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SOIL MANAGEMENT PRACTICES IN RUBBER PLANTATIONS AND THEIR EFFECTS ON THE ENVIRONMENT

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SUMMARY

Rubber plantations were first established in Sri Lanka at the beginning of the century. Since then many individual plantations have undergone three planting cycles of approximately 30 years per cycle without any great adverse effect on the natural environment. In the mean time the commercial yields of rubber have risen from about 250 kg per ha. to the present level of the modern high yielding trees of approximately 1500 kg per ha, a six fold increase. Rubber cultivation involves soil management practices designed to protect the soil from erosion and preserve its fertility. While conservation measures are being pursued to minimize deterioration and thereby maintain the native soil fertility, other agronomic practices simultaneously sustain high crop performance through soil nutrient enrichment. From the time of planting to replanting, the rubber plantations present an environmentally acceptable replacement for the native forest.

INTRODUCTION

Among the terrestrial ecosystems, natural forests sustain the greatest productivity, and most efficient soil and moisture conservation systems, and maintain the highest bio-diversity. Over the last century much of this heritage has been destroyed, along with many of its material benefits. Deforestation for agriculture: arable farming or tree crop plantations, has made soils less productive, water supply more erratic and floods more frequent and severe, all on a serious scale. Over the past decade or so environmental issues have become more important not only in global context but also an area of concern in the rubber cultivation. People have only recently come to realize and appreciate many of the values of areas which are natural or near natural.

Tree crop plantations

From the ecological point of view, cultivation of deep rooting perennial trees is a highly desirable form of land use in the humid tropics compared to rainfed arable farming. Trees not only provide a canopy which reduces the impact of sun and rain upon the soil but they root over a greater depth than annuals, on the whole remove fewer amounts of plant nutrients per unit land area. Long term planting of trees encourages the construction of terraces, control of natural drainage courses and 0permit a permanent ground cover of mixed vegetation under the canopy. The soil conservation measures can be regarded as permanent land improvements which are not carried out in arable farming systems under similar conditions. The aim in tree crop plantation agriculture is to reproduce as far as possible a stable ecological system similar to that provided by the natural forest, with the difference that the tree crop plantation yields a high economic return which the forest does not (Bruning *et al.*, 1978, Arkcoll, 1979).

Rubber plantations

The introduction of the *Hevea* rubber tree to Sri Lanka from its native Amazonian habitat occurred during the late nineteenth century. Surprisingly, the development of rubber plantations also had a sound ecological basis. However, establishment of rubber plantations necessitates the destruction of the natural ecology of the forest. On clearing forests, the soil becomes exposed to high rainfall and temperatures that lead to erosion and leaching (Table 1), (Samarappuli and Yogaratnam, 1994). Rubber planting involves soil management practices designed to protect the soil from erosion and preserve its fertility. While conservation measures are being pursued to minimize deterioration and thereby maintain the native soil fertility, other agronomic practices simultaneously sustain high crop performance through soil nutrient enrichment.

Conservation of soil fertility and productivity through soil management

Contour planting

Both rubber and tea are grown in very steep lands in Sri Lanka where no other agricultural crop could be grown economically. On hilly and steep terrains, rubber is planted on contour lines, with minimum disturbance being effected to the inter-row areas (Table 2). It is well documented that average soil loss in rubber is around 10MT/ha/yr, while the average soil loss in Tea is about 35MT/ha/yr (FSMP, 1995). Eventhough these steep lands contain higher percentage of rocks; tea is not recommended to be planted in more than 20% rockiness (Sivapalan, 1985) compared to rubber which can be grown successfully up to 50% rockiness.

Table 1. *A comparison of erosion and some soil properties between conserved and exposed conditions*

	Erosion* (t/ha)	Run off (liters)	Soil moisture storage capacity (cm)	Organic C (%)	Bulk density (g/cm^3)
Conserved land	3.6	1973	24.3	1.4	1.07
Exposed land	60.9	3701	18.3	0.9	1.58

* Cumulative soil loss in 3 years

Table 2. *A comparison of soil disturbance in rubber and tea cultivation*

Vegetation	No. of exposures to high rains during a 33 year period
Rubber	1 (during replanting)
Tea	1 (during replanting) 8 (pruning cycles)

Drains and stone terraces

Surface soil erosion along the contours is minimized by drains and silt pits, which check the surface runoff during heavy rains. This has also been found to beneficially influence soil nutrient contents, apparently through enhanced soil and moisture conservation (Table 3). On very rocky land, where it is impossible to cut continuous lateral drains, the soil conservation needs are partially satisfied by the construction of stone terraces (Samarappuli, 1983).

Table 3. *Effect of soil conservation by drains with silt pits*

Agronomic practice	Soil nutrients		
	C (%)	N (%)	K (μg/g)
Without drains	1.04	0.08	140
With drains	1.42	0.14	165

Ground cover management

The role of cover crops can be emphasized in preserving the productivity and fertility of soil. The main purpose of cultivating cover crops is to control erosion. The influence of cover crops on soil improvement is also of considerable importance. This is brought about by the addition of organic matter and mineral nutrients to the soil through the natural decaying of leaves, stems and roots (Yogaratnam *et al.*, 1977, Yogaratnam *et al.*, 1984a). It is well known that materials with low C/N ratio would mineralized rapidly with its nutrient becoming quickly available for uptake again by *Hevea* or cover plants (Table 4). As leguminous covers such as *Pueraria* and *Desmodium* do not root deeply, the net effect would therefore be considered as a rapid re-cycling process of nitrogen in the upper soil layers. Leguminous creepers have been able to mobilize greater quantities of nitrogen, phosphorus and calcium compared to other types of covers during the first two years after planting (Table 5). Moreover, ground cover management encourages some degree of regeneration and recolonization of small plant types in the new ecosystem.

Table 4. *N concentrations (%) and C/N ratio, 42 months after planting*

Covers	Cover leaves	Green matter	Litter	Litter C/N
Naturals (Control)	1.60	1.03	1.65	22.26
Legumes	2.22	1.46	2.26	12.09
Elimination of non-legumes	1.98	1.14	2.15	13.38
Naturals with extra N	1.72	1.01	1.68	18.55

Table 5. *Contribution of nutrients from different covers, 24 months after planting*

Cover type	Kg/ha				
	Organic matter	N	P	K	Mg
Legumes	6000	120	10	30	20
Grasses	5100	60	8	20	12
Mikania	8500	62	7	18	15
Naturals	4000	50	6	28	17

Mulching

During the early years after planting, the young rubber plants provide very little protection to the soil due to the absence of adequate ground and canopy cover. It is therefore necessary to adopt suitable techniques to provide an additional form of ground cover during the early stages of the growth of young *Hevea*. In this regard, mulching has the advantage over the establishment of cover crops as mulching material could be applied immediately after planting to give a suitable cover to the soil from the time of planting. Data on the influence of different ground covers on soil erosion losses (Fig.1) indicated that the plots with mulch had the least soil erosion compared to other ground covers. Plots with bare land recorded a total soil loss of 60.9 tones/ha over the 3 year period compared to a loss of only 3.55 tones/ha in the plots with mulch (Samarappuli and Yogaratnam, 1984). Therefore, soil losses that occurred due to erosion from bare lands could be easily reduced by mulching. This would also help in reducing nutrient losses considerably. Levels of soil nutrient contents under different soil management practices are presented in Table 6. In general mulching has enhanced the soil nutrient contents. Mulching also improved the organic carbon content and cation exchange capacity (CEC) of the soil (Samarappuli, 1992b). Among the different soil management practices, dead mulch exhibited the highest soil moisture storage capacity (SMSC), (Table 7), (Samarappuli, 1992a).

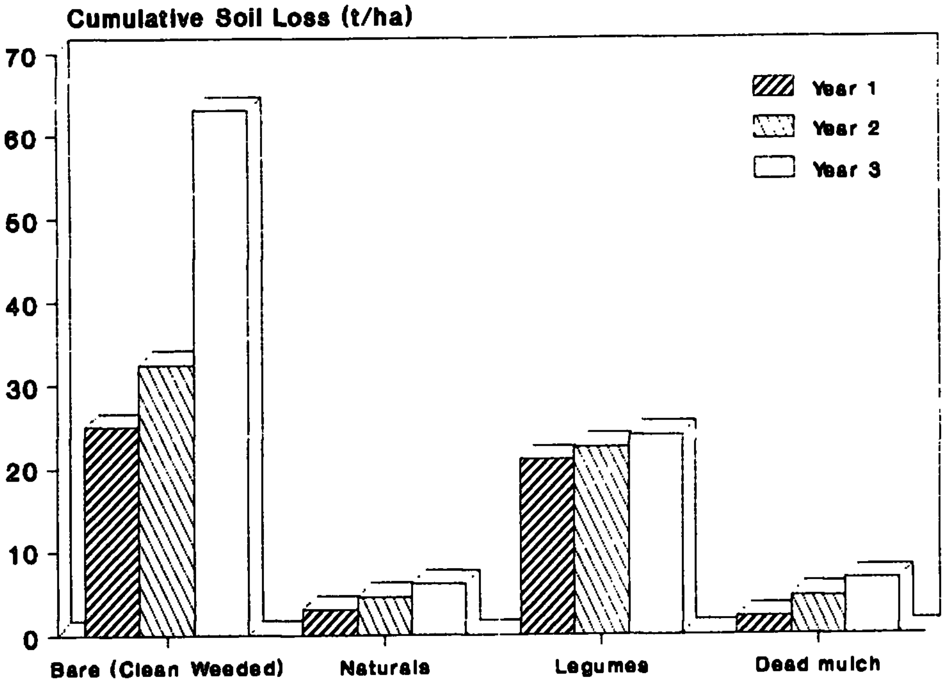

Fig. 1. Effect of ground cover treatments on total soil loss

Table 6. *Effect of different soil management practices on soil nutrient contents*

Treatment	N (%)	P (ppm)	K (cmol/kg)	Mg (cmol/kg)	Ca (cmol/kg)
Naturals	0.165[a]	9.3[a]	0.090[a]	0.1260[a]	0.514[a]
Legumes	0.179[a]	11.5[a]	0.094[a]	0.1480[a]	0.587[a]
Dead mulch	0.145[b]	18.5[b]	0.113[b]	0.2153[b]	1.196[b]

Table 7. *Effect of different soil management practices on organic carbon content, CEC and soil moisture storage capacity (SMSC) of the soil*

Treatment	Organic C (%)	CEC (cmol/kg)	SMSC (cm)
Naturals	1.100[a]	3.9[a]	21.7[a]
Legumes	1.105[a]	5.3[b]	23.3[b]
Dead mulch	1.415[b]	5.5[b]	27.6[c]

Fertilizer application

Regular application of recommended quantities of N,P,K and Mg during the immature and mature phases sustains the soil fertility throughout the lifespan of rubber tree (Yogaratnam *et al.*, 1984a; Yogaratnam *et al.*, 1984b and Yogaratnam & Weerasuriya, 1984). Mature rubber requires comparatively low amount of fertilizers to supplement nutrients and sustain high productivity compared to tea and coconut (Table 8). Moreover, fertilizer inputs are further optimized by application of discriminatory manuring recommendation where only the correct quantities of nutrients given according to site-specific requirements (Table 9). This in turn protects the ground water from pollution by reducing the excess fertilizer. A comparison of nutrient outflow or drainage through the harvested crop for major plantation crops are presented in Table 10. It is clearly evident that the outflow of nutrients for rubber, both in terms of outflow/kg of crop as well as per ha. are lower compared to tea and coconut. This indicates that drainage of nutrients in rubber plantations does not adversely affect the native soil fertility. *Hevea* stand, can therefore, be considered as a self-sustaining ecosystem which is environmentally acceptable.

Table 8. *Recommended nutrient levels for major plantation crops during mature period*

Crop	Yield(Kg/ha/yr)	Amount Nutrients (Kg/ha/yr)			
		N	P	K	Mg
Rubber	1400	32	4	35	3
Tea	1300	160	12	67	5
Coconut	2000	55	11	120	22

Table 9. *Average levels of fertilizer inputs for mature rubber; conventional vs. soil and foliar survey based method*

Method	Amount (Kg/ha/yr)			
	Urea	RP	MOP	Kieserite
Conventional	70	35	70	18
S & F	70	-	70	-

Table 10. *Nutrient removal of different crops via yield*

Crop	Yield (kg/ha/yr)	Nutrient removal via crop (kg)							
		per ha/yr				per 1000kg of yield			
		N	P	K	Mg	N	P	K	Mg
Rubber	1400	9	2	8	2	6.4	1.4	5.7	1.4
Tea	1300	60	5	30	5	46.2	3.9	23.1	3.9
Coconut	2000	48	10	92	13	24.0	5.0	46.0	6.5

Rubber *(Hevea)* as an agroforestry system

The replacement of natural forests with a common agricultural cropping system usually results in lower biomass and nutrient potentials in the new ecosystem. However, this trend is not likely to be true when forests are replaced by a *Hevea* ecosystem (Samarappuli and Yogaratnam, 1995). A stand of conventionally planted budded rubber trees, provided with optimum agronomic inputs, help in the enrichment of organic matter which consequently improves both chemical and physical properties of the soil (Table 11). It can therefore be concluded that the introduction of *Hevea* as an agricultural crop in land development programmes may improve the soil conditions to a great extent and thereby to return it to its original status.

Litter accumulation under rubber has found to be lower than that of natural forest (Table 12), (Gunatilleke *et al.*, 1995). This could be attributed to the faster rate of decomposition due to higher temperature and a higher content of soil P, K and Mg observed in rubber plantations compared to natural forests. Studies done by

Yogaratnam *et al.*, (1984a) and Gunatilleke *et al.*, (1955) indicated that the forest recycled about 9.4t of dry litter per year as compared to about 4.2 t/year under legumes and 6.3 t/year under mature rubber (Table 13).

Table 11. *Some chemical and physical properties of soil at different stages of rubber cultivation*

Stage	Organic C (%)	Total N (%)	Av.P (mg/kg)	Exch.K (cmol/kg)	Bulk density (g/cm^3)
Virgin Soil	2.13	0.16	15.4	0.17	1.01
6 months after planting rubber	1.09	0.14	16.9	0.12	1.23
4 years after planting rubber	2.09	0.19	18.0	0.16	1.09

Table 12. *Biomass and nutrient content of litter accumulation under different vegetation systems*

Vegetation	Biomass (Kg/ha)	Nutrient (Kg/ha)					Total nutrient (Kg/ha)
		N	P	K	Ca	Mg	
Rubber	3000	100	14	46	46	25	231
Natural Forest	8400	140	10	60	63	40	303

Table 13. *Litter fall and nutrient cycling under different vegetation systems*

Vegetation	Mean annual litter fall (t/ha) (dry weight)	Nutrient content (Kg/ha)				
		N	P	K	Mg	Ca
Forest	9.4	140	4.0	36	25	80
Legume cover	4.2	90	4.2	30	12	50
Rubber	6.3	44	4.0	15	12	70

The first rubber plantations were established in Sri Lanka at the beginning of the century. Since then many individual plantations have undergone 3 planting cycles of approximately 30 years per cycle without any great adverse effect on the soil environment. In the mean time the commercial yields of rubber have risen from about 250 kg per ha. to the present level of approximately 1500 kg per ha; a six fold increase. Samarappuli and Rupasinghe in 1995 concluded that in general there is no significant difference in soil chemical and physical characteristics between rubber and natural forest conditions (Table 14 and 15).

Table 14. *Average soil nutrient contents of rubber and forest soils*

Soil Nutrient	Rubber soil	Forest Soil
Soil N(%)	0.347	0.231
Soil P (ppm)	18.38	10.17
Soil K (ppm)	42.74	61.80
Soil Ca (ppm)	89.97	133.69
Soil Mg (ppm)	20.84	37.52
Soil Organic Carbon (%)	1.52	1.88

Although rubber growing is confined to the wet zone of Sri Lanka where annual rainfall is in the region of 2000mm it is suggested that rubber growing can be extended to areas marginal with regard to rainfall by adopting suitable agronomic practices such as mulching, growing of appropriate clones and application of higher level of K fertilizers (Samarappuli *et al.*, 1996). This allows the expansion of rubber cultivation by approximately 70,000 ha, which will be sustainable, conveniently renewable and compatible with nature.

Table 15. *Some physical properties of soil under different vegetation systems*

Vegetation	Depth (cm)	Bulk density (g/cm^3)	Porosity (%)	Water storage capacity (cm/m)
Rubber	0-15	1.11	59	24.6
	15-30	1.22	56	21.2
Natural forest	0-15	1.09	60	26.3
	15-30	1.20	57	22.8

Of all the agro-forestry cropping systems rubber plantations approximate closest to the natural forest system, in terms of canopy, leaf litter and in nutrient cycling. Rubber plantings develop a greater protective canopy and are more effective in nutrient cycling because of lower nutrient removal from the harvest compared to other commercially grown tree crop ecosystems. It concludes that planting to replanting, rubber plantation presents an environmentally acceptable replacement for the natural forest.

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