CHANGES IN ORGANIC CARBON AND SOME SOIL PROPERTIES UNDER RUBBER (*HEVEA BRASILIENSIS*) PLANTATION IN SUB-TROPICAL TRIPURA

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Changes in the status of soil organic carbon (SOC), available phosphorus (av. P), available potassium (av. K), pH and bulk density (BD) were studied in rubber plantations at an interval of two decades in Tripura. Composite soil samples collected at two depths *viz*. 0-30 cm (surface soil) and 30-60 cm (sub-surface soil) during 1986 and 2006 from growers' fields, were analyzed for the physico-chemical properties. The data showed that SOC content increased appreciably under rubber, particularly in the surface layer. It was observed that in a span of twenty years, SOC status in surface and sub-surface soil increased from 0.81 to 0.96 and 0.66 to 0.73 per cent, respectively. The frequency distribution curve for SOC showed a positive shift indicating an increase of SOC under rubber soils over time, up to a depth of 60 cm. A total amount of 10.2 mt C/ha was stored under rubber soils during twenty years of rubber cultivation and the rate of carbon assimilation in rubber soils was found to be 0.24 mt/ha/yr .The frequency distribution curve for av. K showed a building up at both the depths, whereas a decline in av. P status of the soil was observed during that period. No appreciable change in soil pH was recorded during this time and variation in BD of soils was inconclusive. The study revealed that cultivation of rubber in Jhum-lands of Tripura will be beneficial for restoring soil health.

Keywords: Organic carbon, Rubber plantation, Soil properties, Tripura

INTRODUCTION

In North East India, wide spread deforestation is a common practice mainly to meet the need for fuel wood, timber, forage *etc.* and thus destabilising the ecology of this region. The soils in this region are highly degenerated due to shifting cultivation (Datta *et al.*, 2001) which is preceded by burning of organic debris in soil floor, thereby reducing soil organic matter and microbial population. Planting rubber (*Hevea brasiliensis*) in these denuded soils not only gives an excellent cover, but also provides ample revenue to the people. Therefore, as a settlement of local tribes as well as to meet the increasing demand of natural rubber in the country, large-scale rubber plantating was initiated in North-Eastern region of India by many government

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agencies since early part of 1970. Rubber plantation is basically a special type of secondary forest with intensive human activities such as land clearing, pitting, planting, fertilization and tapping. Initially research efforts were mainly confined to the development of location specific rubber clones and adopting better management practices for increasing rubber yield (Krishnakumar and Potty, 1992; Priyadarshan and Goncalves, 2003). Though some work has been carried out to investigate the ecological impact of rubber plantation on sub-tropical soils (Krishnakumar *et al.*, 1990), literature regarding the influence of rubber plantation on physico-chemical properties of soils and carbon sequestration potential therein is very scanty. In the present study, the influence of rubber plantation on soil properties over a period of twenty years was investigated. An attempt has been made to quantify the amount of carbon sequestrated under rubber soils in the subtropical humid climate of Tripura.

MATERIALS AND METHODS

Location

The study area was mainly confined to three districts of Tripura where rubber has been gainfully cultivated from the early part of the seventies. The soils under rubber in Tripura are predominantly sandy loam/ sandy clay loam in texture and are Alfisol and Ultisol in order. The soil temperature regime is hyperthermic and moisture regime is udic. The parent soil materials of the region are sand stone, silt stone and shale (Bhattacharya *et al.,* 1996).

The climate of Tripura is considered as subtropical humid. The climatic data over a period of twenty years showed that mean minimum temperature varied from 7.8-25.9^{o}C and mean maximum temperature varied from 23.1-34.5^{o}C. Relative humidity ranged from 65-92% and mean annual precipitation over the last 20 years was about 2000 mm. South-West monsoon contributed 60% of the total precipitation. During the months of January-March, soil moisture deficit was recorded.

Soil Sampling and Laboratory Analysis

Data derived from composite soil samples were collected at two depths *viz.* 0-30 cm (surface soil) and 30-60 cm (sub-surface soil) from the rubber plantations for prescribing discriminatory fertilization to rubber growers were analysed in this study. In the year 1986-87, 780 soil samples were collected at two depths from rubber growing areas of Tripura. Similarly, 1086 soil samples were collected from the same locations during 2006-07 and analyzed for pH, OC, available phosphorus and potassium, following standard analytical techniques (Jackson, 1973). The critical values for OC, av. P and av. K under rubber soils (Karthikakuttyamma *et al.*, 2000) were taken as standard for fertility evaluation (Table 1).

Table 1. **Critical levels of soil nutrients for rubber**

Nutrient	Low	Medium	High
Organic Carbon (%)	<0.75	0.75-1.5	>1.5
Available Phosphorous (kg/ha)	<22.4	22.4-56	>56
Available Potassium(kg/ha)	<112	112-280	>280

Source: Karthikakuttyamma *et al.* (2000)

Bulk density (BD) of each soil sample was measured by taking core samples from randomly chosen twenty representative locations and mean of these values were taken for soil carbon estimation. Soil organic carbon density was calculated by multiplying mean organic content of soil (g/g), thickness of soil depth (for surface soil, depth = 0.3m) and mean bulk density of soil (Batjes, 1996). For calculation of OC on per hectare basis, the value so obtained for carbon was multiplied by 10,000 t–test was employed for assessing the level of significance at P<0.05.

RESULT AND DISCUSSION

Organic Carbon

Soil organic carbon (SOC) content of soil varied from 0.11 to 1.76 % in surface soil with a mean value of 0.81(Table 2). The corresponding value of SOC for the year 2006-07 was 0.32 to 2.8 % with a mean value of 0.96%. In sub-surface soils, during 1986-87 OC content of soils varied from 0.1 to 1.45 % with a mean value of 0.66 % and in 2006-07, it ranged from 0.22 to1.71% with a mean value of 0.73 %. A wide variation in OC content under rubber soils of Tripura was recorded for both the depths as indicated by higher cv values (27.6 - 44.1 %). This may be due to variation in annual leaf litter addition to the soil floor under mature rubber which ranged from 5.5-7.5 mt/ha/yr and its subsequent decomposition (Varghese *et al*., 2001). Similar rise in organic carbon in soils was also observed in acid soils under agro-forestry plantation (Datta and Dhiman, 2001). In addition, maintenance of leguminous cover crop during immature phase of rubber cultivation might have helped for building up organic matter in certain locations. However, the rate of mineralization of litter and its retention in soil widely varied under rubber soils. The soil samples are classified as very low (<0.5%), low (0.75%), medium (0.75-1.5%) and high (>1.5%) OC and a frequency distribution curve over twenty years for surface soil (Fig. 1a) and sub-surface soil

Table 2. **Distribution of OC and available nutrients under rubber soils*in Tripura**

Soil depth	OC (%)		Av. P_2O_5 (kg/ha)		Av. K_2O (kg/ha)		pH	
	1986-87	2006-07	1986-87	2006-07	1986-87	2006-07	1986-87	2006-07
Surface (0-30cm)								
Range	0.11-1.76	0.32-2.8	0.93-116.5	0.23-77.5	31.3-560	47.1-582	3.99-5.75	3.97- 5.90
Mean	0.81	0.96	6.79	5.60	105.90	136.50	4.45	4.48
SD	0.24	0.36	4.63	4.03	62.10	77.10	0.26	0.32
CV (%)	28.90	37.50	68.40	64.20	58.	56.50	5.80	7.10
Sub-surface (30-60cm)								
Range	0.1 -1.45	0.22-1.71	0.22-89.6	0.21-70.5	38.9- 436	24.5- 495	3.97 -5.81	3.93-5.88
Mean	0.66	0.73	4.48	4.45	89.60	108.20	4.40	4.44
SD	0.18	0.37	3.51	2.68	49.10	69.30	0.19	0.32
CV (%)	27.60	44.10	77.10	60.20	54.70	64.10	4.50	7.50

*n = 543 (2006-07) and n = 390 (1986-87)

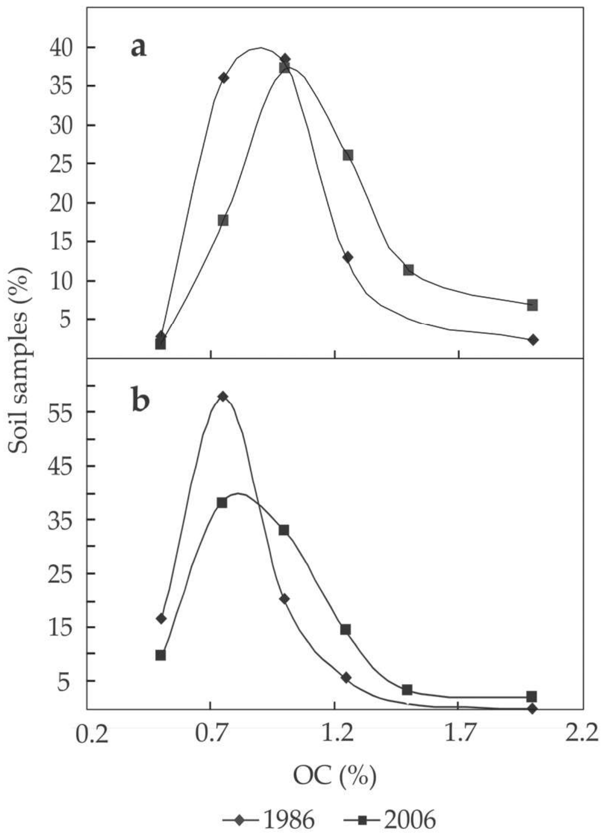

Fig. 1. Frequency distribution curve for OC in the soil samples (a. 0-30 cm, b. 30-60 cm) under rubber soils in Tripura

(Fig. 1b) were prepared. The distribution curve of surface soil showed a positive shift towards higher side of the peak suggesting a building up of OC due to rubber cultivation over the time. A similar trend was also observed in sub-surface soil also, with more number of soil samples showing medium status on OC values during 2006 compared to samples collected during 1986. In general, OC content of the rubber soils of Tripura are reported to be low to medium in fertility status (Chaudhury *et al.*, 2001). Majority of the rubber soils in Tripura were once subjected to shifting cultivation which was preceded by burning of organic debris. This might be the reason for low OC content under rubber soils collected during 1986-87. After rubber cultivation for two decades in these soils, a significant increase in OC values at the surface layer of soil was observed.

Available Phosphorus

Majority of the rubber growing soils in Tripura have low plant available phosphorus. This may be due to higher utilization of native P by plants and higher P-fixation capacity of these soils (Laskar *et al.*, 1983). Inadequate supply of phosphatic fertilizers may be another reason for the low P status of soils under rubber. During 1986-87 available phosphorus content of soils ranged from 0.9 to 116.5 kg/ha in surface soils with

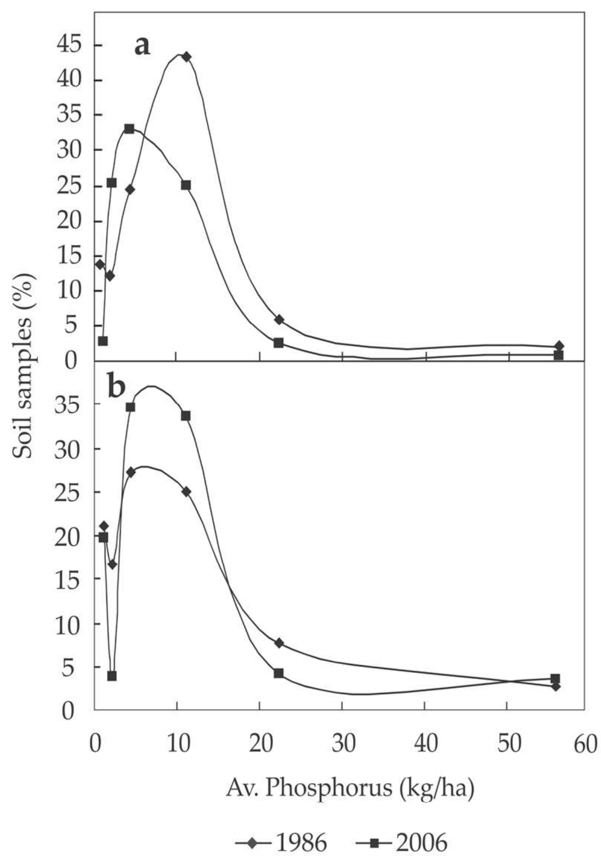

Fig. 2. Frequency distribution curve for available phosphorusin soils under rubber rubber Tripura (a. 0-30 cm, b. 30-60 cm)

a mean value of 6.79 kg/ha and in sub-surface soil, the values ranged from 0.22 to 89.6 kg/ha with a mean value of 4.48 kg/ha. After a gap of 20 years, available P under rubber soils showed a declining trend in both the surfaces and it ranged from 0.23 - 77.5 kg/ha with a mean value of 5.6 in surface soil and 0.21 - 70.5 kg/ha with a mean value of 4.45 kg/ha in sub-surface soil (Table 2). Frequency distribution curve for available P of the soil samples showed a shift in peak towards the lower side of the graph (Figs. 2a and 2b) indicating a declining trend of P over time. Reduction in available P status under rubber soils was also reported early (Philip *et al.*, 1993).

Available Potassium

During 1986 – 87, available K in the soil ranged from 31.3 – 560 kg/ha with a mean value of 105.9 in the surface soils. In sub-surface soil it ranged from 38.9 – 436 kg/ha with a mean value of 89.6 kg/ha (Table 2). Most of the rubber soils of Tripura were low to medium in fertility status for rubber (Chaudhury *et al.*, 2001). In 2006-07, available K status in surface soils ranged from 47.1 – 582 kg/ha with a mean value of 136.5 kg/ha and in the sub-surface soils were 24.5 – 495 kg/ha with a mean value of 108.2 kg/ha. These values are still low to medium in available K for rubber. However, a build up of available K status under rubber soils after twenty years of plantation was observed. A wide variation in available K was noticed (cv = 54.7 – 64.1%) in the rubber soils of Tripura. This may be attributed to the nature and distribution of K bearing minerals present in these soils and their variability in K-release potential. Availability of newer wedge zones in soil matrix due to weathering might be the other reason for higher values for potassium. A build up of available K in the rubber soils of Tripura in both the depths over time was observed and the increase was 28.9% in surface soil and 20.7% in sub-surface soil. In a long term fertilizer experiment in Tripura, Philip *et al.* (1993) also recorded a rise in available K (26-40%) under rubber soils. The frequency distribution curve for soil available K (Figs. 3a and 3b) showed a shift towards higher side indicating an increase in plant available K under rubber soils over the time.

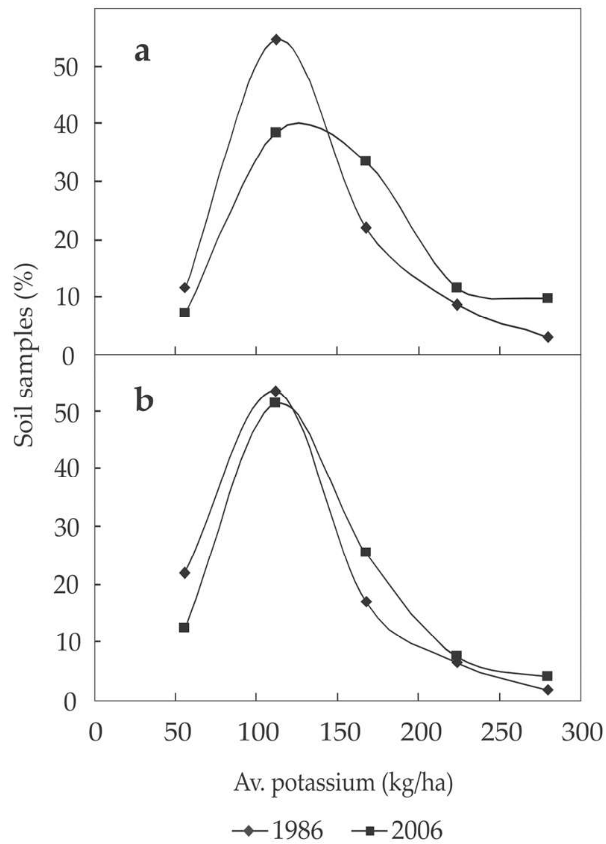

Fig. 3. Frequency distribution curve for available potassium under rubber soils of Tripura (a. 0-30 cm, b. 30 -60 cm)

Soil pH

Rubber plants can grow in soils of wide range of pH (3.8-8.0). However, a pH range of 4.0 to 6.5 has been identified as the

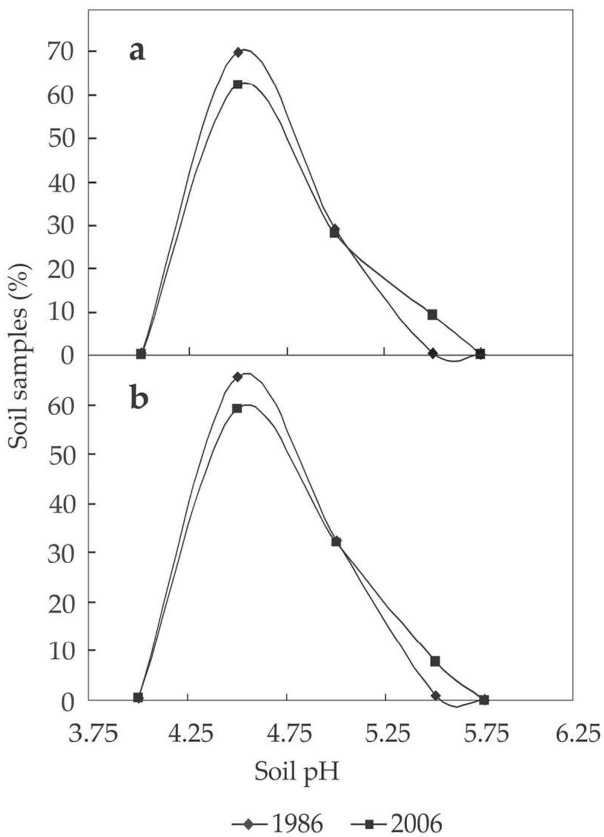

Fig. 4. Frequency distribution curve for pH of rubber soils of Tripura (a. 0-30 cm, b. 30-60 cm)

optimum pH range for rubber (Krishnakumar, 1993). In 1986-87, pH of the soils ranged from 3.99 – 5.75 with a mean value of 4.45 in surface soil whereas pH in sub-surface soils ranged from 3.97 – 5.81 with a mean value of 4.40 (Table 2) . In 2006-07, soil pH ranged from 3.97-5.91 with a mean value of 4.48 in surface soil and 3.93-5.88 with a mean value of 4.44 in sub-surface soil. No appreciable change in soil pH values was observed after two decades of rubber plantation. Low cv (4.5–7.5%) of the pH values also corroborates the result. The frequency curve for soil pH at both the depths (Fig. 4a and 4b) did not record any shift.

Bulk Density (BD)

Data on BD of the soils for 1986-87 were not available. However, BD was randomly measured from 20 locations at two depths. Bulk density ranged from 1.35–1.70 with a mean value of 1.54 Mg/m^3. Pedotransfer function [BD= 0.0181(100 – clay - 5) -0.08 x OC] was used to simulate the BD of the soil samples analyzed during 1986-87 (Singh *et al.,* 2007) and it was found that the values did not change appreciably with time. Therefore, a mean value of 1.54 was taken for calculating organic carbon store in rubber soils.

It was observed that surface soil stored more carbon than sub-surface soil (Table 3). It was obvious because 5.5-7.5 mt leaf litter/ ha was accumulated in the soil floor every year (Varghese *et al*., 2001). Therefore, its subsequent decomposition will increase the OC content of soil, particularly in surface soil. However, considering the huge amount of litter that was being accumulated every year, OC content of soil did not improve much in comparison to initial values. It may be due to higher loss of CO_2 from the decomposed litter. There is also steady loss of OC due to surface run off or loss of top soil due to high rain fall. Over a period of 20 years. 6.93 mt C/ha had accumulated in

Table 3. **Changes in level of organic carbon in soils under rubber plantation in Tripura, during 1986-2006 (mt/ha)**

Soil depth	1986	2006	Net build up
Surface soil (0-30cm)	37.42	44.35	6.93
Sub-surface (30-60 cm)	30.49	33.87	3.28
Total C accumulated in 20 years			10.21

surface soils of rubber plantation. Similarly, 3.28 mt C/ha was stored in sub-surface soils during same time period. A total of 10.21mt C/ha was over a period of 20 years sequestrated up to a depth of 60 cm under rubber soils in sub-tropical Tripura. Taking a mean SOC value of 0.96 % and up to a depth of 0.6m, 88.7 mt C/ha is available under rubber soils of Tripura which is in agreement with the findings of Dey (2005). In forest lands of India, national average for SOC is 153.6 mt C/ha (Jha *et al*., 2003). Rubber soils have the potential to sequestrate high amount of carbon with the passage of time.

CONCLUSION

Analysis of soil samples from rubber plantation in Tripura over a period of twenty years showed a significant increase in organic carbon, particularly in the surface soil, suggesting the beneficial effects of rubber plantation on soil health. Wide variation in soil nutrient status within and between the rubber plantations was observed. Building up of available potassium and depletion in available phosphorus were also observed. No appreciable change in pH and BD of the soils was noticed. The soils under rubber ecosystem accumulated about 10.2 mt C/ha during two decades of rubber cultivation.

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