CARBON SEQUESTRATION IN THE SUBTROPICAL FOREST OF SOUTH KHERI FORST DIVISION OF UTTAR PRADESH

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ABSTRCT

Global warming is defined as the increase of the average temperature on Earth. As the Earth is getting hotter, disasters like hurricanes, droughts and floods are getting more frequent. Over the last 100 years, the average air temperature near the Earth's surface has risen by a little less than 1 degree Celsius or 1.3 degrees Fahrenheit. Deforestation increases the severity of global warming. Carbon sequestration is one of the important functions of forest and the results have shown that forests act as a great sink for carbon dioxide. In a tree, carbon is stored in roots stem, branches and leaves whereas in a forest ecosystem soil and undergrowths also act as a major sink for carbon dioxide. A study was carried out by the author to determine the carbon storage in the Sal (Shorea robusta) forests of Terrai forest of Uttar Pradesh as the forest of Lakhimpur Forest Division is the representative of a typical sub tropical high forest in the country. The forests of this forest division are fairly old and possess well grown valuable species of Sal and its associates. The present study area is situated to the South of Sharda River and lies between 2800'' to 2803'' north latitude and 80060'' to 80035'' east longitude. Maximum amount of carbon has been found to be stored in the stem and that is to the tune of 15072.15 Mt in all the selected 23 species of the study area of 25 compartments whereas second highest storage of carbon is found in the roots at around 3985 Mt. Soil carbon is found to be at 724.34 Mt with leaf, branches and herbs& shrubs placed at 696.664 Mt, 256.04 Mt and 71.39 Mt respectively in the study area of 25 compartments. The top five compartments with the much higher stem carbon are found to be West Gola-10 (2262.87 tc), West Gola-3(1720.56 tc),West Gola-9 (1668.226 tc), West Gola-1 (1022.823tc), Baraucha-5 (897.63 tc) whereas the lowest five stem carbon compartments are Bheera-19 (44.09 tc), Mohrena -20 (100.91tc),Charasi-4(149.52tc),Baraucha-1 (156.240tc), Kalinjarpur(202.54tc), Alanganj3B(218.56tc). Of the five carbon rich compartments two namely, West Gola-10 and west Gola-9 fall under sal improvement circle. The sal (Shorea robusta) forest lying under this circle is primarily comprising of sal(Shorea robusta) as dominant species with plenty of under growths and rich biological diversity. These compartments are sunny also therefore; it is also one of the reasons why these compartments are rich in carbon content as photosynthetic activities are found to be much stronger. The rest other three compartments namely, west Gola-3, west Gola-1 and Baraucha-5 fall under

Teak working circle. Teak (Tectona grandis) is a strong light demander and grows very fast when gets a conducive environment. Teak being a fast growing sequesters more than other species On the contrary the lowest five compartments in stem carbon namely, Bheera-19 (44.09 tc), Mohrena -20 (100.91tc),Charasi-4(149.52tc),Baraucha-1 (156.240), Kalinjarpur(202.54tc), Alanganj3B(218.56tc) fall under teak working circle (the first four compartments) and Forest block plantation working circle(the last two working circle). The forest under this working circle is open, degraded, under tremendous biotic pressure and prone to forest fire therefore, poor in carbon. It is interesting to note that soil carbon in all the three levels i.e. 0-30 cm, 30-60cm and 60-100 cm, in the five compartments namely South Katna 7A, East Gola 5, West Gola 10, West Gola 1 and West Gola 6 the carbon was much higher than rest of the five compartments. This shows that these compartments possess relatively more stabilized soil and the forest has also been found to be relatively less disturbed than the rest of compartments.

KEY WORDS: Carbon Sequestration, Forest Ecosystem, Climate Change, Carbon Sink, High Forest.

INTRODUCTION:

The change in land cover and land use patterns due to developmental activities are the major contributors of the upward shift in temperature (IPCC, 2001). It has been reported that in the last April, 2013 the carbon emission has reached at the level of 400 ppm (Monastersky 2013).Therefore, the global climate change has become a very crucial environmental concern for the entire world community. A large number of environmental and forest scientists have predicted that if no action is taken to limit the emission of green house gases, the temperature would rise in the range of 2 degree Celsius to 5 degree Celsius by the year 2100 (IPCC 2001). It has also been feared that after this rise in temperature, further rise in temperature will be very fast and then it becomes highly unpredictable and uncertain in its range of temperature rise. If this does happen it will be the faster rate of warming at any time since the end of the last ice age occurred about 10,000 years ago. Climate change is likely to have a significant impact on global environment at large and the forest ecosystem in particular. It has been further estimated that due to the global warming the forest ecosystem and the agricultural zones would shift towards the pole by 50 to 550 km in the mid latitude region (UNFCCC, Article 2). Thus a new climatic stress will be created and the impact would be so large that a number of floral as well as faunal species would become extinct. The food security, ocean level, forest ecosystem etc. will all be in jeopardy. The most recent estimates suggest that each year approximately 40 million hectares of tropical forest, being destroyed and the major factors for this destruction are deforestation, biotic pressure the ever growing per capita pressure on forest, repeated forest fire, conversion of forestland for other activities, growing demand of timber in the manufacturing sector and last but not the least the growing economy all-around the world (State Of the Forest Report, 2011). The following Table presents a vivid picture of the extent of growing pressure on forest in India.

TABLE1. GROWING PRESSURE ON FORESTS IN INDIA

Total Fuel-wood Demand	**201 Million ton**
Total Supply	**1.232 Million ton**
Deficit	**199.768 Million ton**
Total Timber Demand	**64 Million cubic meter**
Estimated Supply	**3.175 Million cubic meter**
Deficit	**60.825 Million cubic meter**

Source: India State Of the Forest Report, 2011

FORESTRY AS MITIGATION OPTION:

The carbon sequestration in terrestrial vegetation and soil is considered to be the most significant option of the global warming problem as a mitigation measure (Dinakaran & Rao, 2012). The forests also mobilize atmospheric carbon through plant respiration and organic material decomposition, although these losses are usually less than gains (William Fonseca et al. 2011). That the forest serve as an option for mitigation of global climate change was at first proposed in 1970's although the real thrust came only after the Earth summit held at Rio De Janeiro, Brazil in 1991. At the Conference of parties-3 (COP 3) the Kyoto Protocol was signed by a large number of countries where a major responsibility was laid on the developed countries of the world to reduce 5.2% emission of their green house gases to the 1990 level by 2012 (Anup Shah 2002). A lot of politics came into it and ultimately the United States of America backed out. At the COP 2012 at Doha, which is also called Doha Declaration, it was decided that further negotiation should be carried out to impose a restriction on Green House gas emissions (COP, 2012). Forests also play a role in the conservation of ecosystem, maintain quality of water, and prevent soil erosion besides providing employment opportunities and mitigation of CO2 emission (FAO 2008). Over the last two decades, progressive national forestry legislation and policies in India have aimed at conservation and sustainable management of forests. This has reversed deforestation and transformed India's forests into a significant net sink of CO2. The carbon stocks stored in our forests and trees have increased from 6245 million tons to 6662 million tons, registering an annual income of 38 million tons of carbon or 138 million of CO2 equivalent during 1995-2005 (Kishwan et al. 2009). India is one of the few developing countries in the world which is making a consistent net addition to its forests and tree cover over the last decades and this is why most of the nations particularly the developing countries are asking for budgetary support for reduction in deforestation (REDD) followed by sequestering more carbon as compared to other countries. Putting a conservative value of US$ 5 per ton of CO2 locked in our forests; this huge sink of about 24,000 metric ton of CO2 is worth USD 120 billion, or Rs 6, 00,000 crores incremental carbon under the Indian scenario. There is thus, an addition of a value around USD 1.2 billion or Rs 6, 00000 crores every year to India's treasury of forest sink assuming a value of US$ 7 per ton (Kishwan et al., 2009) The World Resources Institute has estimated (2000-01) that the developing countries shared only 37% of the total cumulative CO2 emission from the industrial sources and landuse changes during the period 1900 to 1999. Due to their higher population, livelihood and growing economy, some of the countries from the developing country share higher CO2 emission which is likely to match or exceed soon to the industrialized nations. The Kyoto Protocol expects the industrialized countries to reduce their GHG emission by weight average of 5.2% based on 1990 GHG level until 2012, but this does not require developing countries to reduce their GHG (Sathaye et al. 2006). As regard the per capita CO2 emission at the global level, the first three countries are those which are dealing with oil as their major economy and these are Qatar, Trinidad & Tobago and Kuwait where the per capita CO2 emission is 44 ton, 35.8 ton and 30.3, respectively. India's per capita CO2 emission is still very low i.e. 1.6 ton (World Bank assessment on carbon emission, 2009). It must be understood, however, that Indian emissions have grown at a rate of 4% per year during 1992 for the period 1990-2000 and are projected to grow further to meet the national GDP growth. It has been predicted that by the year 2020 India's emission would be 5% of the total global emission (Sharma et al., 2006). Therefore, India urgently requires charting out a Climate Change Action Plan for the CO2 mitigation since this will not only have impact on forest ecosystem but also on various facets of day to day life. IPCC 2007 projected possible implications of global climate change for India as frequent dry days, 38% drop in per capita water availability by 2050, 40 cm rise in sea level and displacement of 50 million humans in the coastal region by

DESCRIPTION OF THE STUDY AREA:

The forest of south Kheri Forest Division mainly comprises Sal (Shorea robusta) and Teak (Tectona grandis) and other miscellaneous species. These forests were allotted to the private owners in the early nineteenth century for cultivation. Between the year, 1861 to 1875 the grantees felled forests recklessly for poles in all accessible areas, lying south of Ul river. In the vicinity of Gola and other comparatively larger villages, the forests were clear-felled for firewood and charcoal. This wasteful process was stopped when the Forest Department took over the management of the forest in 1877. Between the year 1887 and 1889, strip felling was initiated in the Gola forest and later replaced by improvement felling during the first Working Plan Period of 1891 to 1894. The entire forest was managed on the basis of different prescriptions given in the Working Plan including the felling of valuable trees. For the management of Sal forest improvement exclusively felling were carried out. The forests of South Kheri Forest Division are fairly old and possess well grown valuable species of Sal and its associates. The present study area is situated to the South of Sharda River and lies between 2800'' to 2803'' north latitude and 80060'' to 80035'' east longitude. The forests are easily accessible by road and rail. There is a good network of roads in the forest area.

REASONS FOR SELECTING THREE WORKING CIRCLES AS STUDY AREA

The forest is managed on the basis of working circles in which they are kept depending upon the prescriptions, crop, soil conditions etc therefore, Working circles may be called as basic management units of the forests The total forest of the study area falls mainly into three working circles viz, Sal improvement working circle, Teak working circle and forest Block Plantation. The total area of the all the working Circles combined together account for 41136.74 hectare of forest land in the forest division. The reason for selecting the three working circles for the study is as follows.

The three working circles were representatives of the typical Sal and Teak forests of the terai areas. This constitutes the major area of the forests and as a rule the crop is almost pure Sal and Teak with a preponderance of middle aged trees with all Sal associates species present in this. This forest also includes certain areas where Teak was introduced in the past because Sal regeneration was lacking. Therefore, the study area has a fairly good mixture of representative species grown over a long period of time.

The Plantation Working Circle covered those areas which were open and blank and fit to be planted. The plantation activities in those areas were carried out since 1930s. Therefore, study area has a fairly good representation of planted forest also

WORKING CIRCLE WISE COMPOSITION OF THE STUDY AREA

There are 105 compartments in Sal Improvement Working Circle of which 10 compartments have been selected randomly for the present study which comes to roughly 9.52 % of the total compartments. Likewise Teak working circle has total 140 compartments of which 12 compartments were selected for study which comes to 9% of the total. Plantation Working Circle consists of areas which are blank and has degraded forest and degraded land. This also consists of those areas which are devoid of Sal regeneration. This working circle mainly comprises of Sal forest, devoid of regeneration, and other blank areas. Therefore only three compartments have been taken into the study which constitutes 2.8% of the total compartments of this working (Working Plan Uttar Pradesh South Kheri van prabhag Lakhimpur 2010) .Twenty five compartments have been indentified for the purpose of carbon sequestration analysis. The following table describes the names of compartments, working Circles and areas included in the Working Circle

TABLE 2 AREA STATEMENTS

S.No.	Names of compartment	Working circles	Range	Area of compartment (in sq. mt.)	Areas of study (insq mt.)	Plot size for enumeration (in sq mt)
1	2	3	4	6	8	9
1	Baraucha-5	Sagaun(Teak)	Gola	1040000.00	10400.00	100X104
2	dakshin katna-7	Sagaun	Mohammadi	2076000.00	20760.00	100X207
3	mohrena-20a	Sagaun	mailani	1202000.00	12020.00	100X120
4	p gola-13	Sagaun	gola	498000.00	4980.00	100X50

5	Baraucha-1	Sagaun	Gola	2060000.00	20600.00	100X200
6	Dakshin Bhira-19	Sagaun	Bheera	1238000.00	12380.00	100X124
7	Kalinjar-1A	Sagaun	Gola	700000.00	7000.00	100X70
8	Chairasi-4	Sagaun	Bheera	1348000.00	13480.00	100X135
9	P Gola-3	Sagaun	Gola	818000.00	8180.00	100X82
10	Gadaniya-2	Sagaun	Mailani	1158000.00	11580.00	100X115
11	P Gola-1	Sagaun	Gola	1712000.00	17120.00	100X171
12	P Gola-12	Sagaun	Gola	878000.00	8780.00	100X88
13	Chairasi-15	Sal(Shorea robusta) Improvement	Bheera	1505000.00	15050.00	100X150
14	Baraucha-7	Sal Improvement	Gola	984000.00	9840.00	100X98
15	Chairasi-14	Sal improveme	Bheera	2177000.00	21770.00	100X218
16	Pansabbi-1	Sal Improvement	Mailani	1319000.00	13190.00	100X132
17	P Gola-5	Sal Improvement	Gola	1795000.00	17950.00	100X179
18	P Gola-10	Sal Improvement	Gola	1469000.00	14690.00	100X147
19	Madhya Mailani-1	Sal Improvement	Mailani	898000.00	8980.00	100X90
20	Allenganj-3A	Sal Improvement	Bheera	1133000.00	11330.00	100X113
21	P Gola-6	Sal Improvement	Gola	1615000.00	16150.00	100X161
22	P Gola-9	Sal Improvement	Gola	1404000.00	14040.00	100X140
23	Allenganj-3B	Forest Block Plantation	Bheera	672000.00	6720.00	100X67
24	Kalinjarpur-1B	Forest Block Plantation	Gola	838000.00	8380.00	100X84
25	Mohrena-19	Forest Block Plantation	Mailani	1591000.00	15910.00	100X159
		Total		**3212800**		

SOURCE: FROM THE THESIS ON CARBON SEQUESTRATION IN NATURAL SAL (Shorea robusta) FOREST OF SOUTH KHERI FOREST DIVISION, LAKHIMPURKHERI, BY UMA SHANKER SINGH

Of the total twenty-five compartments randomly chosen, sampling was undertaken with a view to ear marking 1% of the total area for complete enumeration in terms of girth measurement at breast height. The total area of the twenty-five compartments selected for the present study comes to 3212.80 ha. These compartments represent the all possible forest types for the purpose of detailed study i.e. enumeration and data collection. A sample size of 1% of the total compartment area was selected. In order to achieve this plot of designated dimension amounting to 1% of the total compartment area was randomly laid out in each compartment. The total area thus selected came to 32.13 ha. which is 1% of the selected forest area. The relative advantages of the partial enumeration are many like reduced cost and saving of time, relative accuracy, knowledge of error etc. In the present area of research, the random sampling method was adopted

TOTAL NUMBERS OF TREES ENUMERATED

A total eight thousand two hundred and two trees were enumerated of which Teak constitutes the highest number i.e. 3903 followed by Sal which figured around 1557. Jamun was the third largest in number. The following table presents the total number of tree species wise and their percentage components of the total

TABLE 3 TOTAL NUMBERS OF TREES ENUMERATED

S.no.	Name of species	Total number of trees	Percentage of the total
1.	ARJUN(*Terminalia arjuna)*	156	1.90
2.	ASNA(*Terminalia elliptica)*	163	1.99
3.	BAHERA*(Terminalia bellerica)*	4	0.05
4.	BARGAD*(Ficus bengalensis)*	9	0.11
5.	BEL*(Aegle marmelose)*	28	0.34
6.	DUDHI*(Wrightia tinctoria)*	24	0.29
7.	GOOLAR*(Ficus glomerata)*	6	0.07
8.	JAMUN*(Syzygium cumini)*	516	6.29
9.	KANJI*(Pongamia pinnata)*	35	0.43
10.	KAIM*(Linaria caucasigena)*	5	0.06
11.	KHAIR*(Acacia catechu)*	21	0.26
12.	KUSUM*(Schleichera trijuga)*	21	0.26
13.	LAVERA*(Lavendula vera)*	1	0.01
14.	MAHUA*(Madhuca indica)*	48	0.59
15.	NEEM*(Azadirachta indica)*	1	0.01
16.	PEEPAL*(Ficus reliogosa)*	3	0.04
17.	ROHINI*(Mallotus philippensis)*	492	6.00
18.	TEAK *(Tectona grandis)*	3903	47.59
19.	SAL*(Shorea robusta)*	1557	18.98
20.	SHISHAM*(Dalbergia sisso)*	1	0.01
21.	TENDU*(Diospyros melanoxylon)*	28	0.34
22.	SAFEDA*(Eucalyptus spp.)*	339	4.13
23.	KUKAT	841	10.25
	TOTAL	**8202**	

SOURCE: FROM THE THESIS ON CARBON SEQUESTRATION IN NATURAL SAL (Shorea robusta) FOREST OF SOUTH KHERI FOREST DIVISION, LAKHIMPURKHERI, BY UMA SHANKER SINGH

GIRTH MESUREMENT

The main object of the measurement of individual tree is to estimate the volume of the individual standing tree. Volume of a tree is usually dependent on diameter or girth at the breast height. Diameter or girth measurement is very important for calculating volume. In case of a standing tree the girth was measured at breast height (4 feet 6 inches above ground level). Each individual tree was enumerated by their species and duly recorded in the pre designated format. The species which are important and whose volume equations are separately known were kept in one group and the other which constituted trees of lesser significant and shrubby in character were kept in another group called **Kukat**. Kukats are the group of miscellaneous species which are less significant from forestry point of view

CARBON ESTIMATION

STEM

Circumference of every species was recorded at breast height level and from this figure the diameter for each individual species was calculated by dividing circumference with 3.4 The next stage was to work out the volume of each and every species listed in the study area through regression equation developed for individual species by Forest Survey of India (State of forest report 2009). The volume of each and every species was calculated on the basis of above regression equation. In order to work out the green weight, the volume was multiplied with their respective wood densities. The value of wood density used in the present study are given in from the studies by Sandra Brown in his study on Estimating Biomass and biomass change in tropical forests in 1997 and web sites of FSI (Forest survey of India) Green weight of each species was calculated by simply multiplying volume of individual species with the wood density of that particular individual wood densities of each species. The average dry weight of the wood sample is calculated on the basis of drying the sample of wood pieces of individual species in a drier in the laboratory at a controlled constant temperature of 70^0 C until the wood sample is completely dried. Dry weight factor has been calculated by average dry weight of an individual species divided by green weight of the stem of that species. Green weight/Fresh weight of the stem is the weight which was taken at the time of sample collection of individual tree species. The dry weight of a stem of an individual species is calculated simply by multiplying green weight of the sample of that particular species with dry weight factor of that species Calculation of carbon in the stem of all species has been worked out by the chemical analysis (Walkley-Black Method, 1934 and reaffirmed again in 2006) by taking out wood sample through Pressler's borer.The carbon content of the stem is calculated by simply multiplying dry weight of the stem with carbon factor and this gave the carbon content present in the stem of that particular species.

BRANCHES

The carbon is also locked in branches of the stem. A fully grown tree is very branchy, the branches are thick on the lower side and as one goes up the stem, the branches become thinner. To find out carbon stocking in the branches, two branches of each tree species were chosen, one, the lower most branch and the second branch, just above the first branch. It was not possible physically to calculate carbon in the entire branch system therefore, only two branches were taken for study. The lower branch (henceforth will be called as branch-1) and the upper branch (henceforth will be called branch-2) of all the individual species were cut into small pieces of five centimeter. They were tagged properly with their botanical names, name of compartment, time and date of sample collection and their fresh/green weights were immediately taken and duly recorded. The samples were analyzed with walkley- Black method as stated earlier to find out carbon content. Here also the sample of cylindrical wood were taken out through Pressler's borer as was done in case of stem. The volume of the branches has been calculated on the basis of volume table given by Chaturvedi and Khanna (1982). Green weight of branches is calculated by multiplying volume of branches with their respective densities. Average weights of the branches were also found out. The carbon percentage of branches of individual species was found out in laboratory through chemical analysis (Walkley-Black method 1934 and reaffirmed in 2006) and the carbon was calculated by simply multiplying carbon factor of that particular species with average dry weight of branches of that individual species

ROOTS

Once the carbon content of the branch and the stem were calculated we will now find out the carbon content present in the root. The root content is 26 % of the total biomass of the tree (carbon content of stem + carbon content of the branch). The amount of carbon stored by a tree depends on its size which is influenced by many factors e.g. the age of the species and the local conditions favoring the growth. It is very difficult to dig up the roots and actually measure its volume and weight. That is why the secondary data was used for estimation of root carbon. The biomass of the roots, branches and leaves of a Sycamore tree are known to be around26%, 11% and 1% of the total biomass respectively (Catriona Culnas, Ecometrica, 2011). Based on these assumptions, the carbon in root has been considered to be 26% of the total carbon present in stem and branches.

ESTIMATION OF CARBON IN LEAF LITTER, HERB AND SHRUBS

Leaf litter, herb and shrub were also collected from those ten compartments from where the soil samples were collected. For leaf litter a quadrate of 1 meter x 1 meter was laid out and all the leaves falling into this quadrate were collected and put into a cloth bag, tagged properly with all details and weighed. Likewise, for herb and shrub collection a quadrate of 2 meter x 2 meter was laid and all the herbs and shrubs falling into it were cut at the ground level and put into a cloth bag. All the samples were properly tagged with all details. Leaf litter sample and herb/shrub samples were analyzed exactly the same way as above in order to find out carbon content in leaf litter, herb and shrubs

SOIL CARBON (SC)

A small sketch map of the study area was prepared and the entire major topographical features such as streams, rivers, swarms, gravel beds, forest etc. has been marked. Soil samples were collected from ten compartments out of the twenty five compartments chosen for study area. The reason for having chosen only ten compartments was primarily avoidance for repetition for similar areas. Only those ten compartments were chosen which were found to be different from each other in the physical features of the soil. The rest of the compartments were either alike in its totality or the forest floor looked alike. From each out of the ten compartments selected for soil sample collection were also put to random sampling so as to avoid any personal bias as described earlier.

DIGGING OF SOIL PITS

A Pit of 1 meter x 1 meter was dug with the help of spade. Soil samples were collected at four levels firstly, zero level i.e. the ground level, secondly, at the depth of 30 centimeter, thirdly at the depth of 60 centimeters and fourthly at 100 centimeter. Before collecting soil at zero level it was cleared out of undergrowth. Nearly 1 Kg sample of the soil was collected, weighed and duly recorded. The soil samples were collected in a piece of washed/new clothes or linen and were tagged properly as to indicate the date and time of collection, fresh weight, place of collection, depth at which it was collected etc. Soil samples were analyzed in laboratory for carbon

RESULTS

Carbon sequestration is one of the important functions of forest and the results have shown that forests act as a great sink for carbon dioxide. In a tree, carbon is stored in stem, branches, and roots and leaves whereas in a forest ecosystem soil and undergrowths also act as a major sink for carbon dioxide. Maximum amount of carbon has been found to be stored in the stem and it is to the tune of 15072.15 Mt in all the selected 23 species of the study area of 25 compartments whereas second highest storage of carbon is found in the roots at around 3985 Mt. Soil carbon is found to be at 724.34 Mt and with leaf, branches , herbs &shrubs carbon was placed at 696.664 Mt, 256.04 Mt and 71.39 Mt respectively. If the results are examined carefully then a very interesting pattern emerges. The top five compartments with the much higher stem carbon are found to be West Gola-10 (2262.87 tc), West Gola-3(1720.56 tc),West Gola-9 (1668.226 tc), West Gola-1 (1022.823tc), Baraucha-5 (897.63 tc) whereas the lowest five stem carbon compartments are Bheera-19 (44.09 tc), Mohrena -20 (100.91tc),Charasi-4(149.52tc),Baraucha-1 (156.240), Kalinjarpur(202.54tc), Alanganj3B(218.56tc). Of the five carbon rich compartments two namely, West Gola-10 and west Gola-9 fall under sal improvement circle. The sal forest lying under this circle are primarily comprising of sal (*Shorea robusta*) forest with plenty of under growths and rich biological diversity. The average crop density of these two compartments are around 0.7 and the site quality will range in between 1to 4. The crop is middle aged with other sal associates. These compartments are sunny also therefore; it is also one of the factors why photosynthetic activities are much stronger and sequester more carbon The rest other three compartments namely, west Gola-3, west Gola-1 and Baraucha-5 fall under Teak Working circle. Teak (Tectona grandis) is a strong light demander and grows very fast when gets a conducive environment. Teak was introduced in the early nineteenth century ultimately replaced the existing sal forest. Teak forest ecosystem is very dry compared to sal forest and is very vulnerable to forest fire. The teak crop in these three compartments are open and evenly spaced, the average crop density will be more than 0.6 and the teak being a fast growing sequesters more than other species

On the contrary the lowest five compartments in stem carbon namely, Bheera-19 (44.09 tc), Mohrena -20 (100.91tc),Charasi-4(149.52tc),Baraucha-1 (156.240), Kalinjarpur(202.54tc), Alanganj3B(218.56tc) fall under teak working circle (the first four compartments) and Forest block plantation working circle(the last two working circle). The forest under this working circle is open, degraded, under tremendous biotic pressure and prone to forest fire therefore, poor in carbon.

The soil carbon percentage was found through bulk density i.e. by multiplying the carbon factor with the biomass. It is interesting to note that at all the three levels i.e. 0-30 cm, 30-60cm and 60-100 cm, in the five compartments namely South Katna 7A, East Gola 5, West Gola 10, West Gola 1 and West Gola 6 the carbon was much higher than rest of the five compartments. This shows that these compartments possess relatively more stabilized soil and the forest has also been found to be relatively less disturbed than the rest of compartments. Therefore, this can be safely argued that a stable forest has a stable soil containing more carbon. Disturbance of any kind ultimately disturbs carbon balance in all the components of Forest ecosystem.

Forests are a significant part of the global carbon cycle. Plants use sunlight to convert CO2, water, and nutrients into sugars and carbohydrates, which accumulate in leaves, twigs, stems, and roots. Plants also respire, releasing CO2. Plants eventually die, releasing their stored carbon to the atmosphere quickly or to the soil where it decomposes slowly and increases soil carbon levels. However, little information exists on the processes and diverse rates of soil carbon change. How to account for changes in forest carbon has been contentious. Land use changes—especially afforestation and deforestation—can have major impacts on carbon storage. Foresters often cut some vegetation to enhance growth of desired trees. Enhanced growth stores more carbon, but the cut vegetation releases CO2; the net effect depends on many factors, such as prior and subsequent growth rates and the quantity and disposal of cut vegetation (Ross W Gorte 2009). Tropical forests store 25% of global carbon and harbor 96% of the world's tree species, but it is not clear whether this high biodiversity helps sequester more carbon or not but in my study it has been found that a biodiversity rich forest contains more carbon than otherwise. Few studies have been carried out to show the relative importance of forest attributes and environmental drivers for ecosystem functioning, and no such study exists for the tropics.(L. Poorter et al 2015) . Carbon stocks of the forests were governed by labile and stable C fractions, soil moisture, and plant diversity. The soil fulvic fraction acts as a focal point of interacting the variables such as soil N, free litter fraction (FLF) and humic fraction. During dry period in the dry zone forest, carbon soil (CS) was governed by maximum relative humidity through an atmosphere-floor litter-soil continuum. Air temperature and FLF play a vital role in determining soil N. In addition, MacIntosh distance (U) diversity index showed a significant positive relationship with soil N. The dry zone forests are seen to be more climatic sensitive and vulnerable than the wet zone forests in Sri Lanka due to influence of more climatic parameters that govern the soil organic carbon fractions. (K. A. J. M.Kuruppuarachchi et al 2016) .The total carbon content in the forest ecosystem of the study area has been given in the following table

TABLE 4 CARBONS IN TOTAL 25 COMPARTMENTS OF STUDY AREA

Name of compartments	Total area of the compartments	Total carbon						Grand total
		Stem	Branch	Root	Leaf	Soil	Herb & Shrub	
Alanganj 3a	113.30	295.143	5.725	78.2257	25.56452	12.09683	2.034465	418.7895
Alanganj 3b	67.20	218.56253	4.5103	57.9989	25.56452	12.09683	2.034465	320.7675
Baraucha 1	206.00	156.240	12.669	43.9163	25.56452	12.09683	2.034465	252.5211
Baraucha 5	104.00	897.63169	153.354	273.2563	25.56452	12.09683	2.034465	1363.938
Baraucha 7	98.40	472.875	3.426	123.8383	25.56452	12.09683	2.034465	639.8351
Bheera 19	123.80	44.097442	3.6058	12.4028	25.56452	12.09683	2.034465	99.80186
Charasi 4	134.80	149.52805	0.4521	38.9948	25.56452	12.09683	2.034465	228.6708
Charasi 14	217.70	642.897	2.181	167.7203	25.56452	12.09683	2.034465	852.4941
Charasi 15	150.50	242.221	3.843	63.9766	25.56452	12.09683	2.034465	349.7364
East gola 5	179.50	450.84008	9.2401	119.6208	25.39046	47.281712	3.600632	655.9738
Gadaniya 2	115.80	1314.900	0.888	342.1049	25.39046	47.281712	3.600632	1734.166
Kalinjarpur 1a	70.00	202.543	2.478	53.3055	25.39046	47.281712	3.600632	334.5993
Kalinjarpur	83.80	23.443225	4.5214	7.2708	25.39046	47.281	3.600	111.5082

1b		7				712	632	
Madhya Mailani	89.80	576.87411	0.6498	150.1562	25.39046	47.281 712	3.600 632	803.9529
Mohrena 19	159.10	344.5347	13.817	93.1714	25.39046	47.281 712	3.600 632	527.7959
Mohrena 20	120.20	100.915	6.519	27.9328	25.39046	47.281 712	3.600 632	211.6396
Pansabbi 1	131.90	583.20963	0.5911	151.7882	25.39046	47.281 712	3.600 632	811.8617
South Katna 7a	207.6	484.75704	3.6928	126.9970	172.6734	38.518 359	3.042 797	829.6814
West Gola 1	171.20	1022.823	14.068	269.5917	9.175298	50.972 727	3.724 803	1370.356
West Gola 3	81.80	1720.468	4.556	448.5062	9.093091	21.171 01	4.928 816	2208.723
West Gola 6	161.50	477.940	2.129	124.8179	14.46488	37.434 741	2.825 896	659.6124
West Gola 9	140.40	1678.226	0.951	436.5860	21.33524	19.405 622	2.789 432	2159.293
West Gola 10	146.90	2262.8769	0.5450	588.4897	15.9335	49.768 283	1.109 373	2918.723
West Gola 12	87.80	471.770	1.567	123.0676	1.63941	12.885 146	1.928 996	612.8582
West Gola 13	49.80	236.838	0.386	61.6782	19.14551	7.0642 534	3.9286	329.0406
Total	**3212.8**	**15072.15**	**256.044**	**3985.415**	**696.6647**	**724.3453**	**71.39395**	**20806.3393 6**

. **SOURCE: FROM THE THESIS ON CARBON SEQUESTRATION IN NATURAL SAL (*Shorea robusta*) FOREST OF SOUTH KHERI FOREST DIVISION, LAKHIMPURKHERI, BY UMA SHANKER SINGH**

TABLE 5 PER **HECTARE ABOVE AND BELOW GROUND CARBON OF THE STUDY AREA**

S.NO.	Above ground carbon (AGC) Carbon calculated per hectare (in ton)				Total carbon per hectare in AGC (in ton) (2+3+4+5)	Below Ground Carbon Carbon calculated per hectare (in ton)		Total carbon Per hectare in BGC (in ton) (7+8)	Total carbon per hectare (in ton) (6+9)
	Stem	Branch	Leaf	Herb & Shrub		Soil	Root		
1	2	3	4	5	6	7	8	9	10
	469.128	7.969	0.237	0.0225	**477.3565**	0.223	124.070	**124.293**	**601.649**

SOURCE: FROM THE THESIS ON CARBON SEQUESTRATION IN NATURAL SAL (Shorea robusta) FOREST OF SOUTH KHERI FOREST DIVISION, LAKHIMPURKHERI, BY UMA SHANKER SINGH

The total carbon content has been worked out hectare wise for above as well as below ground biomass and this has been found that AGC comes to 477.356 ton per hectare whereas BGC is found to be 124.293 t/ hect. The total carbon per hectare works out to be 601.649.

DISCUSSION

Global warming is defined as the increase of the average temperature on Earth. As the Earth is getting hotter, disasters like hurricanes, droughts and floods are getting more frequent. Over the last 100 years, the average air temperature near the Earth's surface has risen by a little less than 1 degree Celsius or 1.3 degrees Fahrenheit. Deforestation increases the severity of global warming (M. Venkataramanan and Smitha 2011) In the light of the growing awareness of environmental changes related to climate change; the issue of carbon balance in the atmosphere has become one of the more crucial issues to be understood. As has been repeatedly emphasized, the growing forests and tree plantations and their soils are major sinks of atmospheric carbon (IPCC 2007) and thus the influence of forests in the global carbon cycle is now widely recognized (Basu 2009, Bonan 2008) This is because the forest vegetation captures atmospheric CO_2 through photosynthesis and stores it mainly in different tissue systems with a slow turnover rate of 14-90 years for native forest in Chile, around 50 -100 years in Amazon and an average of 50 years in other forest (Reeburgh, 1997). The forests also mobilize atmospheric carbon through plant respiration and organic material decomposition although these losses are usually less than the gains (William Fonseca *et al,* 2011). The human-beings are responsible for accelerating the rate of increase in atmospheric CO_2 by burning the fossil fuel, land use changes, deforestation and shift in forest management, and it is now an established fact. Consequently, the average CO_2 concentration in the atmosphere has increased from 280-ppm to 364-ppm in 1994 and is currently augmenting at the rate of about 1.5-ppm per year (Kelling and whorf, 1998). The latest observation shows that the concentration of carbon dioxide value has increased to a level which is more than 400-ppm in April 2013, a value never reached at this key surveillance point for a few million years (Nature, 2013). At 400-ppm the countries across the globe will have to pass through a difficult time if proper check is not applied on the global warming. Presumably, if all the CO_2 emission is stopped today then also global warming process will not stop, on the contrary the amount of CO_2 emissions we have in the atmosphere will be enough to increase the temperature by 0.3^0C by the end of this century. The new Global Carbon Cycle Model with a realistic CO_2 e-fold lifetime reveals that the half lifetime of CO_2 is 38 years. Therefore, a massive effort is required to enlarge the sink of CO_2 and reduction in deforestation at all the levels. Near the moon escape summit of the Mauna Loa Volcano in Hawaii, an infrared analyzer has made a history as this has started measuring concentration of CO_2 on day-to-day basis and since then the values of CO_2 have followed an upward slope showing no sign of leveling. Emissions of other green house gases have also been increasing, rather pushing, and the total equivalent concentration of CO_2 in the atmosphere to around 478 ppm in April 2013. The climate models also suggest that land and oceans will not keep pace with an increase in the emission of green-house gases.

STORAGE OF CARBON IN THE GLOBAL FORESET

The storage of carbon depends on the fixation of CO_2 through photosynthesis and the release of carbon as CO_2 through the respiratory activities of plants though the rate of CO_2 fixation is always much higher than the CO_2 release during respiration. Currently the total above ground biomass in the world's forest is 421×10^9 tons distributed over 3869 Mha. Out of this 95% is of natural forests and 5% of plantation forests. When calculated it comes to 108.81Mtc/ha. This paper does not describe the methodology to find out the carbon contents in the global forests, but presumably it is calculated on the basis of finding out of the growing stock of the total forest and then coming to the total biomass. According to the author, through suitable forest management regimes the rate of carbon sequestration may be enhanced to 1.6 Pg C yr^{-1} in future. The carbon sequestration and release vary substantially in the forest system. Each biome varies edaphically and climatically and a series of factors which are different from each other also play a role. Therefore, the carbon content for each biome is likely to be necessarily different. The following Table gives the average carbon stocks for various biomes:

TABLE 6 AVERAGE CARBON STOCK IN VARIOUS BIOMES

(Carbon in tons)

Biomes	Plants	Soil	Total	Biomes	Plants	Soil	Total
Tropical Forests	133.33	135.80	269.13	Tropical savannas	32.09	128.39	160.48
Temperate Forests	61.72	106.17	167.89	Temp. Grasslands	7.40	259.25	266.65
Boreal Forests	71.60	377.77	449.37	Desert/ semi desert	2.46	46.91	49.37
Tundra	7.40	140.74	148.14	Wetlands	46.91	708.64	755.55
Croplands	2.46	88.88	91.34	-	-	-	-

Source- Intergovernmental Panel on Climate Carbon Stocks in Vegetation and Carbon Pools Down to a Depth of 1m (meter.)

The CO_2 absorption rate is directly proportional to the growth rate. In commercial, even aged stands of the forests, it is simpler to estimate incremental growth. Bolin *et al* (1986) estimated that in tropical rainforest contains 3.88-5.10 ton of carbon while Jordan's (1989) estimation was 6.36-12.30 Mt of carbon in Rainforest of Ivory Coast. Cannel (1982) examined the Seasonal tropical forest and found out that carbon was present to the tune of 2.75-3.60 Mt/h It is clear from the above Table that carbon has been estimated on the basis of biomass and also with the assumptions that carbon should be fifty per cent of the dry matter contents. Brown and Lugo (1994) have calculated the carbon content of the tropical vegetation by using destructive sampling and timber volume estimation methods. In 1982 they calculated the tropical forest biomass density by means of destructive sampling, based on the selection of small areas of less than 30 hectare which were clear- felled in order to directly measure the biomass. The results from both the two methods show a remarkable difference in carbon estimation. The amount of carbon calculated through destructive method was much higher than that of the estimation through volume. It has been estimated that in low-land rainforest the carbon in aboveground biomass is 172 tC/ha whereas the value for soil is 180 tC/ha. For lowland and moist forest the values are little higher i.e. 185 tC/h and 88 tC/ha, respectively. For the closed primary forest the total carbon i.e. aboveground as well as soil amounts to 283 tC/h and for closed secondary forest it is has been estimated to be in the range of 152-237 tC/h

CARBON STOCK POTENTIAL OF INDIAN FORESTS

India is spread over an area of 328.7 million hectare or about 2.5 % of the world's total land area. As per the records of the Forest Survey of India (FSI 2009) the national carbon stock has grown substantially from 6,225 Mt. Carbon (1995) to 6,621 Mt. Carbon (2009). India's forest serves as a one of the very important sink of CO_2. This has been estimated that India's forest and tree cover is capable of fixing 11.25% of India's total green-house gas emissions (CO_2 equivalent) at 94 levels. The aggregate emissions from the anthropogenic activities in India has been amounted to 7, 93,490 Gg of CO_2; 18-083 Gg of CH_4 ; and 178 Gg of N_2O. In terms of CO_2 equivalent these emissions amounted to 1228540 Gg. The per capita CO_2 has been 0.87 t-CO_2 in 1994, 4% of the U.S. per capita CO_2 emissions in 1994. 8% of Germany, 9% of U.K., 10% of Japan and 23% of global average. CO_2 emissions contributed 65% of the total green-house gases. (NATCOM, 1994). Carbon stock in India's forest and tree cover is increasing at 0.6% per annum. Under this scenario the total carbon stored by the Indian forests in 2015 shall augment to 6998 mt and if the carbon stocks in India's forest increases more than 0.6% then by 2015 the scenario of carbon storage in India's forest shall become 7,283 mt. The studies carried out by Gupta (2009) on the biomass and carbon budget using the interpretation of satellite data as well as by processing the field inventory data collected from the grids over Ranchi district. The entire forest was divided into two strata, Sal stratum and miscellaneous forest stratum. The total biomass was converted into carbon and it was found that the carbon for miscellaneous stratum was 6.569 t C/ha. Whereas for Sal stratum it was 6.232 tC/ha. The forestry sector cannot only sustain its carbon but also has the potential to absorb carbon from the atmosphere. The annual productivity of the Indian forest has increased from 0.7 m^3/ ha. in 1985 to 1.37 m^3/ha. in 1985 (Lal and singh 2000). Carbon stock in India's forest and tree cover is increasing at 0.6% per annum. In a separate study the biomass, carbon storage and carbon di-oxide mitigation potential of plantation of *Populous deltoids, Dalbergia sissoo, Mangifera indica, Litchi chinensis and Prulus salicina had been assessed* and observed that the maximum total biomass 98.4 ton/hectare in ten years old Delbergia plantation, however in Populus it was reported to be 63 ton/hectare (N. Kanime, 2013) In yet another study on the carbon sequestration potential of sub tropical forests on Himalayan hills of Gharhwal this has been found that Pinus roxburghii forest along three different altitudes i.e., 1100, 1300 and 1500 meter above mean sea level of Himalaya to understand the effect of altitudes on carbon stocks (live trees and soil) in Pinus roxburghii forest. Tree density of this forest ranged between 590 tree ha−1 (upper altitude) to 640 tree ha−1 (lower altitude). The highest total carbon density (TCD) of above and belowground carbon was 66.33 ± 29.92 Mg ha−1 at lower altitude followed by 57.64 ± 16.75 Mg ha−1 in middle altitude and 52.92 ± 6.52 Mg ha−1 in upper altitude. Soil organic carbon was highest (33.20 ± 2.77 Mg ha−1) at lower altitude followed by middle (22.61 ± 7.17 Mg ha−1) and upper altitude (12.65 ± 6.10 Mg ha−1). Total carbon stock (trees + soil) of Pinus roxburghii forest was maximum (99.53 Mg ha−1) at lower altitude and Minimum 65.57 Mg per hectare at upperaltitude minimum (65.57 Mg per hectare) at upper altitude (S.Kumar et al 2013)

SOIL AS CARBON SINK IN INDIA

Plant species have the potential to influence soil carbon pools and their dynamics through variations in carbon inputs and also by influencing the carbon losses including soil organic matter decomposition. The total soil organic carbon pools in Indian forest have been estimated 6.81 Pg in top one meter soil depths (Chhabra *et al*., 2003). The Land-use and carbon sequestration model has also been predicted that by the turn of 2050, the above ground vegetation biomass of India will be twice the value we have today . The effectiveness of agro-forestry systems in the storage of carbon depends on both the environmental and the socio-economic factors. The humid tropic agro-forestry systems have the potential to sequester over 70 ton per C hectare on the top 20 cm of the soil (Murthy *et al*., 2013). The carbon sequestration potential system of agro-forestry has been studied by Indian Institute of Sciences, Bangalore under different ecosystems of Southern India falling in various ecological zones. There is a common practice of agro-forestry in the villages of Karnataka and Tamil Nadu on irrigated as well as rain-fed crop-lands either as bund or block plantations. Coconut, mango, tamarind and other species of monetary benefits are grown by the villagers on the land of the forest. Among the Karnataka villages, the highest biomass carbon stock has been recorded at the level of 5 ton/hectare and the average soil carbon was 3.93 ton/hectare (Murthy *et al.*, 2013). Soil samples have been collected from ten randomly selected plot areas in the compartment measuring 1m x1m were dug for collection of soil samples which were carried out at three levels i.e. 0-30 cm, 30-60 cm and 60-100 cm deep. After their chemical analysis, the soil carbon has been found to be 0.21258457 ton/hectare which is much lesser than the average National value i.e. 88.49 ton/hectare. The soil carbon in Kolli Hills of Eastern Ghats, Tamil Nadu was estimated to be 103.05 ton/hectare). The National value of 88.49 ton/hectare had been arrived on the basis of the calculations performed by Forest Survey Of India. The carbon in Kolli Hills had been calculated by SOC density (mg ha^{-1}) x forest area (ha). In my study the soil carbon samples were collected and analyzed in the laboratory. Total carbon percentage was collected through bulk density i.e. by multiplying the carbon factor with the biomass.It is interesting to note that at all the three levels i.e. 0-30 cm, 30-60cm and 60-100 cm, in the five compartments namely South Katna 7A, East Gola 5, West Gola 10, West Gola 1 and West Gola 6 the carbon was much higher than rest of the five compartments. This shows that these compartments possess relatively more stabilized soil and the forest has also been found to be relatively less disturbed than the rest of compartments. Forest ecosystem is very important for storage and there should be a concerted effort to keep it intact. In a recent studies on peat lands potential to store carbon in Congo basin peat land complex it was found that Peatlands are carbon-rich ecosystems that cover just three percent of Earth's land surface1, but store one-third of soil carbon. Peat soils are formed by the build-up of partially decomposed organic matter under waterlogged anoxic conditions. Most peat is found in cool climatic regions where unimpeded decomposition is slower, but deposits are also found under some tropical swamp forests (C.Greta et al 2017)

Therefore, this can be safely stated that a stable forest has a stable soil containing more carbon. Disturbance of any kind ultimately disturbs carbon balance in all the components of Forest ecosystem.

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