A PRELIMINARY ESTIMATION OF CARBON STOCK SEQUESTRATED THROUGH RUBBER (*HEVEA BRASILIENSIS*) PLANTATION IN NORTH EASTERN REGION OF INDIA

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Introduction

There is a growing awareness all over the world about adverse impacts of green-house gas emission and the consequent climate change. Carbon dioxide (CO_2), one of the most important greenhouse gases, is added into the atmosphere naturally (volcanoes, respiration etc.) and unnaturally by human activities (Dhand *et al.*, 2003). The CO_2 concentration in atmosphere increased from 280 ppm at the beginning of the industrial revolution to 368 ppm by the year 2000 and it is projected to increase up to 540 ppm by 2100 (Houghton *et al.*, 1996). Concentration of atmospheric carbon dioxide is increasing at the rate of 1.5μ L yr^{-1} giving rise to an alarming situation (Lee and Dodson, 1996). Three quarters of this added CO_2 has come from burning fossil fuels and roughly a quarter from destruction of tropical rain forests (Singh *et al.*, 2003). Carbon (C) sinks can play an important role in meeting the challenges of climate change.

Carbon sinks could also be increased to a greater extent through rubber plantations. Carbon sequestration can be defined as the capture and secure storage of carbon that would otherwise be emitted to or remain in the atmosphere (Rawat and Rawat, 2003). The idea is to remove carbon from the atmosphere by various means and store it. Rubber tree *(Hevea brasiliensis)* is a natural forest tree which originated from the Amazonian basin of South America. This is a fast growing species that is extremely efficient in converting solar energy into biomass. Rubber plantation has been gaining importance for plantation in marginal and degraded jhummed land in the North-Eastern states. At present, 51,510 ha area is being occupied by rubber plantation in NE region out of 5,69,670 ha in India (Dey, 2004). There are four components of carbon storage in a rubber eco-system. These are : trees, plants growing on the floor (understory material), detritus such as leaf litter and other decaying matter on the rubber floor, and soils. The proportion of carbon stored in these components varies widely depending on age of plantation and prevailing climatic condition.

This paper is an attempt to estimate the carbon stock sequestrated through rubber plantation by using published information in the North-East region of India.

Materials and Methods

Study site : The study site is situated in the research farm of Regional Research

Station of the Rubber Research Institute of India, Agartala, located at longitude 91° 15' E and latitude 23° 53' N and at an altitude of 30 m above msl. The biomass and other data were collected from in and around of research farm.

Climate : The mean annual temperature of the area during the last 19 years was 25.2°C, the maximum and minimum temperature being 30.5°C and 19.8°C respectively. April, May and June are the hottest and December and January the coldest months of the year. The mean annual rainfall is 1972 mm. The major share of the rainfall is received during months of June-September (60%).

Soil Organic Carbon : Soil Organic Carbon (SOC) values under rubber plantation in the North Eastern States were collected from published literature (Choudhury *et al.*, 2001; Chaudhury and Dey, 2003; Chaudhury, 2004) These SOC values were estimated in 5009 soil samples collected from rubber plantation areas of different North-Eastern states under DFR project. The SOC values multiplied by the weight of 60 cm deep soil for total area of rubber plantation in different states using general assumption that 60 cm layer of 1 ha soil weight 8 million kg (Jha *et al.*, 2003).

Biomass : Based on the information on rubber plantation area, published in Indian Rubber Statistics (Anon., 2003), estimation was made for biomass and carbon stock for the corresponding areas of NE region. The estimated growth or growing stock was converted into biomass. Growth data were collected from research farm and different large plantation units in Tripura. Since age-wise plantation areas are not available, average growth of different age groups is used for estimation of total biomass. It was further improved by including underground woody root biomass. There are three rubber clones viz. RRIM 600, RRII 105 and GT 1 prevalent in this region with maximum percentage of area under RRIM 600 and the remaining with the other two clones. Due to this reason, the equation given by Dey *et al.* (1996) was used for estimation of the shoot biomass (400 trees/ha). However woody root biomass below bud union was estimated by using the following equation :

$R = 0.6065\ G^{1..1011}$

where :
R = root biomass,
G = girth at 150 cm height.

This equation was developed by harvesting woody root biomass (excluding fine roots) of 14 trees of the clone RRIM 600, which were uprooted due to heavy wind in April 2003. The samples were oven dried and total dry weight was computed and fitted with best regression line using standard procedures.

In this study, undergrowth vegetation was studied by using the "Quadrat method" (Misra, 1968). Fifty quadrats of 1 x 1 m size were laid along transects from various directions and the aboveground biomass was estimated by harvesting vegetation from quadrats. These plants were brought to laboratory and oven dried at 85°C to constant weight. Similar methods were used for cover crop and litter fall estimation.

Carbon : Oven dried plant components were burnt in electric furnace at 550°C temperature and the ash (inorganic elements in the form of oxides) left behind was weighed and carbon per cent was

calculated (Negi *et al.*, 2003; Dhand *et al.*, 2003) by using the following equation :

Carbon% = 100 – (Ash weight + molecular weight of O_2 (53.3) in $C_6H_{12}O_6$)

The carbon stock in the shoot and root biomass was computed using the following formula:

Carbon (tonnes) = Biomass (tonnes) x Carbon%

Results and Discussion

Soil Organic Carbon : Soil is one of the major sinks of carbon on earth especially under forestry/plantation, because these soils have normally higher soil organic matter. The SOC values under rubber plantation in different States of NE region are presented in Table 1. The average SOC of NE states is estimated to be around 92.7 tonnes/ha. The soils of Tripura showed a maximum SOC store of 1.925 million tonnes having an area of 28,853 ha of rubber plantation followed by Assam having 0.919 million tonnes of SOC. A total of 3.734 million tonnes of SOC store was estimated under rubber plantation of NE region. SOC of rubber plantation is comparable to other plantations in NE region (Dey *et al.*, 2004). Jha *et al.* (2003) reported that North Eastern States have SOC store of 218 t/ha in the forest lands. National average (27 States and UTs) for the states in the forest lands have SOC store of 153.63 t/ha (Jha *et al.*, 2003).

Biomass stock of rubber plantation : Above ground and woody root biomass of three clones in different ages groups and corresponding carbon are presented in Table 2. Average above-ground biomass and woody root biomass of clones are estimated to be 111.9 t/ha and 24.7 t/ha respectively. There is marginal difference observed in carbon contents among the clones and different ages. As per estimate,

Table 1

State-wise Soil Organic Carbon (SOC) store (up to 60 cm depth) in the rubber cultivated area of North Eastern region.

States	SOC (tonnes/ha)	Area under rubber plantation as on 2002-03 (ha)	Total carbon ('000 tonnes)
Tripura	66.4	28853	1915.8
Assam	69.6	13208	919.2
Manipur	60.0	1708	102.4
Mizoram	89.6	696	62.4
Meghalaya	98.4	4586	451.2
Nagaland	108.0	2087	225.4
Arunachal Pradesh	156.8	372	58.4
North-East (Total)	92.7 (Average)	51510	3734.8

Table 2

Standing biomass and carbon in the rubber plantation

Clone	Age (yrs)	Aboveground biomass (tonnes/ha)	Woody root biomass (tonnes/ha)	Total biomass (tonnes/ha)	Carbon (%)	Carbon (tonnes/ha)
RRIM 600	6	34.7	14.6	49.3	44.5	21.9
	17	152.5	30.5	183.0	44.6	81.6
	25	174.6	32.1	206.7	44.7	92.4
RRII 105	6	31.1	13.8	44.9	44.2	19.8
	17	134.7	28.3	163.0	44.9	73.2
	25	157.7	30.7	188.4	44.7	84.2
GT 1	6	35.9	14.8	50.7	44.5	22.5
	17	136.0	28.4	164.4	44.9	73.8
	25	150.0	29.8	179.8	44.7	80.3
Mean		111.9	24.7	136.6	44.6	61.1

average Carbon Stock in rubber plantation is 61.1 tonnes/ha excluding harvested rubber (Table 2). Results indicate that standing biomass and carbon is highest in Tripura State followed by Assam and Meghalaya (Table 4).

Litterfall : Being a deciduous tree, a mature rubber plantation adds leaf litter to the soil up to 7.35 tonnes/ha in this region (Table 3). Annual litter fall in 14 year old rubber plantation has been reported in the range of 6.8 to 7.8 t/ha in this region by Varghese *et al.* (2001). A large portion of litter mass is reduced to humus and soil organic matter through complex decomposition processes. A carbon fraction of 0.407 was used for converting litter fall to carbon (Table 3). Carbon percentage in most of the leaf litter of tree species was reported to be vary from 40-48%, when measured by dry combustion method (Raizada *et al.*, 2003). Raizada *et al.*, (2003) also advocated that soil organic carbon (SOC) build up is the function of total carbon input to the soil and higher the carbon flux from vegetation to the soil, higher will be the build up of C.

Undergrowth : Weed growth in immature phase is a common phenomena in rubber plantation. It is a general practice to grow cover crops to suppress weed growth which can also fix atmospheric nitrogen. Dry biomass of the cover crop (*Pueraria bracteata*) varied from 4.8 to 7.6 tonnes/ha/year (Table 3). There are undergrowth even in mature rubber plantation due to availability of some quantity of light. The average undergrowth biomass was observed 7.69 tonnes/ha/year during immature phase and undergrowth in mature stage was 3.59 tonnes/ha/year. Onyibe and Gill (1991) studied the weed biomass production in a mature rubber plantation in Nigeria and reported that

Table 3

Annual addition carbon in the rubber plantation

State of rubber plantation	Biomass (tonnes/ha)	Carbon (%)	Carbon (tonnes/ha)
Immature phase :			
Undergrowth	7.69 (3.66 – 9.81)	41.0	3.15
Cover crop (*Pueraria phaseoloides*)	6.44 (4.8 – 7.6)	32.8	2.11
Mature phase :			
Undergrowth	3.59 (2.29 – 5.18)	38.5	1.38
Litter fall	7.35 (6.48 - 7.85)	40.7	2.99
Average	6.14	39.0	2.40

*Range values are given in parenthesis

Table 4

Total carbon in rubber plantations in NE region

('000 tonnes)

States	Area under rubber plantation (ha)	SOC under rubber plantations	Carbon in rubber plants	Annual addition of Carbon due to under vegetation	Total Carbon
Tripura	28853	1915.8	1762.9	69.2	3747.9
Assam	13208	919.2	807.0	31.7	1757.9
Manipur	1708	102.4	104.3	4.1	210.8
Mizoram	696	62.4	42.5	1.7	106.6
Meghalaya	4586	451.2	280.2	11.0	742.4
Nagaland	2087	225.4	127.5	5.0	357.9
Arunachal Pradesh	372	58.4	22.7	8.9	90.0
N-E region (Total)	51510	3734.8	3147.1	131.6	7013.5

higher biomass was produced during the rainy season.

Area under rubber plantation in different states in NE region and carbon contents are presented in Table 4. Excluding soil and undergrowth, the total estimated carbon per hectare of rubber plants during 25 years of growth period in the NE region is around 103.8 tonnes, out of which 17.5% in dry rubber. Hence, average annualized carbon sequesteration of rubber plants is only 4.15 tonnes/ha for this region. As per our study, average SOC store is around 92.7 tonnes/ha and annual addition of carbon through litter fall and

under growth is around 2.40 tonnes/ha in rubber plantations of this region. Jacob and Mathew (2004) reported that the mean annual carbon sequestration during 21 year period is around 7.83 t/ ha/year in Kerala which appears to be much higher than that for pine or temperate deciduous forest.

In this paper, the carbon stocks of in standing biomass of Rubber plantation have been estimated. Some amount of CO_2 released in the plantation soils, due to microbial activity. It is assumed that the release of CO_2 from soil could be equivalent to the store of under ground weed biomass and fine roots of rubber plants. Due to this reason these biomass were not accounted here. Further, it is assumed that the rubber harvested by tapping does not result in long-term storage of carbon in the field, which is also unaccounted in this estimation. However, the harvested rubber is used as different finished products. Overall average carbon store of rubber plantation (excluding harvested rubber) including soil and under growth is around 136 tonnes/ ha and total stock is around seven million tonnes in NE region. An assessment made by the Rubber Board indicates that rubber could be cultivated in the NE region on 4,50,000 ha area (Krishnakumar and Meenattoor, 2000). The carbon mitigation potential of this crop would be nine times more than the present value over a period of time after completion of targeted area.

Conclusions

It is evident that the needs of the local people be met on a sustainable basis through rubber plantation (Dey, 2004). The plantations will conserve soil and water, prevent soil erosion and lead to increased water availability. Soil conservation practices are required to be strengthened to conserve these resources so that the carbon store may not be depleted from the hilly terrains of NE states. The undergrowth vegetation on plantation floor influences the microclimate of plantation and also plays a major role in nutrient cycle in the plant ecosystem (Mathur and Soni, 1983). While the objectives of rubber plantations were to meet industrial and social needs, they also helped to sequester substantial quantities of carbon in their biomass, at any given point of time. This is preliminary estimation of carbon stock available in the rubber plantation in the NE region. However, further detail study is required to substantiate the carbon sequestration potential of rubber plantation in this region.

SUMMARY

Global concern on increasing levels of greenhouse gases specifically carbon dioxide in the atmosphere, has led to the search for various mitigation options. In this context, carbon sequestration through managed rubber plantation is gaining importance. Rubber plantation has been expanding in the North East (NE) region and covers an area of 51,510 hectare. In this study, the carbon stock of rubber plantation in the NE region has been estimated and results indicate that an average carbon store in rubber plantation is around 136 tonnes/ha, out of which 92.7 t C/ha is contributed by soil and 2.40 t C/ha addition through litter fall and undergrowth vegetation. About seven million tonnes of carbon is store in the rubber plantations of this region. On completion of projected area of 4,50,000 ha., the carbon store would be around nine times higher than the present value. This study reflects the immense ecological value that rubber plantations provide, by storing carbon despite low productivity in these marginal lands.