Indian J. Nat. Rubb. Res. 4(2) 134-141, 1991

ECOLOGICAL IMPACT OF RUBBER *(HEVEA BRASILIENSIS)* PLANTATIONS IN NORTH EAST INDIA:

2. SOIL PROPERTIES AND BIOMASS RECYCLING

A. K. Krishnakumar, Chandra Gupta, R. R. Sinha, M. R. Sethuraj, S. N. Potty, Thomas Eappen and Krishna Das

Krishna Kumar, A. K., Chandra Gupta, Sinha, R.R., Sethuraj, M. R., Potty, S. N., Thomas Eappen and Krishna Das (1991). Ecological impact of rubber (*Hevea brasiliensis*) plantations in North East India: 2. Soil properties and biomass recycling. Indian J. Nat. Rubb. Res. 4(2): 134–141.

Influence of rubber and teak plantations and natural forest on soil properties, nutrient enrichment, under-storey vegetation and biomass recycling has been studied in the Siliguri sub-division (Darjeeling district) of West Bengal. The study indicates that rubber, teak and natural forest had comparatively high input of organic carbon enriching the soil. Teak had the highest organic matter content in the surface layers. However, the depletion of organic carbon with depth was the highest for teak and the least for natural forest, depletion pattern for rubber being close to that of natural forest. The water retention characteristics showed that soil under rubber had the highest volumetric water content at field capacity (–0.033 MPa) and also at -1.5 MPa. The results suggest that the depletion of sub-surface soil moisture would be less under rubber than teak. The soils under teak showed a higher calcium content in the surface layers. The distribution of available nutrients otherwise did not show much variation in the soils under rubber, teak and natural forest.

Biomass and floor accumulation revealed luxurient under-storey vegetation under all the three conditions. The data on floor accumulation showed that litter accumulation under rubber was lower than that of teak and natural forest which could be attributed to a faster rate of decomposition under a higher moisture regime and higher available nutrient. The study establishes ecological desirability of rubber in terms of habitat diversity, soil physical properties and nutrient recycling.

Key words:- Ecological impact, Rubber plantation, Soil properties, Biomass, North East India.

A. K. Krishnakumar, (for correspondence) and Thomas Eappen, Rubber Research Institute of India, Regional Research Station, Agartala-799 006, India; Chandra Gupta, R. R. Sinha and Krishna Das, Rubber Research Institute of India, Regional Research Station, Gawahati-781 003, India and M. R. Sethuraj and S. N. Potty, Rubber Research Institute of India, Kottayam–686 009, India.

INTRODUCTION

Ecological implications of plantation forestry in the tropics in general and that of rubber in particular have been studied only to a limited extent. Though rubber cultivation had been traditionally confined to the southern districts in India, the crop has been extended to non-traditional regions during the last two decades and the north-eastern zone is regarded as one of the important areas. Raising forestry plantations is one of the methods adopted to recuperate the fragile ecology resultant of denudation of forests for various purposes, including shifting cultivation, in the north-eastern region.

An earlier report (Krishnakumar *et al.*, 1990) has indicated the beneficial effect of rubber plantations in this region in improving the soil physical properties. Voluminous literature is available on the comparison of the eco-systems under various plantations with natural forest (Evans, 1982). However, studies on comparison of rubber plantations with other forestry plantations or with natural forests are sparse (Aweto, 1987). *Hevea* is an introduction from the Amazon rain forests and the tree has all the attributes of a forestry species. Rubber plantations, though of mono-species, cannot be regarded as totally unnatural as even within the most untouched natural forests localised species dominance is observed (Brunig *et al.*, 1978). Nevertheless, a wide range of species of plants are observed to grow under rubber also (Mukherjee, 1988 and Vijayakumar *et al.*, 1989).

A comparison of soil physical properties distribution of available nutrients, density and species multiplicity of understorey vegetation, litter accumulation and nutrient recycling in rubber and teak plantations and natural forest has been attempted in the present study.

MATERIALS AND METHODS

A site located about 50 km from Siliguri (26°38'N; 88°19' E) in Darjeeling district of West Bengal was chosen for the study. The area receives a mean annual rainfall of 3000 mm and the soils belong to the order Alfisols (Table 1).

For species identification and litter collection twelve 1 x 1 m quadrats each were randomly demarcated in an area of about 1 ha inside rubber and teak plantations and natural forest. Observations were taken just prior to the wintering period. Monocots and dicots were enumerated and their biomass determined after oven drying of the samples at 70°C to constant mass.

Floor accumulation was collected together and the litter components were not separated. The litter was washed, oven dried at 70°C, powdered and analysed for N, P, K, Ca and Mg (Jackson, 1973). The monocots and dicots were also similarly processed and analysed.

Soil samples were collected from the sample plots, after removal of biomass and litter, at 0–15, 15–30 and 30–60 cm depths, air dried, sieved through 2 m mesh and analysed for organic carbon, available phosphorus, potassium, calcium and magnesium (Jackson, 1973). Soil colour was recorded using Munsell's colour chart (Munsell, 1975). The bulk density and particle density were determined from core samples as per the method described by Black (1965). Total porosity was calculated from the formula:

$$St = 100\ (1 - Db/p)$$

where St is the total porosity, p the particle density and Db the bulk density. Particle size distribution was determined by the

Table 1. **Site details**

Vegetation	Elevation (m msl)	Other details
Rubber (*Hevea brasiliensis*)	300	10 to 12 years old, mixed clones; no tapping; grown under natural forest conditions with no regular agromanagement practices; density 350–400 trees/ha.
Teak (*Tectona grandis*)	280	Plantation with full natural cover ; density approximately 1000 trees/ha.
Natural forest	290	Fully covered with natural cover.

international pipette method (Piper, 1950). Soil moisture retention characters were studied using pressure plate apparatus with disturbed sample (Richaıds, 1949) and the available water storage capacity (AWSC) was calculated from the formula:

$$\underset{(mn\,/\,n)}{AWSC} = Db \times \left[\frac{\left(\begin{matrix}\text{Moisture\% at}\\ -0.033\ \text{Mpa}\end{matrix}\right) - \left(\begin{matrix}\text{Moisture\% at}\\ -1.5\ \text{Mpa}\end{matrix}\right)}{100}\right] \times 10 \times 100$$

where, Db refers to bulk density, 10 is for conversion to mm and 100 is for conversion to mm and 100 is for conversion to mm/m.

Simple correlation and 't' tests were worked out to establish inter relation of the various parameters (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

The particle size distribution of soils are summarised in Table 2. The textural classification of soils under rubber and teak was sandy loam for all the three layers whereas for natural forest it was sandy clay loam for the 0–15 and 30–60 cm layers and sandy loam for the 15–30 cm layer. The data points to a more or less homogenous soil type with respect to texture in all the three sites.

An evaluation of the physical properties (Table 3) under the three situations showed that the bulk density increased with the depth in all the cases. The porosity decreased and the particle density increased in general with the depth. However, in soils under rubber, particle density decreased slightly with depth. There was a negative correlation between the bulk density and porosity (r = –0.99). The field bulk density was the highest in soils under teak (1.84 g/cc) and the least in rubber (1.71 g/cc) indicating a higher compaction in the soils under teak. The porosity was the highest in the soils under rubber. The lower compaction in the surface layer can be attributed to higher root density at the surface which moderates the structure. In natural forest, the bulk, density was less than that of soil under teak. Hardening of soils under teak has been reported by Bell (1973).

Table 2. **Colour and particle size distribution of soil**

Vegetation	Depth (cm)	Colour		Particle size distribution(%)				Textural classification
		Moist	Dry	Coarse sand	Fine sand	Silt	Clay	
Rubber	0–15	10YR 3/1	10YR 4/2	37.43	21.60	21.24	19.73	Sandy loam
	15–30	10YR 2/2	10YR 4/3	41.51	25.08	21.80	11.61	Sandy loam
	30–60	10YR 3/1	10YR 5/3	44.52	20.08	20.28	15.12	Sandy loam
Teak	0–15	10YR 3/1	10YR 4/2	40.76	23.66	19.64	15.94	Sandy loam
	15–30	10YR 2/1	10YR 4/2	44.53	22.25	13.68	19.54	Sandy loam
	30–60	10YR 2/2	10YR 4/3	48.05	20.59	10.00	21.36	Sandy loam
Natural forest	0–15	10YR 3/1	10YR 3/3	39.05	22.12	9.78	29.05	Sandy clay loam
	15–30	10YR 3/2	10YR 4/2	38.38	12.41	26.39	22.82	Sandy loam
	30–60	10YR 3/2	10YR 4/3	46.08	20.15	8.91	24.86	Sandy clay loam

Studies on water retention characteristics reveal that soil under rubber retains the highest percentage of moisture at field capacity (–0.033 MPa). Though there was a concomittant increase in the moisture retained at –1.5 MPa (wilting point), volumetric water content was the highest for soils under rubber followed by natural forests and then teak (Table 4). This can be attributed to the soil type and the structural characteristics of soils under rubber. The higher water retention reduces surface run-off and consequently checks erosion. It indicates higher moisture availability for the sustanance of the trees and the under-storey vegetation during dry period.

Table 3. **Organic carbon content and some physical properties of soil**

Vegetation	Depth (cm)	Organic carbon (%)	Bulk density (g cm^{-3})	Particle density (g cm^{-3})	Porosity (%)
Rubber	0–15	2.93	1.33	2.56	48.05
	15–30	2.39	1.43	2.55	43.92
	30–60	2.13	1.44	2.54	43.31
Teak	0–15	3.74	1.15	2.37	51.47
	15–30	2.34	1.32	2.44	45.90
	30–60	1.74	1.37	2.46	44.30
Natural forest	0.15	2.64	1.39	2.43	42.79
	15–30	1.91	1.41	2.54	44.48
	30–60	1.81	1.47	2.59	43.24

Table 4. **Available water storage capacity of soils**

Vegetation	Depth (cm)	Soil water potential (%)		Available water storage (Volumetric water content mm m^{-1})
		–0.033 MPa	–1.5 MPa	
Rubber	0–15	25.54	9.82	209.08
	15–30	22.13	11.00	159.16
	30–60	19.44	8.33	159.98
Teak	0–15	23.10	8.50	167.90
	15–30	17.92	7.30	140.18
	30–60	15.45	6.71	119.74
Natural forest	0–15	22.11	9.23	179.03
	15–30	18.84	9.09	137.47
	30–60	18.44	10.27	120.09

The organic carbon content (Table 3) in the surface layers was the highest for teak (3.74%) followed by rubber (2.93%) and natural forest (2.64%). Distribution of organic carbon showed a declining trend with depth in all the three situations. Brown and Lugo (1990) reported that carbon content in soils under mature wet forests declined fairly rapidly with depth in the top 40 cm, beyond which there was no change. The distribution of organic carbon in the soil under rubber showed a drop of 10.88 per cent from the 15–30 cm to 30–60 cm layer and in soil under natural forest the variation within the corresponding sample layers was 5.24 per cent. However, in the soil under teak the variation was 25.64 per cent. The data suggest that the rate of decline of organic carbon with depth had been the least in the soil under natural forest closely followed by rubber. The higher organic carbon in the lower profiles of rubber soil may be due to higher transportation of humus.

The statistical analysis of data on organic carbon for the various layers shows that there was no significant difference between rubber and teak in terms of content of organic carbon. However, the organic carbon content at the 15–30 cm layer was significantly higher (P = 0.05; SE = 0.148) for rubber than natural forest. Teak had significantly higher organic carbon content compared to natural forest for the top two layers.

The data on distribution of available nutrients are given in Table 5. The data revealed no significant difference in general in the content of available nutrients between rubber, teak and natural forest. There was a surface enrichment of nutrients in general in all the situations. The 30–60 cm layer soil from natural forest had significantly higher available potassium content than teak while it was on par with that under rubber. The soil under teak, however, had significantly higher calcium content in the surface layer when compared to that of natural forest and rubber (P=0.05). However, in the sub-surface layers the calcium content in the teak plantation differed drastically and soils under both natural forest and rubber had significantly higher calcium content than that under

Table 5. **Distribution of available nutrients and pH**

Vegetation	Depth (cm)	Nutrients in soil, kg ha-1				Soil pH (H_2O) (1:2.5)
		P	K	Ca	Mg	
Rubber	0–15	3.4	120.8	388.8	117.6	4.34
	15–30	1.0	91.2	225.6	107.0	4.30
	30–60	1.2	78.8	182.4	93.4	4.33
Teak	0–15	2.6	106.0	648.0	102.0	4.40
	15–30	2.2	84.6	269.4	76.2	4.34
	30–60	0.4	52.0	100.0	65.6	4.39
Natural forest	0–15	5.6	140.0	413.4	108.6	4.39
	15–30	1.6	112.6	233.2	81.8	4.35
	30–60	0.2	80.0	161.4	106.2	4.33

Table 6. **Percentage decline in available nutrients with depth**

Vegetation	Depth of soil (cm)	% of carbon	P	K	Ca	Mg
Rubber	0–15 to 15–30	18.43	70.58	24.50	41.97	9.01
	15–30 to 30–60	10.88	-20.00*	13.60	19.15	12.71
Teak	0–15 to 15–30	37.43	15.38	20.20	58.43	25.30
	15–30 to 30–60	25.64	81.80	38.50	62.88	13.91
Natural forest	0–15 to 15–30	27.65	71.40	19.57	43.60	24.68
	15–30 to 30–60	5.24	87.50	28.95	30.79	-29.83*

* Increase

teak. The extent of variation of available nutrients between layers was minimum for natural forest and maximum for teak. The decrease in percentage of available nutrients depth-wise is given in Table 6. The enrichment of nutrients in the surface layers could be attributed to the higher litter fall observed in teak plantations and also lower absorption and recycling of nutrients due to lower content of feeder roots in the surface layers when compared to natural forest and rubber. The litter composition of teak also might have contributed to a higher calcium concentration. It has to be mentioned here that stand per hectare of teak was much higher (around 1000 ha^{-1} as compared to 350–400 for rubber).

The data on under-storey biomass and floor accumulation are given in Table 7.

Table 7. **Biomass and nutrient content of under-storey vegetation and floor accumulation**

Vegetation	Under-storey vegetation/litter	Biomass (kg ha^{-1})	Nutrients (kg ha^{-1}) N	P	K	Ca	Mg	Total nutrients (kg ha^{-1})
Rubber	Monocot	124.1	2.98	0.27	2.09	0.66	0.35	6.34
	Dicot	1417.4	38.13	3.69	25.80	22.68	7.23	97.57
	Litter	3544.2	65.21	10.28	17.37	22.68	16.30	131.84
	Total	5085.7	106.32	14.24	45.25	46.02	23.88	235.70
Teak	Monocot	73.1	1.68	0.11	1.09	0.26	0.26	3.41
	Dicot	1544.4	43.40	2.32	23.17	25.95	7.72	102.55
	Litter	5421.7	111.69	15.18	35.24	19.52	35.78	217.41
	Total	7039.2	156.77	17.61	59.50	45.73	43.77	3[illegible].36
Natural forest	Monocot	85.7	2.16	0.14	2.74	0.59	0.43	6.06
	Dicot	1063.2	26.26	1.38	16.91	13.29	3.94	61.77
	Litter	5235.3	98.95	5.76	32.46	39.79	31.94	208.89
	Total	6384.21	127.37	7.28	52.11	53.67	36.31	276.72

The data suggest a luxurient under-storey vegetation in all the systems. The vegetation consisted of both monocots and dicots and the species multiplicity was more under rubber. Twelve species of plants could be identified (9 dicots and 3 monocots) under rubber, whereas under teak and natural forest six species of dicots and one species of monocots each only could be found. The data on biomass of under-storey vegetation revealed that monocot biomass was the highest under rubber followed by natural forest and then teak. Teak had the highest dicots biomass followed by rubber and the lowest for natural forest (Table 7). The population of monocots was higher in rubber plantations.

The floor accumulation is contributed by leaves of the trees, under-storey vegetation, twigs, wooden particles, flowers and fruits. Rodin and Bazilerich (1967) have reported a floor accumulation of 5000 kg ha^{-1} in the sub-tropical forests. The data obtained in this study are in conformity with the above study. Litter accumulation is dependent upon factors such as the rate of decomposition which again is decided by the nutrient content of litter, moisture content of soil and also the nutrient recycling character of the species. Litter accumulation under rubber has been found to be lower than that of teak or natural forest. This could be attributed to a faster rate of decomposition under a higher moisture regime and a higher content of P, K and Mg, than teak.

The data suggest that from the micro-ecological point of view rubber is comparable with teak. Though rubber and teak plantations might differ in terms of habitat diversity when compared with natural forests, rubber plantations can very well be compared with teak plantations. In terms of the positive influence on the soil physical properties, nutrient recycling and species diversity of the under-storey vegetation, rubber can be considered a desirable candidate for the region with necessary ecological attributes.

REFERENCES

Aweto, A. O. (1987). Physical and nutrient status of soils under rubber (*Hevea brasiliensis*) of different ages in South Western Nigeria. *Agricultural Systems*, **28**: 63–72.

Bell, I. I. W. (1973). Erosion in the Trinidad teak plantations. *Commonwealth Forest Review*, **52**: 223–233.

Black, C. A. (1965). Methods of soil analysis. Part I. American Society of Agronomy, U.S.A.

Brown, S. and Lugo, A. E. (1990). Tropical secondary forests. *Journal of Tropical Ecology*, **56**: 1–32.

Brunig, E. F., Heuveldop, J. and Schneidar, T. W. (1978). Dependence of productivity and stability on structure in natural and modified ecosystems in the tropical rain forest zone: Preliminary conclusion from the MAB-pilot project at San Carlos de Rio Negro for the design of optimal agro-silvicultural and silvicultural systems. *Proceedings of 8th World Forestry Congress*, 1978, Jakarta, FFF/7–15.

Evans, Julian (1982). Plantation forestry in the tropics. Oxford Science Publication, Clarendon Press, Oxford.

Jackson, M. L. (1973). Soil chemical analysis. Prentice Hall of India (P) Ltd., New Delhi.

Krishnakumar, A. K., Thomas Eappen, Nageswara Rao, Potty, S. N. and Sethuraj, M. R. (1990). Ecological impact of rubber (*Hevea brasiliensis*) plantations in North East India : 1. Influence of soil physical properties with a special reference to moisture retention. *Indian Journal of Natural Rubber Research*, **3**(1): 53–63.

Mukherjee, T. K. (1988). Integration of local and crossbred goats in a rubber and a coconut plantation. *Wallaceana*, **149** (52–53): 1–7.

Munsell (1975). Munsell's colour charts. Macheth Division of Kollmorgah Corporation, 2441 North Calvert Street, Baltimore, Maryland, 21218, USA.

Piper, C. S. (1950). Soil and plant analysis. University of Adelaide, Adelaide.

Richards, L. A. (1949). Methods of measuring soil moisture tension. *Soil Science*, **68**: 95–112.

Rodin, L. E. and Bazilerich, N. I. (1967). In: *Production and Mineral Cycling in Terrestrial Vegetation*. (Transl. Ed. G. E. Goff). Oliver and Boyd, Edinburgh, 228 p.

Snedecor, G. W. and Cochran, W. G. (1967). Statistical methods. Ed. 6. Oxford and IBH Publishing Co., Calcutta.

Vijayakumar, K. R., Rao, P. S. and Sethuraj, M. R. (1989). Natural rubber : A commercially important forest species. *Rubber Board Bulletin*, **24** (3): 21–23.