 5460 Kg. * 650 = INR 35,49,000. So total monetary benefit from carbon and Oxygen is INR 38,15,254/ha/yr.

IV. Discussions

The plantation sites are taken for successive years of plantation in Garhwa district beginning from 2015-16 (first year plantation) to 2006-07 (tenth year plantation). Ten successive years have been taken on three considerations: (i) to obtain species wise growth in different years (ii) to find out the carbon variation in different species (iii) it is the general principle in the State Government to replant the areas after tenth year. Over a period of years people cut the trees mostly for fuel wood and small timber purposes hence it is assumed that, the time plant reaches its tenth year growth, the area shall have to be restocked.

The GBH increases slowly till the plants attain 5-6 years. After that growth in GBH is very rapid.

(Figure – 1): Girth at Breast Height vs Carbon Sequestration



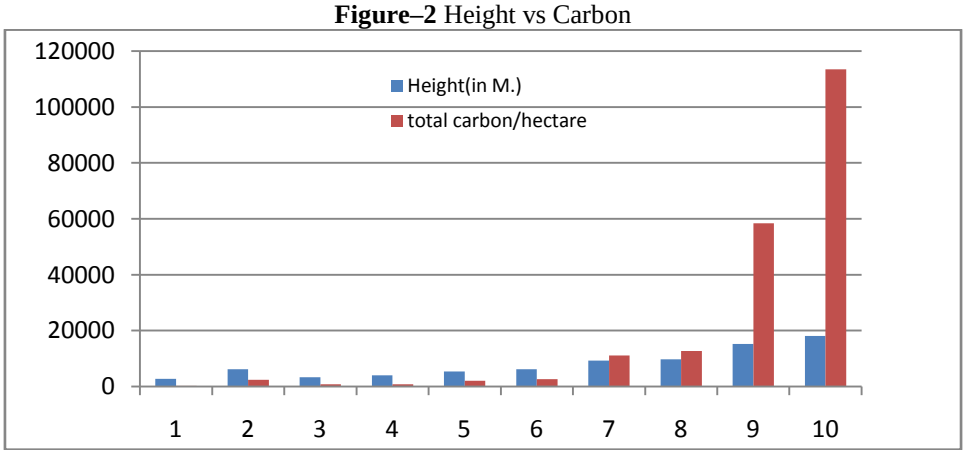
The second year plantation of Bahiyar Khurd (24^0 15' 56" N and 83^0 32' 52" E) has shown unusually high growth. This is attributed to the factor that the plantation site is in plain area where as other sites constitute mostly hilly areas. Because of the plain area water retention and fertility of soil is more. Again good rain fall in that year might have played a role. Average annual GBH does not exactly correspond to the average growth of height. In 2013-14, better growth in GBH is found but corresponding growth in height is less.

Table No 1 Summary Field Data

Year of Plantation	GBH (in Metre)	Diameter (in Metre)	Height (in metre)	Basal area (in m^2)	Volume of stem (In m^3)	Biomass Fresh wt. (In Kg)	Biomass dry wt. (in kg) AGB	BGB	AGC	BGC
1	3	5	7	8	9	10	11	12	13	14
2015-16	32.159	10.242	714.268	0.223	0.417	187.823	112.694	29.300	56.347	14.650
2014-15	50.279	16.013	1269.116	0.657	2.834	1275.202	765.121	198.932	382.561	99.466
2013-14	35.646	11.352	652.073	0.385	0.976	439.258	263.555	68.524	131.777	34.262
2012-13	56.770	18.080	1647.561	0.774	4.159	1871.565	1122.939	291.964	561.469	145.982
2011-12	41.791	13.309	908.689	0.420	1.124	505.885	303.531	78.918	151.766	39.459
2010-11	57.442	18.294	1491.677	0.725	3.395	1527.663	916.598	238.315	458.299	119.158
2009-10	74.930	23.863	1485.793	1.784	10.494	4722.470	2833.482	736.705	1416.741	368.353
2008-09	73.348	23.359	1624.543	1.765	12.516	5632.401	3379.441	878.655	1689.720	439.327
2007-08	71.303	22.708	1387.195	4.094	31.324	14095.937	8457.562	2198.966	4228.781	1099.483
2006-07	305.435	97.272	5018.293	16.479	184.512	83030.423	49818.254	12952.746	24909.127	6476.373
Total	**799.103**	**254.491**	**16199.207**	**27.306**	**251.753**	**113288.628**	**67973.177**	**17673.026**	**33986.588**	**8836.513**

The year 2010 – 11 shows less growth in GBH but corresponding increase in height is more. Similar disproportionate growth is also marked for the year 2009 – 10.

Figure–2 Height vs Carbon



This might have happened due to two factors: 1. more height accruing species or girth accruing species have been cut or 2. Different soil slopes of the region. All together twenty two varieties of tree species were planted in these plots out of which (Chakundi) *Cassia siamea*, (Chilbil)*Holoptelia integrifolia* , *(Gamhar)Gmelina arborea, (Khair)Acacia catechu and (Shisam)Dalbergia sisso* showed appreciable amount of carbon sequestration. Among these five species, (Shisam)*Dalbergia sisso* topped the list in its carbon sequestration.

Figure – 3 Species vs Carbon Sequestration

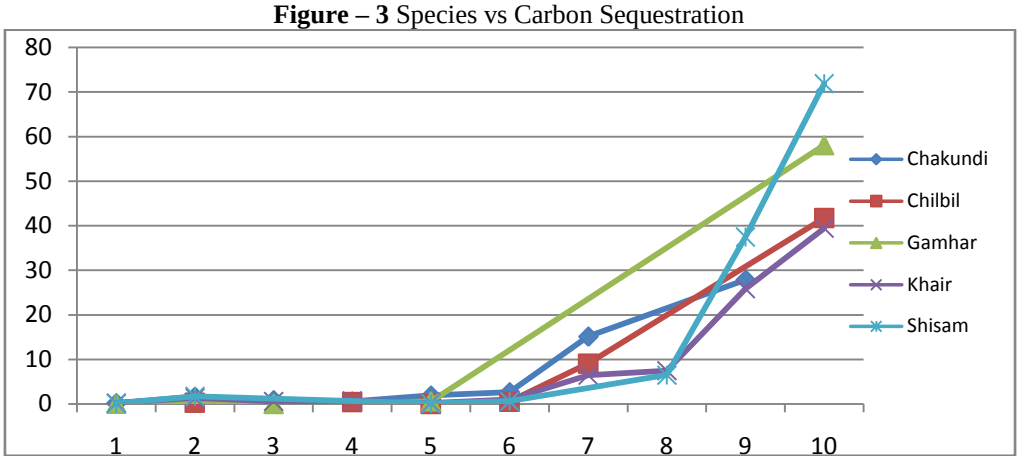


Table – 1 shows the AGC and BGC based on the plants survived in the corresponding year. This data has been normalized to per hectare for each plot. Since 3m * 2m spacing has been adopted in these plantations, in one hectare of area 1666 plants has been planted.

(Table – 2) Normalized summary field data per hectare

Year of Plantation	GBH (in Metre)	Diameter (in Metre)	Height (in metre)	Basal area (in m^2)	Volume of stem (In m^3)	Biomass Fresh wt. (In Kg)	Biomass dry wt. (in kg) AGB	BGB	AGC	BGC	Total Carbon
1	3	5	7	8	9	10	11	12	13	14	15
2015-16	34.298	10.923	761.777	0.238	0.445	200.315	120.189	31.249	60.095	15.625	75.719
2014-15	68.764	21.899	1735.703	0.898	3.876	1744.026	1046.416	272.068	523.208	136.034	659.242
2013-14	51.318	16.343	938.743	0.554	1.405	632.369	379.421	98.650	189.711	49.325	239.035
2012-13	59.996	19.107	1741.172	0.818	4.395	1977.904	1186.742	308.553	593.371	154.276	747.648
2011-12	51.273	16.329	1114.882	0.515	1.379	620.677	372.406	96.826	186.203	48.413	234.616
2010-11	57.442	18.294	1491.677	0.725	3.395	1527.663	916.598	238.315	458.299	119.158	577.457
2009-10	130.496	41.559	2587.616	3.107	18.277	8224.527	4934.716	1283.026	2467.358	641.513	3108.871
2008-09	122.246	38.932	2707.571	2.942	20.861	9387.336	5632.401	1464.424	2816.201	732.212	3548.413
2007-08	218.131	69.468	4243.722	12.524	95.828	43122.439	25873.463	6727.100	12936.732	3363.550	16300.282
2006-07	308.085	98.116	5061.835	16.622	186.113	83750.861	50250.516	13065.134	25125.258	6532.567	31657.825
Total	**1102.049**	**350.971**	**22384.699**	**38.943**	**335.974**	**151188.117**	**90712.870**	**23585.346**	**45356.435**	**11792.673**	**57149.108**

From this study it has become evident that after fourth year, the carbon sequestration has increased considerably. As per the study done by Kirti, A. and Abhinav, M. published in 2014 " USA CO_2 price forecast starts at $ 15 / ton in 2015, and rises to approximately $ 80 / ton in 2030. This high forecast represents a $ 43 / tonne levelized price over the period 2015 – 2030 (Johnston et.al., 2011). However, Molly et.al., 2012 have discussed that a wide range of price for global carbon is observed – ranging from less than $ 1 / t CO_2 to over $ 100 / CO_2 in 2011. Thus it can be assessed that valuation of carbon is varying and no concrete figures can be obtained." Chiabai, A., Travisi, C.M., Markandeya, A. and Nunes, P.A.L.D., 2009 cited " In particular, lower estimates are based on the Marginal Damage Cost (MDC) approach; while higher estimates are based on the Marginal Avoidance Cost (MAC) approach, assuming the EU target of a 30 percent reduction in 2020 compared to 1990." According to them, MDC (lower- bound) is 6.43 Euro / t CO_2 in 2007 and MAC (upper – bound) is 15.8 Euro in the year 2007. In the present study the value for carbon sequestration has been taken as $ 20 per ton of carbon (Kumar, M., 2011).

V. Conclusions

At present world is facing two major problems i) green house gas emissions and ii) increase in global temperature. The basic reason for both of these problems lie in deforestation thereby not only carbon content is diminishing but also atmospheric carbon dioxide is increasing at an accelerated rate. Energy alternatives have to be found along with increased energy efficiency. The Government as well as the people have to understand not only the atmospheric pollution but also about the cost of forest ecosystem services. The present study only shows the value of carbon dioxide and oxygen production cost. But forest ecosystem serves many other purposes such as increase in soil water retention capacity, soil fertility, provision for non-timber forest products and prevention of soil erosion, maintaining quality water provision, sustaining biodiversity, increase natural pollination and increased agricultural output along with maintaining aesthetic values. The money spent on afforestation activities per hectare is INR1,35,965 which is very less in comparison to the huge loss of associated benefits only in terms of money i.e. INR38,15,294. Hence increase in plantation activity is the immediate need of the hour.

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