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RESEARCH ARTICLE

CARBON SEQUESTRATION BY TEAK (*Tectona grandis*) PLANTATION AT MALANJKHAND COPPER PROJECT, DISTRICT BALAGHAT, M.P.

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ABSTRACT

Soil carbon sequestration is the process of storing carbon underground to curb the accumulation of carbon dioxide in the atmosphere. Although the earth naturally stores carbon in forest, oceans, and soil, these carbon sinks are unable to excessive and increasing amount of carbon dioxide humans continue to emit. As a result, researchers have begun to explore ways of enhancing the absorption of natural carbon sinks, as well as ways to artificially store carbon dioxide underground. This experiment was conducted to study the carbon sequestered by teak trees within the 5km radius of Malanjkhand Copper Mine, Malanjhkhand, District- Balaghat, (M.P.), India. Malanjkhand referred to as MCP (Malanjkhand Copper Project) is an open- pit copper mine in India. This was compared with the carbon sequestered by teak trees situated nearby mining and forest areas. The results and findings reveals that there are inherent problems associated with a development of copper project and due to copper mining some of the trees sequestered less carbon comparison to forest area. The teak trees underneath soil situated nearby copper mine having poor health than the soil taken underneath teak trees situated at forest area.

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INTRODUCTION

Teak (*Tectona grandis*) is the economical tree species commonly recommended for plantation programmes in dry tropical regions for timber production. The durability and workability of teak were recognized in our country, due to its widespread distribution and cultivation throughout the tropics. Teak among the top five tropical hardwood species established worldwide relatively easy to established by plantations and global demand for its products with good prospects. Teak grown up as a tall tree species indigenous to India, Myanmar and Thailand but also grows in seasonal dry tropical areas in Asia (Bunyavejchewin, 1983). It is highly rated among hardwood plantations due to its durability, mellow color, and long straight cylindrical bole. The wood of teak is used for furniture, flooring, joinery, trim, doors, wooden panels, carving, musical instruments, turnery, vats, boat masts and decks, railway sleepers, mine props, fuel, and fence posts (Nair and Chavan 1985; Tiwari 1992; Bhat 1995; Brennan and Radomiljac 1998; Trockenbrodt and Josue 1998; Priya and Bhat 1999; Bhat 2000; Baillères and Durand 2000; Kokutze *et al.,* 2004).

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The heartwood of teak is golden brown with a distinct grain and has a specific gravity of 0.55 (Longwood 1961). Although natural teak is distributed in relation to productive soils, derived from e.g. limestone (Tanaka *et al*., 1998), teak is planted over many tropical countries, such as Nigeria, the Sierra Leone in Africa, and Costa Rica, Panama, Colombia, Trinidad and Tobago and Venezuela in central America, as well as Asian countries (Kashio and White, 1998; Pandey and Brown, 2000). It can grow in a wide variety of soils, tolerate a wide range of climates, and have best growth under the conditions that the minimum monthly temperature is above 13°C and the maximum monthly temperature is below 40°C. Optimal rainfall for teak ranges between 1250 and 3750 mm per year, however, for the production of good-quality timber the species requires a dry season of at least four months with less than 60 mm precipitation (Kaosa-ard, 1981). Teak occurs on a variety of geological formations such as trap, limestone, granite, gneiss, mica schist, sandstone, quartzite, conglomerate, shale and clay (Tiwari, 1992). It usually grows on the soils with a pH range of 6.5 to 7.5. Below pH 6.0 it is absent and beyond pH 8.0 it suffers stress in growth. Altitude plays an important role in the plant growth. Normally teak does not grow at altitude of over 900 m and the plant vigour decreases over 750 m (Takle and Mujumdar, 1956). Similarly aspects of the locality also affect the plant's growth and the plants grow better on the cooler northern and eastern aspects than on the hotter southern and western ones (Seth and Yadav, 1957). Teak is one of the most extensively planted tree species in the tropics, constituting about 6.0 million ha plantation area worldwide (Bhat and Hwan Ok Ma, 2004). Approximately 94% plantations of this net area are located in Tropical Asia, with 44% in India and 31% in Indonesia. The plantations of other countries in the region contribute significantly with 7% in Thailand, 6% Myanmar, 3.2% Bangladesh and 1.7% Sri Lanka. The area of teak plantations in Tropical Africa is about 4.5% of total area of teak plantations and the rest are in Tropical America, mostly in Costa Rica and Trinidad and Tobago (Pandey, 1998). The plantation forests of 5.3 million ha teak in Asian Pacific region have been managed under 35 to 80-year rotations, yielding 5 to 20 m3.ha-1.year-1, while 310000 ha plantations in Africa are harvested at 20-year rotations, yielding between 4 and 13 m3.ha-1.year-1 (Bhat and Hwan Ok Ma, 2004).

By the year 2004, global teak plantation area reached 6 million hectares and is still growing for investment by small landholders in agro-forestry management as well as industrial wood supply (ITTO, 2004). However, the expansion of teak plantation has been propounding discussion from environmental perspectives, such as reduced biodiversity by mono-cultural plantations involving the clearing of undergrowth vegetation; soil erosion by fire treatment and litter raking; nutrient losses during harvesting; the spread of pests such as defoliators, the bee hole borer, skeletonizer; and the effects of water cycling (Niskanen, 1998; Pandey and Brown, 2000; Hallett *et. al*., 2011). Plantation of teak, in India, started during the middle of the 19th century. In the year 1842, Conolly, collector of Malabar initiated plantation of teak in Nilambur (Kerala) with a view to ensuring quick regeneration of teak forests (Dwivedi, 1993).

From that year until 1862, more than 1 million teak plants were raised for plantation development. The area planted is now about 980 000 ha. Current teak plantation management is dominated by the public sector, especially Government Forest Departments or state corporations/enterprises. Private involvement in establishing teak plantations is a recent development and the area under private sector management is expected to increase rapidly as long as teak planting is perceived as a commercially attractive investment. Under clear and favorable tenure conditions, less restrictive policies, and the provision of economic incentives, teak plantings have particularly expanded in small woodlots and homesteads. Nowadays, one of the incentives for planting teak is to meet the demand in terms of carbon sequestration by indigenous tree species, at least in Indochina, with high economical return (Pibumrung *et al*., 2008; Jayaraman *et al.,* 2010).

However, despite several studies on carbon and biomass distribution in teak plantation in many countries, the carbon cycling of teak plantation has rarely been reported (Khanduri *et al.,* 2008; Kraenzel *et al.*, 2003; Viriyabuncha *et al.*, 2002; Pande, 2005). Teak plantation production varies widely among countries and depending on soil conditions (Enters, 2000; Kaosa-ard, 1998). For example, the mean annual increment ranged from 2.0 m3 ha-1 y-1 in poor sites in India to 17.6 m3 ha-1 y-1 in prime sites in Indonesia with 50 year rotation periods (Pandey and Brown, 2000). Thus, the quantative illustration of carbon cycling in teak plantations is useful for understanding the key carbon sequestration channels, which may serve as the basis for improving forest management. Although forest tree plantations have only had a small contribution to the total balance of terrestrial carbon (3.8% or 140 million ha of the world's total forest area; FAO 2006) but their potential to absorb and store carbon has been recognized to play a more important role in the future mitigation of climate change (Canadell *et al.,* 2007).

Soil carbon sequestration can be accomplished by management systems that add high amounts of biomass to the soil, cause minimal soil disturbance, conserve soil and water, improve soil structure, and enhance soil fauna activity (Alan Sundermeier *et al*., 2005). Copper substantially affects the growth of the teak plants (Pichhode and Nikhil, 2015,a). Further copper mining and associated pollution and significantly affected the growth by decreasing the photosynthesis pigmentation in teak and other plantation at MCP, HCL, district Balaghat, M.P (Pichhode and Nikhil, 2015,b)

Site details

The nine Teak trees (*Tectona grandis*) were randomly selected around the 5km radius of opencast copper mining of Malanjkhand Copper Project situated at Malanjkhand in the Mohgaon Panchayath of Baihar tehsil under district Balaghat, Madhya Pradesh. Malanjkhand referred to as MCP (Malanjkhand copper project) of Hindustan Copper Limited (HCL), Govt. of India undertaken is an open-pit copper mine in India, located near the town of Malanjkhand, 90 km northeast of Balaghat in Madhya Pradesh. Further, these nine teak trees were compared with 9 teak trees situated at forest of same age. The geographical coordinates are as follows:

Latitude and Longitude: 22° 1' North, 80° 43' East

Latitude and Longitude (Decimal Degrees): 22.0166666667, 80.7166666667

MATERIALS AND METHODS

Soil Sampling and Analysis

Randomly selected nine teak trees (*Tectona grandis*) of 20yrs old (approximately) in 25sq.km., areas of Malanjkhand opencast copper mines were compared with nine numbers of twenty years age of teak trees present within 100sq.km., randomly selected for this study. The height, diameter of particular nine trees species of 20yrs old each within the 25sqkm and 100sqkm were recorded and compared for carbon sequestration achieved. Besides this, soil underneath from each tree were analyzed for pH, Electrical conductivity (EC), Organic carbon (OC), Available ammonical nitrogen, Available phosphorus and Available potassium parameters. (Amthor, J.S.2000). All the soil parameters were analyzed prescribed through soil international standards and ICAR, New Delhi.

Fig.1. Teak tree at MCP, HCL, district Balaghat, M.P

Carbon Sequestration

The rate of carbon sequestration depends on the growth characteristics of the tree species, the conditions for growth where the tree is planted, and the density of the tree's wood. It is greatest in the younger stages of tree growth, between 20 to 50 years (http://www.rcfa-cfan.org/english/issues.13.html). Further, complicating the issue is the fact that far less research has been done on tropical tree species as compared to temperate tree species. Nevertheless, we can roughly estimate the amount of CO_2 sequestered in a given tree, and if we divide by the tree's age, get a yearly sequestration rate.

The process of calculating carbon sequestration is being done by NCSLP given below:

- Determination of the total (green) weight of the tree.
- Determination of the dry weight of the tree.
- Determination of the weight of carbon in the tree.
- Determination of the weight of carbon dioxide sequestered in the tree
- Determination of the weight of CO_2 sequestered in the tree per year.
- Determination of the total (green) weight of the tree, based on tree species in the Southeast United States, the algorithm to calculate the weight of a tree is (Clark, 1986):

W = Above-ground weight of the tree in pounds
D = Diameter of the trunk in inches
H = Height of the tree in feet
For trees with $D < 11$:
W = 0.25D2H
For trees with $D >= 11$:
W = 0.15D2H

Depending on the species, the coefficient (e.g. 0.25) could change, and the variables D2 and H could be raised to exponents just above or below 1. However, these two equations could be seen as an "average" of all the species' equations. The root system weighs about 20% as much as the above-ground weight of the tree. Therefore, to determine the total green weight of the tree, multiply the above-ground weight of the tree by 120%. Determination of the dry weight of the tree is based on an extension publication from the University of Nebraska (Scott DeWald, 2005).

This publication has a table with average weights for one cord of wood for different temperate tree species. Taking all species in the table into account, the average tree is 72.5% dry matter and 27.5% moisture. Therefore, to determine the dry weight of the tree, multiply the weight of the tree by 72.5%. Determine the weight of carbon in the tree The average carbon content is generally 50% of the tree's total volume (Richard, 1992). Therefore, to determine the weight of carbon in the tree, multiply the dry weight of the tree by 50%. Determine the weight of carbon dioxide sequestered in the tree CO_2 is composed of one molecule of Carbon and 2 molecules of Oxygen.

The atomic weight of Carbon is 12.001115. The atomic weight of Oxygen is 15.9994. The weight of CO_2 is C+2*O=43.999915. The ratio of CO_2 to C is 43.999915/12.001115=3.6663. Therefore, to determine the weight of carbon dioxide sequestered in the tree, multiply the weight of carbon in the tree by 3.6663 (http://www.ncsec. org/ cadre2/team18_2/students/helpCalcCO2.htm).

Table.1: Carbon Sequestration capability of Teak Trees of approximately an age of 20 years situated near MCP, HCL, within 5km diameter around mining areas nearby mine working phase, office and residential areas

S. N	Tree Height (in feets)	Breast Height Diameter (in inches)	Above Ground Fresh Biomass (AGFB) (In pound)	Below Ground Fresh Biomass (BGFB) (In pounds)	Total Fresh Biomass (TFB) (In pounds)	Total Dry Biomass (TDB) (In pounds)	Total Carbon Content of tree (In pounds)	CO2 Sequestered after 20 years age of trees (In pounds)	CO2 Seq (in Pounds/ year/trees	CO2 Seq (in Kg/ year/trees
1	40	37	8214.00	1642.00	9856.80	7392.60	3696.3	13551.74	677.59	291
2	38	28	4468.80	893.76	5362.56	3887.86	1908.94	6998.74	349.94	158
3	45	39	10266.75	2,053.35	12320.10	8932.07	4385.65	16079.09	803.95	364
4	40	34	6936.00	1387.2	8323.20	6034.32	2962.85	10862.7	543.14	246
5	39	39	8897.85	1779.57	10677.42	7741.13	3800.89	13935.22	696.76	269
6	43	38	9313.80	1862.76	11176.56	8103.01	3978.58	14586.65	729.33	313
7	42	38	9097.20	1819.44	10916.64	7914.56	3886.05	14247.43	712.37	323
8	38	37	7803.30	1560.66	9363.96	6788.87	3333.34	12221.01	611.05	277
9	43	35	6982.50	1396.5	8379.00	6074.78	2982.71	10935.53	546.78	280

Table 2. Carbon Sequestration capability of Teak Trees of approximately an age of 20 years situated near MCP, HCL, within 10 kms. diameter around mining areas in forest

S. N	Tree Height (in feets)	Breast Height Diameter (in inches)	Above Ground Fresh Biomass (AGFB) (In pound)	Below Ground Fresh Biomass (BGFB) (In pounds)	Total Fresh Biomass (TFB) (In pounds)	Total Dry Biomass (TDB) (In pounds)	Total Carbon Content of tree (In pounds)	CO2 Sequestered after 20 years age of trees (In pounds)	CO2 Seq (in Pounds/ year/trees	CO2 Seq (in Kg/ year/trees
1	45	42	11907.00	2381.40	14288.40	10359.09	5086.31	18647.95	932.39	422
2	42	38	9097.20	1819.44	10916.64	7914.56	3886.05	14247.42	712.37	323
3	43	34	7456.20	1491.24	8947.44	6486.89	3185.06	11677.40	583.87	264
4	39	38	8447.40	1689.48	10136.88	7349.238	3608.47	13229.75	661.48	300
5	41	34	7109.40	1421.88	8531.28	6185.18	3036.92	11134.26	556.71	252
6	37	39	8441.55	1688.31	10129.86	7344.14	3605.97	13220.59	661.02	299
7	41	37	8419.35	1683.87	10103.22	7324.83	3596.49	13185.82	659.29	299
8	43	34	7456.20	1491.24	8947.44	6486.89	3185.06	11677.40	583.87	264
9	44	39	10038.60	2007.72	12046.32	8733.58	4288.19	15721.79	786.09	356.57

Table 3. Chemical Properties of soil beneath the teak trees of approximately an age of 20 years in mining and forest site situated at MCP, HCL, Malanjkhand, Balaghat, M.P

Soil sampling Site	pH	EC (mmhos/cm)	OC (%)	Available Ammonical Nitrogen (NH^{4+}) in Kg/ha	Available Phosphorus (P_2O_5) in Kg/ha	Available Potash (K_2O) in Kg/ha
Forest	6.98	0.76	0.62	327	9	291
Mining	7.13	0.70	0.53	600	45	347

Determination of the weight of CO2 sequestered in the tree per year has to be divided by the weight of carbon dioxide sequestered in the tree by the age of the tree. Estimation of the growth rates and sizes of agroforestry trees were taken from the World Agroforestry Centre's "Agroforestree Database" (http://www.world agro forestrycentre.org/ Sites/ TreeDBS/ aft.asp).

A tree of 10 years old with 15 feet tall with a trunk about 8 inches in diameter. Therefore: W = 0.25D2H = 0.25 (82) (15) = 240 lbs. green weight above ground. 240 lbs. * 120% = 288 lbs. green weight (roots included) 288 lbs. * 72.5% = 208.8 lbs. dry weight 208.8 lbs. * 50% = 104.4 lbs. carbon 104.4 lbs * 3.6663 = 382.8 lbs. CO2 sequestered 382.8 lbs / 10 years = 38.3 lbs. CO2 sequestered per year Or consider a 10-year-old Grevillia robusta, 45 feet tall with a trunk 6 inches in diameter. Using the same calculations as above, the amount of CO2 sequestered would be 64.6 lbs. per year. Or a newly-planted Acacia angustissima, 2.5 years old, 15 feet tall with a trunk 3 inches in diameter: 21.5 lbs. of CO2 sequestered per year. Albizzia lebbek, 15 years old, 30 feet tall, with a 12 inch trunk: 68.9 lbs. of CO2 sequestered per year.

According to tropical tree plantations of pine and eucalyptus can sequester an average of 10 tons of carbon per hectare per year (Norman, 1991). Therefore, the plantation can sequester an average of 20,000 lbs * 3.6663 = 73,326 lbs CO2/ha/year, or, taking an average of 1,000 trees per hectare, 73.326 lbs CO2/tree/year. Of course, the planting of pine and/or eucalyptus in our agroforestry systems is being discouraged due to this may not grow as fast or as straight as eucalyptus, but they are not invasive, and they do not destroy the water table and the soil. This methodology is based on research papers, university publications, and other information freely available on the Internet.

RESULTS AND DISCUSSION

Height and Diameter

The height of the teak tree were shown in Table.1 and 2 found increments after 20 years of their growth as 40, 38, 45, 40, 39, 43, 42, 38 and 43 with 45, 42, 43, 39, 41, 37, 41, 43 and 44 feets, whereas the diameter at breast height (dbh) was 37, 28, 39, 34, 39, 38, 38, 37 and 35 with 42, 38, 34, 38, 34, 39, 37, 34 and 39 inches nearby mining and forest areas respectively. The volume and subsequently, biomass was reported to be related with diameter (dbh) and height (H) (FSI 1996, Jha, 1999 and Kiyono *et al*., 2010). This could be explained by the fact that volume (V) and above ground components of trees were dependent upon dbh and height (Bohre *et al*., 2012a, b and 2013).

Total Green Biomass

The teak trees has gain the total green biomass (above and below ground biomass) as 9586.8, 5362.56, 12320.1, 8323.2, 10677.42, 11176.56, 10916.64, 9363.96 and 8379.00 with 14288.4, 10916.64, 8947.44, 10136.88, 8531.28, 10129.86, 10103.22, 8947.44 and 12046.32 pounds by teak trees nearby mining and forest area respectively (Table 1 and 2).

The findings were comparable with the results of Datta and Agarwal (2003), Karmacharya and Singh (1992), Buvaneswaran *et al*., (2006); Nandeswar *et al.,* (1996), Pozgaj *et al*., (1996), Leith *et al*., (1986) Bohre *et al*., (2012a,b; 2013), Chaubey *et al*., (2012).

Carbon Sequestration

The carbon sequestration attained as 291, 158, 364, 246, 269, 313, 323,277 and 280 Kg/year/tree by the teak trees of approximately an age of 20 years situated near MCP, HCL, within 5km diameter around mining areas nearby mine working phase, office and residential areas followed by 422, 323, 264, 300, 252, 299, 299, 264 and 357 in forest teak plantation respectively were compared (Table.1 and 2).

Chemical analysis of the soil

The chemical analysis for the parameters like pH, Electrical Conductivity (EC), Available Nitrogen, Phosphorous and Potassium analyzed for soil collected below of the teak tree selected randomly for this study. An average pH for the nine soil samples collected below of the teak tree's selected randomly from the forest as well as nearby mining area resulted 7.13 and 6.98 respectively. Whereas the Electrical Conductivity (EC) was respected to 0.76 and 0.70 mhos/cm teak tree's in forest and mining area respectively. The average Organic Carbon content was found 0.62 and 0.53 percent in forest and mining area respectively. Similarly, the available nitrogen, phosphorus and potassium were reported as 327, 9, 291 with 600, 45 and 347 kg/ha for the forest and nearby mining area soil respectively (Table.3).

Though, the nature of biomass accumulation may vary in the same species under different localities under such factors as accumulation of nutrient in the soil, management practices and availability of light and other environmental factors. The results were in agreement with the findings of Chaturvedi and Behl (1996), Goel and Behl (1999a,b, 2004, 2005), Singh and Goel (2009) who estimated the production potential of exotic and indigenous tree species of degraded soil sites under sodicity stress conditions. The better performance of this species in plantation forests might be primarily due to well drained and highly porous texture of soil media as found in mined overburdens. Re-vegetation of reclaim land presents and excellent opportunity optimize the carbon sequestration on this land.

In attractive revegetation strategy for extreme environment is the use of native vegetation i.e. well adapted for similar environment. The carbon content between 25 to 90 kg/ha for two years old tree, between 514 to 841 kg/ha for three year old tree and 5519 to 25,005 kg/ha for seven year old tree, whereas in this experiment an average 1665 and 1531 kg/ha carbon content for the teak tree after 10 years in forest and mining area respectively. Further, carbon sequestration rate 5028 kg/ha/year, 9685 kg/ha/year, 17363 kg/ha/year, 9888 kg/ha/year for different trees grown at reforestation of mine site. In own study teak wood had accumulated 252 to 422 kg/ha/year grown in forest area. Whereas teak wood had accumulated 158 to 364 kg/ha/year grown near mining area.

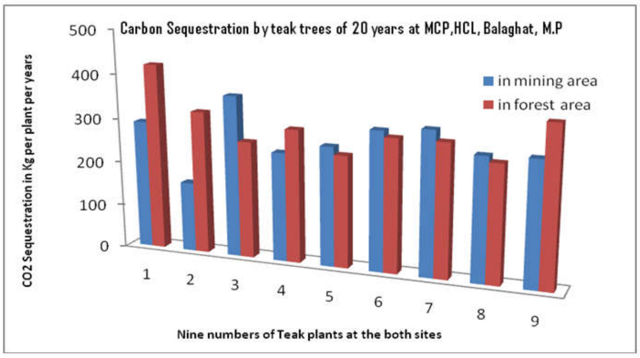

Figure 2. Carbon sequestration by teak trees of 20 years situated in mining and forest areas compared at MCP, HCL, Malanjkhand, Balaghat, M.P

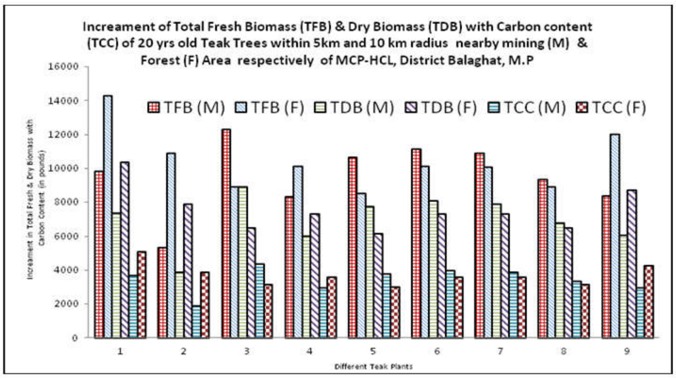

Figure 3. Increments of TFB, TDB and TCC by teak trees of 20 years compared within mining and forest areas at MCP, HCL, Malanjkhand, Balaghat, M.P

These shows the less accumulation of carbon by the teak tree present nearby mining area. Whereas, carbon accumulation 47 to 272 Mg/ha at mine site and 142 to 250 Mg/ha at natural site. This shows an average more carbon accumulation at mine site. But our study was contracted at copper mining where less carbon emission was notified resulting less accumulation by the teak trees grown nearby mining site. The more carbon accumulation by the teak tree in the forest area reveals that due to more plant density the carbon release by the other plants in the forest is more resulting more carbon accumulation by the teak tree (Harrison *et al*., 1999).

The higher amount of carbon sequestration found in 5 teak trees among the 9 teak trees sampled for this study can be attributed to higher total above ground biomass which in turn was due to favorable soil (Table 3) which is densely populated with vegetation of teak and other plant species within the 5km radius of MCP, HCL mining areas than the teak trees of forest area located within 10km radius (Fig.2 and Fig.3). This was with the agreement with the Reddy *et al*., 2014. It might be because of the fact that increment in teak tree biomass is directly proportional to the increment in age. It was also reported that species level carbon sequestration of teak was done in Panama and revealed that the teak plantations contain 351 tons of 'C'/ha at the end 20-year rotation period under tropical conditions (Margaret *et al*., 2003; Rawat and Negi, 2004).

Conclusion

The objective of conducting this experiment was to know the importance of native tree species nearby mining area to optimize the environmental condition of that area. For prevailing the objective, carbon sequestration was calculate to know the difference in the growth of teak trees present near mining and forest area. Carbon sequestration is the methodology to calculate the growth, biomass and carbon content of the tree. In our experiment it is very well prove that the teak tree grown in mining had more or less accumulated more biomass and carbon content than that forest area. Experiment conducted by scientist working in the same line had same vision and findings. Therefore, for achieving more carbon accumulation in mining area selection of trees species and plantation density in very much imported to be taken care. Government must have a strong policy for the mining company for the compulsory afforestation in terrestrial land in such a manner so that the species planted must have more capacity to fix carbon in more quantity of CO2 sequestration and the same time the survival of local species must be significant. The study had had done in a limited area and results may not be much versatile. It is being suggested to carry this experiment in bigger area in all the threes season to have more accuracy and authentication of data to be compared from others site to be studied.

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