Rubber cultivation improves soil health in Northeast

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Introduction

Soil health provides an overall picture of soil functionality. Assessment of soil quality is an invaluable tool in determining the sustainability and environmental impact of agricultural ecosystems. Soil health refers to the continued capacity of soil to function as a vital living system, by recognizing that soil contains biological elements that are key to ecosystem function within land-use boundaries (Doran and Zeiss, 2000; Karlen *et al.*, 2001). Soil health management is very much necessary because it represents the biological, chemical and physical features essential for long term sustainability in agricultural productivity with least ecological impact.

In humid tropics the major storehouse of nutrients is the standing vegetation, not the soil (Greenland and Herrera, 1975). Therefore, large fractions of nutrients freed after slashing and burning are lost, if not consumed in plant uptake, through leaching, runoff and soil erosion (Ruthenberg, 1983). Excessive deforestation coupled with shifting cultivation practices have resulted in tremendous soil loss (200t /ha /yr) and poor soil physical health in this region (Saha *et al.*, 2012). Decrease in water holding capacity and decline in soil pH, organic carbon, Cation exchange capacity, exchangeable cations, available phosphorus and potassium has been reported with the increase in shifting cultivation period, by Datta *et al.*, 2001. In general, shifting cultivation practices deteriorate the soil fertility due to huge soil loss of about 2-200 t /ha/yr. (Singh and Singh, 1978). It has been estimated that loss of soil through erosion in a forest with closed canopy is only about 100 kg/ ha (Megahan, 1972). *Hevea* has a closed canopy which helps to conserve the soil by reducing soil erosion.


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In Tripura, rubber (*Hevea brasiliensis*) plantations were raised to check soil degradation that happened due to the slash and burn agriculture practiced by the local tribal people, and also as a part of their rehabilitation programme. The hilly Northeastern region of India is characterized by heavy soil erosion, loss of soil fertility and deforestation causing acute environmental degradation and severe ecological imbalance (Sachchidananda, 1989). The replacement of natural forests due to shifting cultivation (jhumming) had a harmful effect on ecology. Shifting cultivation has been identified as one of the main human impacts influencing biodiversity in Tripura(Gupta, 2004). Shifting cultivation, which has been providing the subsistence requirements of a large number of people in the hills of Northeast India under a situation of low population became environmentally and economically unsuitable practice with increasing population and sharp decline in shifting cycle from earlier 5 - 6 years to 2 - 3 years

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or even less. Rubber (*Hevea brasiliensis*), a native of Amazon rain forests, which has all the attributes of a forest species, was hence introduced in this region.

At present in India, Kerala has the maximum area under rubber followed by Tripura. At present a total area occupied by rubber is 544953 ha and 101685 ha in traditional region and North East respectively (Rubber Board, 2012). Over the years various soil conservation practices has been adopted in rubber plantation to sustain high crop performance.

In this paper, an attempt is made to review how rubber cultivation in Northeast has improved the soil health. An appraisal of the various studies undertaken will help to reduce the time and effort required to obtain vital information.

Properties used for determining soil health

Among the variables to assess soil health, these indicators are of prime importance.

A. Physical Properties

i) Infiltration rate and moisture retention

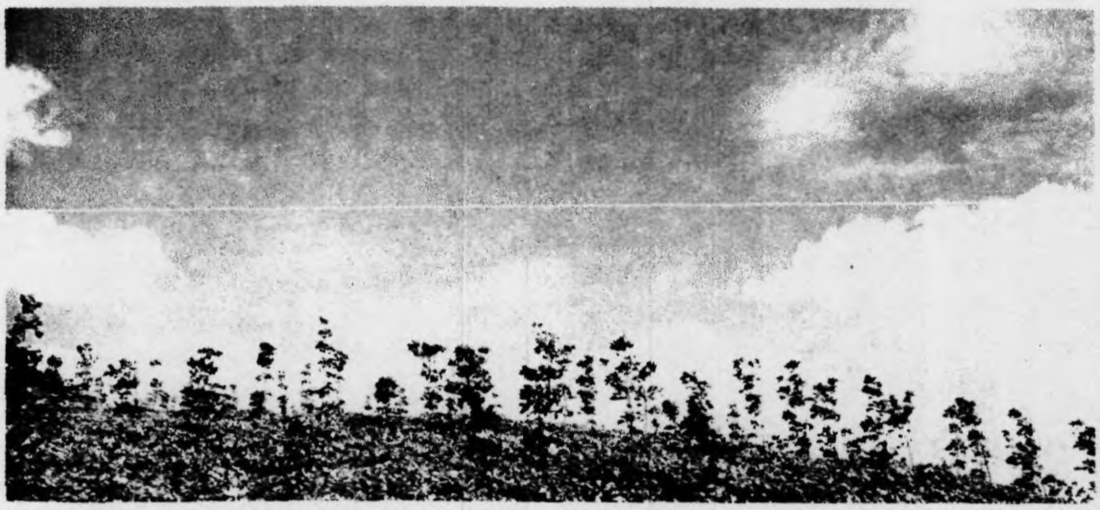
Rate of infiltration are related to important changes with soil use, management, and time. They are influenced by plant roots, earthworm burrows, soil aggregation, and overall improvement in stable organic matter. Depending on the soil type, texture, structure, and soil water content, the water infiltration rate may improve after the loosening of surface crusts or compacted areas. The infiltration flow rate inside rubber plantation is higher (138%) compared to fields subjected to shifting cultivation (Krishnakumar *et al.*, 1990). A higher available water storage capacity (AWSC) of rubber soils and moisture desorption pattern showed that at - 0.5 M Pa 90.34 percent of available moisture was desorbed from surface soil whereas for the same layer it is only 67.38 per cent outside the plantation (Krishnakumar *et al.*, 1990).

ii) Bulk density and porosity

Bulk density is an indicator of soil compaction. Bulk density of rubber soil ranged from 1.35 - 1.70 with a mean value of 1.54 Mg/m^3 and the values did not change appreciably with time (Mandal *et al.*, 2012). Moreover, comparing the porosity of surface layers from within and outside the rubber plantation, the highest was recorded from within the plantation in all the profiles (Krishnakumar *et al.*, 1990).

iii) Soil aggregates

In general, tillage disrupts aggregates and soil structure, creating the potential for renewed compaction and surface crusting, and leading to a loss of continuous surface - connected pores. But mature rubber plantation does not undergo any major tillage operations. Mean weight diameter (MWD) and percentage aggregate stability were



marginally higher for the soil under rubber particularly at the surface level which suggested an improved soil structure under rubber plantation (Mandal *et al.*, 2001; Krishnakumar *et al.*, 1991). Leguminous cover also helps in the formation of large size aggregates and causes higher rate of infiltration (Krishnakumar, 1989).

B. Chemical properties

i) Soil pH

Soil reaction is measured in terms of pH by estimating hydrogen-ion activity in a soil solution. Soil pH affects the solubility of soil minerals, the *availability of plant nutrients, and the activity of* micro-organisms. Rubber grows 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 optimum range for rubber (Krishnakumar, 1993). There is no considerable changes in soil pH for rubber soils after two decades of plantation. Its mean value is 4.45 and 4.4 in surface and sub surface layers respectively in initial years and 4.48 and 4.44 after twenty years of rubber cultivation (Mandal *et al.*, 2012).

ii) Ion exchange capacity

The soil's ability to supply major plant nutrients, *mainly calcium, magnesium and potassium*, is reflected by its ion-exchange capacity. Specifically, the cation exchange capacity (CEC) is, to a large extent, related to the amount of soil colloids, organic matter, and clay, which are negatively charged and thus enable the soil to retain cations.

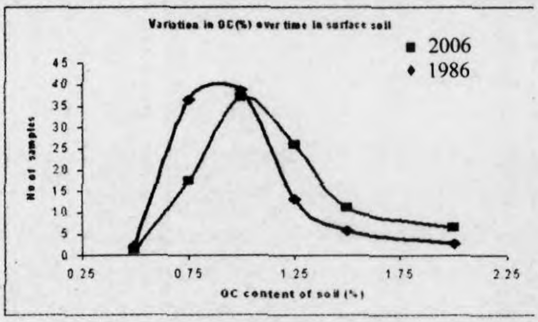


Fig 1. Frequency distribution curve for pH of *rubber soils of Tripura* (0-30 cm)

CEC is mostly governed by the clay content, surface characteristics of the clay and organic matter content of the soil (Gupta and Tripathi, 1992). Changes in pH and salt content also affect the CEC. CEC of rubber soils were on par with other forest plantations but it was significantly higher than the fallow land (Choudhury *et al.*, *2006)*.

Fertility status of rubber soils of Tripura

Most of the rubber soils of Tripura were low to medium in fertility status (Chaudhury *et al.*, 2001). *Hevea* plantations are often considered a *sustainable system which, in some cases, might* even upgrade the level of soil fertility (Gilot *et al.*, 1995). Maintaining soil fertility is an important factor for sustainable agriculture. It was evident from different studies that rubber improves the physio-chemical properties of soil in comparison to the fallow land on par or even better in some of the parameters than other forest species commonly cultivated in the state.

i) Organic Carbon

Soil organic matter (SOM) comprises all living soil organisms and all the remains of previous living organisms in their various degrees of decomposition. Soil carbon is the generic name for carbon held within the soil, primarily in association with its organic content. Soils contain carbon (C) in both organic and inorganic forms. In most soils (with the exception of calcareous soils) the majority of C is held as soil organic carbon (SOC). SOM correlates with a number of important soil parameters viz. physical, *chemical and biological properties of soil. From* a qualitative point of view, SOM influences the physical and chemical properties of soil as well as the availability of nutrients for microbial and plant growth.

Majority of the rubber soils in Tripura were once subjected to shifting cultivation. It has been found by Nye and Greenland (1964) that there is a rapid loss of organic matter in the first year of shifting

Table 1. State-wise soil organic carbon (SOC) store (up to 60cm depth) in the rubber cultivated area of North Eastern region

States	SOC (tonnes / ha)	Area under rubber (as on 2009 - 10)	Total carbon ('000 tonnes)
Tripura	66.4	55415	3679.6
Assam	69.6	28102	1955.9
Manipur	60.0	2723	163.3
Mizoram	89.6	908	81.3
Meghalaya	98.4	9196	904.9
Nagaland	108.0	4141	447.2
Arunachal Pradesh	156.8	1200	188.1
North East (Total)	92.7 (Average)	1011685	93783.1

cultivation cycle in Tripura soils. Organic carbon of soil varied from 0.11 to 1.76% in surface soil (0-30cm) with a mean value of 0.81 and after 20 years of rubber cultivation it varied from 0.32 to 2.8 % with a mean value of 0.96%. Similar trend was observed in the sub-surface soil. Here it initially 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 % after 20 years of rubber cultivation (Mandal *et al.*, 2012).

The distribution curve of surface and subsurface soil showed a positive shift towards higher side of the peak suggesting a building up of OC due to rubber cultivation over the time. This may be attributed to the addition and subsequent decomposition of annual leaf litter to soil floor over the years under mature rubber which ranged from 6.8-7.8 t/ha/yr (Varghese *et al.*, 2001). Rubber being a deciduous plant has a defoliation cycle by which large quantities of litter is added to the soil (Philip *et al.*, 2003). Litter fall under mature plantation can reach values that are nearly as large as for forests. The biomass added to the soil every year by way of leaf litter and cover crop is considerable (Kothandaraman *et al.*, 1989; Krishnakumar *et al.*, 1990) and with very little removal of biomass prior to felling from the plantation improves the soil properties to a large extent.

Cultivation of cover crops in rubber is an essential part for control of soil erosion; this also adds organic matter and mineral nutrient to the soil through natural decay of leaves, stems and roots and also retains soil moisture. Cover crops helps in improvement of soil structure and other physical properties (Soong & Yap, 1976). The most widely used leguminous cover crop in India are *Pueraria phaseoloides* and *Mucuna bracteata* which adds total biomass of 4.61 and 15.63 tonnes/ha respectively at the end of fourth year and increases the organic carbon in both layers (Kothandaraman *et al.*, 1989). *Mucuna bracteata* is the native species of Northeast specific to Tripura.

ii) Available P

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). Over a period of twenty years phosphorus content of soils shifted from 6.79 kg/ha and 4.48 kg/ha in surface and sub-surface layer respectively to 5.6 kg/ha and 4.45 kg/ha (Mandal *et al.*, 2012). Reduction in available P status under rubber soils was also reported early (Philip *et al.*, 1993).

iii) Available K

There is a build up of available K from 105.9 kg/ha and 89.6 kg/ha respectively in both the layers to 136.5 kg/ha and 108.2 over a period of 20 years in the rubber soils of Tripura; the increase was 28.9% in surface soil and 20.7% in sub-surface soil (Mandal *et al.*, 2012). Philip *et al.* (1993) also recorded a rise in available K (26-40%) under rubber soils.

Biological indicators

A wide range of factors affect soil microbial life. Among these factors, plant type, soil type and management regime are the three main factors controlling soil microbial community and diversity. Rhizosphere microbial population has a vital influence on plant growth as it plays a significant role in making soil nutrients available to plants. In rubber plantations, microbial population was higher in the surface layer due to the higher organic matter status in those layers. According to horizontal distribution of bacteria showed maximum activity in the region of higher root concentration and mycorrhizal infection was found higher towards the base of the trees (Deka *et al.*, 1998). Similarly, Mandal *et al.* (2001) also reported higher population density of various groups of soil micro-organisms under rubber. The universal occurrence of vesicular-arbuscular mycorrhiza in feeding roots of *Hevea brasiliensis* has also been reported (Wastie, 1965).

Earthworms in rubber soil

Tree plantation may influence earthworm abundance by altering the physico-chemical properties of soils viz. temperature, moisture regime, pH, soil organic content, litter inputs, etc. (Tian *et al.*,2000). Mature rubber plantation does not undergo any major tillage operations and thereby earthworms thrive better. Survey of earthworm species in rubber plantations of Tripura revealed the presence of atleast 20 species of earthworms belonging to 10 genera and 5 families (Choudhuri *et al.*, 2008). *Hevea* agro-ecosystem is largely dominated by endogeic earthworm species as indicated by their total biomass value (> 85% of earthworms communities). Epigeic species form minor component of earthworm communities in rubber plantation. Concentration of earthworms in the top soil is due to horizontal distribution of *Hevea* roots and slowly decomposing *Hevea* litter on the plantation floor that reflect better aerobic feeding-cum breeding zone (Chaudhuri *et al.*, 2008). Earthworms contribute to cycling and accumulation of nutrients by casting at the soil surface. The worm casts are considerably higher in soluble nutrient content than those of the original soil. The annual cast production of earthworms in the rubber plantation (24 tonnes/ ha) was higher than that in the mixed forest. (21.3 tonnes/ ha) (Chaudhuri *et al.*, 2009).

Apart from that earthworm burrows improves water infiltration and soil aeration to a large extent. Earthworm tunneling can increase the rate of water entry into the ground 4 to 10 times higher than fields that lack worm tunnels (Sullivan, 2001). This reduces water runoff, recharges groundwater and helps store more soil water for dry spells. Vertical earthworm burrows pipe air deeper into the soil, stimulating microbial nutrient cycling at those deeper levels. Tillage done by earthworms can replace some expensive tillage work done by machinery. A good population of earthworms can process 20,000 pounds of topsoil per year, with turnover rates as high as 200 tons per acre having been reported in some exceptional cases (Sethuraman and Naidu, 2008).

The annual litter fall in rubber plantation is about 7 tonnes/ha (Jacob, 2000). Moreover, rubber wood industry can produce 70,000 tonne sawdust (Mathew *et al.*, 2000). Both these rubber leaf litter and wood saw dust are good substrates for vermiculture (Pal and Dey, 2006).

Soil Carbon sequestration potential

In India, soil carbon has fallen below the critical level of 0.50 per cent in many locations, rendering the soil fragile, poor in buffering capacity and resilience against biotic or abiotic stress (Mandal and Pal, 2011). 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 time. According to

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Mandal *et al.* (2012), 88.7 mt C/ha is available under rubber soils of Tripura. An average carbon store in rubber plantation is around 136 tonnes/ha, out of which 92.7 t C/ha is contributed by soil in Northeast region (Dey, 2005). Mean annual carbon sequestration during 21 year period is around 7.83 t/ha/year in Kerala (Jacob and Mathew, 2004).

Conclusion

There is a need for a holistic consideration of soil health approaches that integrate biological, chemical and physical strategies to achieve soils supporting a sustainable system. Comparative studies have shown that rubber plantations have a green image and are inherently environment friendly and can increase both SOM accumulation and microbial activity. It has influenced favorably in moderating the deleterious effect of jhumming by improving soil health and species diversity. Moreover, the organic C lost during intensive agriculture could be regained through sustainable management practices. Over the years, rubber has established itself as a symbol of ecological prosperity and a potential crop for sustainable farming in this region.

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