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ECOLOGICAL IMPACT OF RUBBER *(HEVEA BRASILIENSIS)* PLANTATIONS IN NORTH EAST INDIA. 1. INFLUENCE ON SOIL PHYSICAL PROPERTIES WITH SPECIAL REFERENCE TO MOISTURE RETENTION

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An attempt is made to quantify the influence of rubber plantation on soil physical properties with special reference to moisture retention. It was observed that rubber plantations, adopting proper agro-management practices, helped in the enrichment of organic matter which consequently improved physical properties such as bulk density, soil porosity, moisture retention and infiltration. An increase in organic matter in the surface layer was recorded. Moisture retained at field capacity (–0.033 MPa) was higher by 5.45 per cent. A higher available water storage capacity (AWSC) was also recorded in the samples from plantation. The moisture desorption pattern showed that at –0.5 MPa 90.34 per cent of the available moisture was desorbed from surface soils from the rubber plantation whereas from outside the plantation in the same layer only 67.38 per cent was desorbed. Infiltration studies revealed that flow rates initially and after attaining steady state were respectively 67.5 and 138 per cent higher inside the plantation, compared to the field subjected to shifting cultivation. A preliminary study conducted to compare the other forestry species on their influence on soil moisture retention also has been presented.

Key words - Hevea brasiliensis, Ecology, Rubber plantation, Shifting cultivation, Soil physical properties, Moisture retention, Field capacity, Organic matter enrichment, Infiltration rate.

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INTRODUCTION

North Eastern region presents a fragile ecological system which is the outcome of indiscriminate felling of trees mainly for the traditional shifting system of cultivation, locally known as 'jhumming'. When jhumming was practised with hardly any pressure on land, the damage caused to the environment was minimum since the time lag between successive jhummings had been long enough for the re-establishment of a luxuriant vegetation.

As the practice of jhumming involves a slash and burn prior to the undertaking of cultivation, it leads to destruction of organic matter which is further aggravated by increase in the rate of decomposition due to high microbial activity and the consequent loss of soil structure (Woodmasee and Wallah, 1981). When burning is frequent woody vegetation hardly become established since fire destroys seedlings, encouraging grasses to establish (Jordan, 1985). The worst affected natural resource, as a result of shifting cultivation, is the soil, particularly in its physical properties. Burning of organic debris is reported to reduce the water intake capacity of the soil, due to deposition of aliphatic hydrocarbons which are hydrophobic substances and also moisture retention (Woodmasee and Wallah, 1981). This increases surface run off and results in increased erosion.

Most of the plantations in North Eastern region, particularly in the private sector, are raised on tilla lands (hillocks) earlier subjected to shifting cultivation. *Hevea* is a deciduous forest tree and the plantation management practices adopt a near zero tillage system with raising of luxuriant leguminous ground cover crop. The biomass added to the soil every year by way of leaf litter and cover crop is considerable (Kothandaraman *et al.*, 1989; Krishnakumar, 1990) and with very little removal of biomass from the plantation improves the soil properties to a great extent. It has been estimated that loss of soil through erosion in a forest with closed canopy is only about 100 kg ha^{-1} (Megahan, 1972). *Hevea* has a closed canopy which helps to conserve the soil by reducing soil erosion. The micro-climate in the plantation also gets moderated reducing diurnal fluctuations.

Though some studies were attempted to compare the influence of rubber plantations established on newly cleared forests on soil properties with that of a forest (Aweto, 1987), no report is available on the influence of rubber plantation on soil physical properties in areas once subjected to shifting cultivation. The present study is aimed at quantifying the influence of rubber plantations on improving the soil physical properties in areas subjected to shifting cultivation in Tripura.

MATERIALS AND METHODS

Profiles were excavated to represent each site and samples were collected from the plantations and also from adjacent fields, earlier subjected to shifting cultivation from the three districts of Tripura (Table 1).

One profile each was also excavated in areas under sal (*Shorea robusta*) and acacia (*A. auriculiformis*). The samples were collected upto a depth of 120 cm. Undisturbed core samples were collected for determination of bulk density. The samples were sieved through 2 mm sieve and were stored, for laboratory analysis. Soil colour was recorded using Munsell's colour chart (Munsell, 1975). Organic carbon was determined by Walkley and Black's method as described by Jackson (1973). Bulk density and particle density were determined as per the method described by Black (1965). Total porosity was calculated from the formula:

$$S_t = 100\ (1 - D_{b/p})$$

where S_t is the total porosity, p the particle density and D_b the bulk density. Particle size distribution were determined by the international pipette method (Piper, 1950). Soil moisture retention characters were studied using a pressure plate apparatus with disturbed samples (Richards, 1949) and available water storage capacity (AWSC) was calculated from:

$$AWSC = \frac{\text{Moisture \% at } -0.033 \text{ MPa} - \text{Moisture\% at } -1.5 \text{ MPa}}{100} \times BD \times 10$$

where BD refers to bulk density and 10 is for conversion to mm. The rate of infiltration was measured by the method described by Dakshinamurthi and Gupta (1968). Simple correlation was worked out to establish inter relation of the various parameters (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

Physical properties of the soil under rubber plantation and that of soil from outside the plantation are given in Tables 2 and 3. The organic carbon content showed a marked increase inside the plantation in all the three sites, compared to that under areas subjected to shifting cultivation, the difference being maximum in the surface layers. As depth increased, the difference narrowed down. In the profile from South Tripura, the organic carbon content increased by 65 per cent in the surface layer (0–15 cm) and by 14.5 per cent in the 15–30 cm layer. Similarly, the enrichment of organic carbon was 29.52 per cent more in the surface layer of the samples from North Tripura. It is to be mentioned that in North Tripura even the jhum cultivated field was reasonably covered with vegetation. The increase in organic carbon content in West Tripura soils was 25 per cent in the surface layer.

Though the plantations in West and North Tripura were older, soil organic matter enrichment was not to the extent as that recorded in plantations of South Tripura which was only 10 years of age. This can mainly be attributed to the management practices. The earlier plantations, like those in North and West Tripura, were brought up under natural cover whereas the plantation in South Tripura was established in association with leguminous ground cover (*Peuraria phaseoloides*). In general, bulk density showed an increase with depth and the particle density distribution did not show any definite pattern. The bulk density of surface layers was lower in soils from plantations at two sites. Porosity distribution did not show any definite trend, although the values in the surface layers were the highest in most cases. Comparing the porosity of the surface layers from within and outside the plantation, the highest was recorded in the samples from within the plantation in all the profiles. The texture of the soils ranged from sandy clay loam to clay. The distribution of clay showed an increase with depth and this could be due to clay migration.

Moisture retention characteristics of the profiles from inside the plantation and from the sites subjected shifting cultivation are illustrated in Figure. 1. The data on available water storage capacity are summarised in Table 4. It is noted that the moisture retained at -0.033 MPa in the surface layer (0–15 cm) was 1.76 and 5.45 per cent higher respectively in the profiles from plantations of South Tripura and North Tripura, compared to the corresponding sites earlier under shifting cultivation. Similarly, the moisture retained at -1.5 MPa (wilting point) also was higher in the samples of profiles from inside the plantations. The AWSC of the profiles was highest in the profiles from within the plantation in two of the three sites. The profile from South Tripura indicated a lower AWSC which is the result of a concomitant increase of moisture at -1.5 MPa. However, the retention of water in this site at -0.033 MPa in samples from within the plantation was higher by 4 per cent in the surface layer and 3.42 per cent in the 15–30 cm layer than the corresponding field under shifting cultivation. The influence exerted by rubber plantation on water storage and retention at different tensions has been manifested upto 120 cm depth also. Studies indicate that moisture retained at -0.033 MPa is positively and significantly

Table 1. **Site details of profiles**

Profile No.	Location	Site details	
1(1)	South Tripura	Kulasimukh	— 10 year old rubber of TFDPC
1(0)	South Tripura	Kulasimukh	— Barren field, with scanty vegetation, once subjected to shifting cultivation.
2(1)	North Tripura	Manu	— 27 year old rubber plantation of TFDPC.
2(0)	North Tripura	Manu	— Field, with full of natural cover, once subjected to shifting cultivation.
3(1)	West Tripura	Pathalia	— 21 year old rubber of TFD-PC.
3(0)	West Tripura	Pathalia	— Barren field, with scanty vegetation, once subjected to shifting cultivation.

Table 2. **Comparison of soil physical properties in areas subjected to shifting cultivation and rubber plantations**

Profile	Depth (cm)	Organic carbon (%)		Bulk density (g/cm^3)		Particle density (g/cm^3)		Porosity (%)	
		0	I	0	I	0	I	0	I
I	0–15	0.86	1.42	1.28	1.18	2.61	2.48	50.95	52.42
	15–30	0.62	0.71	1.27	1.25	2.59	2.49	50.96	49.80
	30–60	0.46	0.56	1.35	1.16	2.60	2.57	48.07	54.87
	60–90	0.34	0.46	1.34	1.33	2.56	2.63	47.65	49.43
	90–120	0.31	0.46	1.58	1.32	2.64	2.56	40.15	49.40
II	0–15	1.05	1.36	1.31	1.21	2.57	2.60	49.02	53.46
	15–30	0.78	0.93	1.29	1.30	2.50	2.49	48.40	47.80
	30–60	0.84	0.78	1.23	1.28	2.55	2.66	51.76	51.88
	60–90	0.99	0.54	1.26	1.30	2.42	2.47	46.69	47.37
	90–120	0.66	0.39	1.19	1.35	2.56	2.48	53.51	45.57
III	0–15	1.12	1.40	1.22	1.28	2.55	2.46	52.15	47.97
	15–30	0.63	0.73	1.36	1.46	2.64	2.51	48.48	41.83
	30–60	0.58	0.52	1.31	1.61	2.57	2.58	49.02	37.60
	60–90	0.34	0.33	1.34	1.51	2.57	2.59	47.85	41.70
	90–120	0.32	0.32	1.44	1.55	2.59	2.60	44.40	40.38

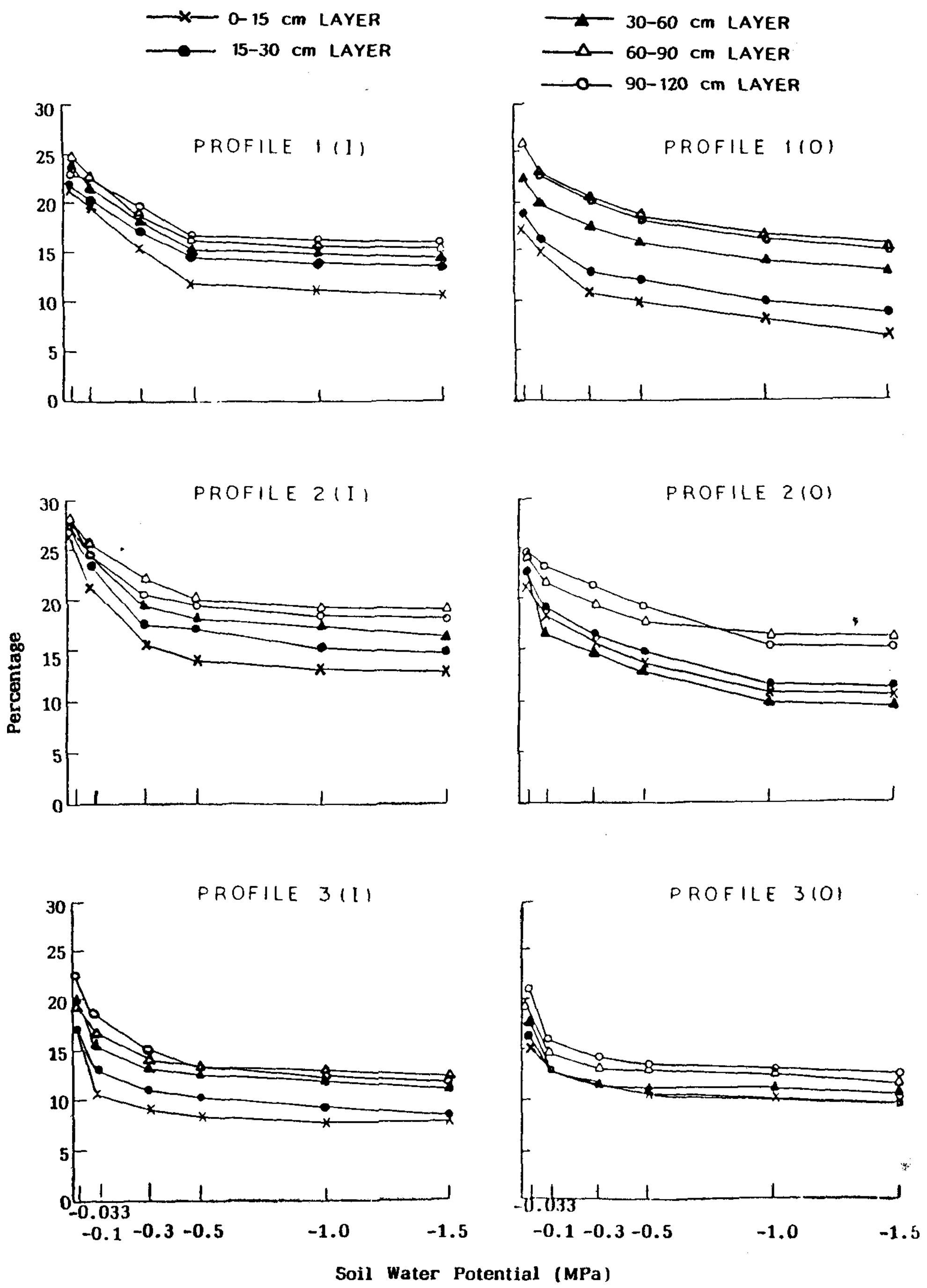

Fig. 1. Soil moisture retention characteristics

Table 3. **Colour and mechanical composition of soils under plantation and in field subjected to shifting cultivation**

Pro-file	Depth (cm)	Inside plantation							Outside plantation						
		Colour		Mechanical separates				Texture	Colour		Mechanical separates				Texture
		Moist	Dry	Coarse sand	Fine sand	Silt	Clay		Moist	Dry	Coarse sand	Fine sand	Silt	Clay	
I	0–15	10 YR 4/3	10 YR 5/4	14.6	27.5	26.1	31.8	Clay loam	10 YR 3/3	10 YR 5/3	14.60	27.50	26.10	31.80	Clay loam
	15–30	10 YR 4/5	10 YR 6/4	11.5	25.7	28.4	34.4	Clay loam	10 YR 4/4	10 YR 5/4	11.50	25.70	28.40	34.40	Clay
	30–60	10 YR 6/6	7.5 YR 4/6	8.7	34.9	16.0	40.4	Clay loam	7.5 YR 5/8	10 YR 6/8	8.71	31.20	20.00	40.00	Clay
	60–90	7.5 YR 6/6	7.5 YR 4/4	10.8	27.2	19.0	43.0	Clay	7.5 YR 5/8	7.5 YR 5/6	7.10	26.30	22.30	44.30	Clay
	90–120	10 YR 6/6	7.5 YR 6/8	10.1	25.8	19.8	44.3	Clay	5 YR 5/6	7.5 YR 5/6	8.80	29.30	15.80	46.10	Clay
II	0–15	10 YR 3/4	10 YR 5/3	15.2	32.3	23.7	28.8	Sandy clay loam	7.5 YR 4/4	10 YR 5/4	22.20	24.00	20.10	33.70	Sandy clay loam
	15–30	10 YR 4/6	10 YR 4/6	16.7	25.1	21.2	37.0	Clay loam	7.5 YR 4/4	10 YR 5/3	19.40	20.50	27.90	32.20	Clay loam
	30–60	7.5 YR 5/8	7.5 YR 7/8	15.1	19.7	20.0	45.2	Clay	7.5 YR 4/4	10 YR 5/3	22.00	28.50	16.10	33.40	Sandy clay loam
	60–90	5 YR 4/6 (7.5 YR 4/6)	7.5 YR 7/8	18.2	23.0	15.3	43.5	Clay	7.5 YR 4/6	7.5 YR 6/6	14.80	23.00	16.00	46.20	Clay
	90–120	5 YR 5/6	7.5 YR 7/8	19.7	20.0	16.0	44.3	Clay	5 YR 5/8	7.5 YR 5/6	16.60	19.90	10.50	53.00	Clay
III	0–15	10 YR 3/3	10 YR 3/3	38.9	24.6	11.0	25.5	Sandy clay loam	10 YR 4/3	10 YR 6/6	37.00	19.50	16.00	27.50	Sandy clay loam
	5–30	7.5 YR 4/4	7.5 YR 5/4	36.1	21.9	12.5	29.5	,,	7.5 YR 4/4	10 YR 6/6	37.00	12.90	17.60	32.50	,,
	30–60	7.5 YR 5/8	7.5 YR 6/6	24.1	27.9	15.0	33.0	,,	7.5 YR 4/6	7.5 YR 6/6	30.00	20.00	17.50	37.50	,,
	60–90	7.5 YR 5/8	7.5 YR 6/8	28.8	18.5	17.2	35.5	,,	7.5 YR 4/6	7.5 YR 6/8	26.00	16.50	17.50	40.00	Clay loam
	90–120	7.5 YR 5/8	7.5 YR 6/7	40.1	6.9	17.5	35.5	,,	5 YR 5/6	7.5 YR 5/6	25.00	30.00	12.50	32.50	Sandy clay loam

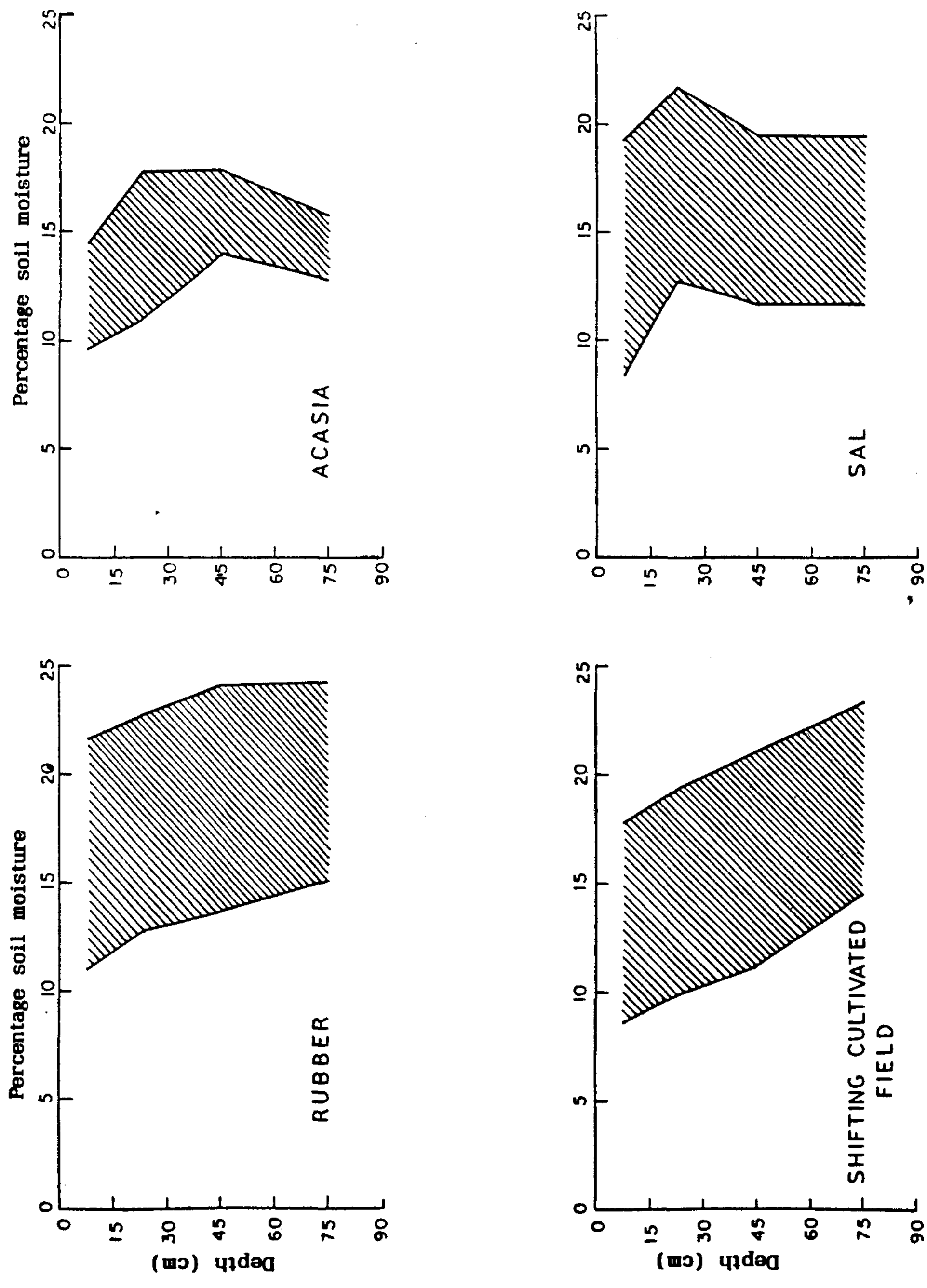

Fig. 3. Available water storage capacity

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

Profile	Depth (cm)	Soil water potential -0.033 MPa	-1.5 MPa	Av. water content mm/m	Profile	Depth (cm)	Soil water potential -0.033 MPa	-1.5 MPa	Av. water content mm/m
1 (I)	0 – 15	21.05	10.69	122.25	1 (0)	0 – 15	17.05	6.26	138.11
	15 – 30	22.14	13.62	106.50		15 – 30	18.72	8.92	124.46
	30 – 60	23.81	14.14	112.17		30 – 60	22.52	12.91	129.74
	60 – 90	24.47	15.07	125.02		60 – 90	26.12	16.15	133.60
	90 –120	22.88	15.65	95.44		90 –120	26.38	15.83	166.69
2 (I)	0 – 15	26.63	12.80	167.34	2 (0)	0 – 15	21.18	10.12	144.89
	15 – 30	28.50	14.89	176.93		15 – 30	23.02	11.20	152.48
	30 – 60	27.84	16.28	147.97		30 – 60	21.75	9.92	123.00
	60 – 90	28.34	19.00	121.42		60 – 90	24.00	16.08	102.17
	90 –120	27.95	18.17	132.03		90 –120	24.67	15.09	112.81
3 (I)	0 – 15	16.83	7.83	115.20	3 (0)	0 – 15	15.07	9.51	67.83
	15 – 30	17.36	8.54	128.77		15 – 30	16.38	9.76	90.03
	30 – 60	20.65	11.24	151.50		30 – 60	18.51	10.55	104.28
	60 – 90	20.00	12.27	116.72		60 – 90	19.97	11.36	115.37
	90 –120	22.57	11.42	172.83		90 –120	20.83	12.63	118.08

Table 5. **Moisture desorption at –0.5 MPa**

Location	Depth (cm)	Percentage moisture desorbed: Inside plantation	Shifting cultivated field
South Tripura	0 – 15	90.00	59.22
	15 – 30	89.31	58.87
	30 – 60	88.41	68.36
	60 – 90	88.40	71.52
	90 –120	85.89	74.59
North Tripura	0 – 15	88.48	66.27
	15 – 30	84.42	68.27
	30 – 60	81.92	74.21
	60 – 90	89.18	79.41
	90 –120	83.12	57.38
West Tripura	0 – 15	92.55	76.79
	15 – 30	79.81	88.51
	30 – 60	86.39	88.94
	60 – 90	87.83	81.18
	90 –120	83.40	93.78

Table 6. **Correlation studies**

		Inside plantation	Shifting cultivated field
Soil moisture	at –1.5 MPa Vs. Clay	0.85**	0.76**
,,	at –0.033 MPa Vs. Clay	0.64**	0.70**
,,	at –1.5 MPa Vs. Organic carbon	–0.42	–0.49*
,,	at –0.033 MPa Vs. Organic carbon	–0.19	0.43
,,	at –1.5 MPa Vs. Bulk density	–0.30	0.54*
,,	at –0.033 MPa Vs. Bulk density	–0.31	0.54*
,,	at –1.5 MPa Vs. Porosity	0.29	–0.39
,,	at –0.033 MPa Vs. Porosity	0.38	–0.46
,,	at –0.033 MPa Vs. Silt	0.28	0.19
Available water	Vs. Clay	–0.18	0.21
,,	Vs. Organic carbon	0.10	–0.06
,,	Vs. Bulk density	0.22	0.69**
,,	Vs. Porosity	–0.24	–0.49*
,,	Vs. Silt	0.02	0.72**
Bulk density	Vs. Clay	–0.09	–0.14
,,	Vs. Organic carbon	–0.44	–0.64**

* Significant at 5 per cent
** Significant at 1 per cent

correlated with clay (Table 6). Similarly moisture retained at –1.5 MPa was also positively correlated with clay for the profiles from inside as well as outside the plantation. Available water was positively correlated with bulk density, the correlation being significant for profiles from outside the plantation. The increase in moisture retention for soils under rubber plantation can be attributed to the nature and content of organic matter and the indirect influence of the organic matter on soil structure by aggregating soil particles (Sanchez, 1976).

The effective feeder root zone of rubber is taken as 60 cm. Analysing the moisture desorption pattern (Table 5) it is seen that at the tension of –0.5 MPa, 90.34 per cent of the available moisture (mean of three sites) is desorbed from the 0–15 cm layer in the plantation. At the same tension, only 67.43 per cent available moisture was desorbed for samples from shifting cultivated fields. For 15–30 cm layer while 84.51 per cent of the available moisture desorbed from samples within the plantation, 71.88 per cent was desorbed from samples from the shifting cultivated fields. The above tension limit has been reported to be of vital importance to moisture availability to *Hevea* (Krishnakumar *et al.*, 1990). The results indicate that the soils under the plantations helped in increasing the moisture storage as well as desorption.

Observations on the rate of infiltration in the ten year old plantation and an adjoining shifting cultivated presently barren field in West Tripura, revealed that both the initial rate of flow as well as the steady flow are more in the soils under rubber plantations. The initial flow rate during the first 15 minutes was 67.5 per cent more than that of field under shifting cultivation and the flow rate after attaining steady state was 138 per cent. This is of high practical significance since the intake of water following rainfall depends on the infiltration rate. As a result of high rate of infiltration, the surface run off and the consequent erosion will be reduced drastically. A marked difference in the cumulative infiltration also has been recorded (Fig. 2).

The AWSC of soils under rubber, sal, acacia and shifting cultivation, for a depth of 75 cm, is illustrated in Figure 3. The moisture retention at -0.033 MPa was the highest for rubber plantation, followed by sal forest. Considering the AWSC sal had the highest water storage in the surface layer followed by rubber and shifting cultivated

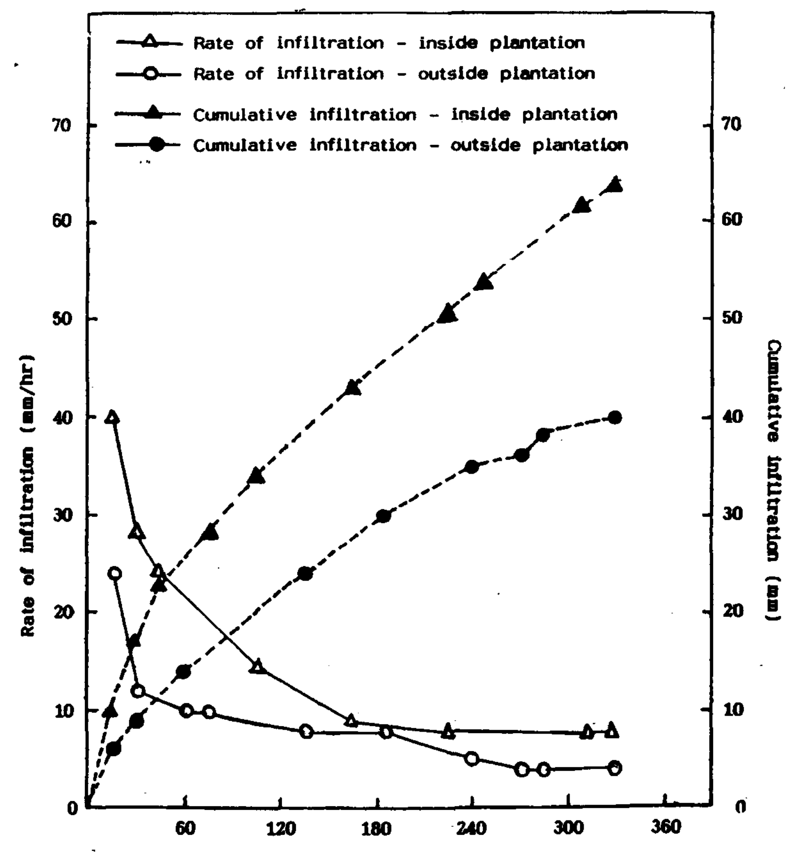

Fig. 2. Infiltration characteristics

field. However, considering 75 cm solum, on the whole rubber was superior even to sal. This comparison however, is only preliminary and further studies are being pursued. It may be mentioned that both sal and acacia are being popularised in Tripura under social forestry.

The studies reveal that rubber cultivation has influenced favourably in moderating the deleterious effect of shifting cultivation by improving the soil physical properties. Enrichment of organic matter, favourable bulk density, increased porosity and resultant increased aeration, higher moisture retention, high rate of infiltration and a highly favourable moisture desorption pattern point to the extreme beneficial factors in recuperating the depredated ecology.

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