SOIL CHARACTERISTICS IN NATURAL FORESTS AND *TECTONA GRANDIS* AND *ANACARDIUM OCCIDENTALE* PLANTATIONS IN KERALA, INDIA

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BALAGOPALAN, M. 1995. Soil characteristics in natural forests and *Tectona grandis* and *Anacardium occidentale* plantations in Kerala, India. This study was initiated to characterise the soils of natural forests and plantations of different species in the Malayattoor Forest Division, Kerala, India. Sites were selected in the evergreen (West Coast tropical evergreen) and moist deciduous (South Indian moist deciduous) forests, grassland and plantations of teak (*Tectona grandis*) and cashew (*Anacardium occidentale*). A total of 45 soil pits, 8 each from the evergreen and moist deciduous forests, 20 from the teak plantation, 5 from the cashew plantation, and 4 from the grassland were taken. Soils in the evergreen forest, cashew plantation and grassland were sandy loam while in the moist deciduous forest and teak plantation, they were loamy sand. The soils were moderately acid in all the five vegetation types. Excluding gravel, silt, P, Ca and Mg, all other properties differed significantly due to vegetation types. Soils in the plantations were found to be deteriorated when compared to those in natural forests.

Key words: *Tectona grandis* - *Anacardium occidentale* - plantations - natural forest - grassland - soil properties - site deterioration

BALAGOPALAN,M. 1995. Ciri-ciri tanih di hutan-hutan asli dan ladang-ladang *Tectona grandis* dan *Anacardium occidentale* di Kerala, India. Kajian ini dimulakan untuk mencirikan tanih-tanih hutan-hutan asli dan ladang-ladang pelbagai spesies di Bahagian Hutan Malayattoor, Kerala, India. Tapak-tapak dipilih di hutan-hutan malar hijau (hutan malar hijau Pantai Barat Tropika) dan hutan lembap daun luruh (hutan lembap daun luruh Selatan India), padang rumput dan ladang-ladang jati (*Tectona grandis*), dan gajus (*Anacardium occidentale*). Sejumlah 45 tanih telah diambil, 8 setiap satu daripada hutan malar hijau dan hutan lembab daun luruh, 20 daripada ladang jati, 5 daripada ladang gajus dan 4 dari padang rumput. Tanih di hutan malar hijau, ladang gajus dan padang rumput adalah berpasir lom sementara tanih di hutan lembap daun luruh dan ladang jati adalah pasir berlomi. Tanih-tanih tersebut dari kelima-lima jenis tumbuh-tumbuhan kesemuanya agak berasid. Ciri-ciri lain yang tidak termasuk kerikil, kelodak, P, Ca dan Mg mempunyai perbezaan yang ketara yang disebabkan oleh jenis tumbuh-tumbuhan. Tanih-tanih dalam ladang-ladang semakin buruk berbanding dengan tanih-tanih dalam hutan-hutan asli.

Introduction

Soils play an important role in the growth and development of forests. Differences in soil properties influence both the composition of forest vegetation and the rate of tree growth. A thorough knowledge of the nature and properties of soils of forest ecosystems is important for proper management of the environment and utilisation

of resources. Ecosystem studies are relatively recent. No safe soil management system can be devised without adequate knowledge of the dynamic interaction between soil, climate and forest management. This study was undertaken to evaluate the nature and properties of soils in the natural forests and plantations of different species of Malayattoor Forest Division, Kerala, India.

Materials and methods

Study area

The study area lies between 9° 47' and 10° 17' N and 76° 16' and 76° 57' E in the Malayattoor Forest Division, Kerala, India (Figure 1). The area (1150 ha) is compact and covered with evergreen (West Coast tropical evergreen) and moist deciduous (South Indian moist deciduous) forests, grassland, and plantations of teak (*Tectona grandis*) and cashew (*Anacardium occidentale*). The areas under the above five vegetation types are 142, 258, 504, 128 and 118 ha respectively. The plantations of teak and cashew were established in 1965. The vegetation types lie close to one another in the above sequence. The area receives both southwest and northeast monsoons. The annual rainfall for the last 10 years (1982 - 1992) was between 2010 and 2870 mm with the average value at 2275 mm (Balagopalan 1993). The climate is warm and humid for the greater part of the year with a dry cool spell from December to February and hot summer from March to May. Annual occurrence of fire is a common feature especially during summer days in the teak plantation and grassland.

Soils

The parent material is crystalline rocks of Archean age composed chiefly of granitic gneiss. The soils belonged to the group of red soils or Oxisols or red ferrallitic soils. The colour of these soils was red, of different intensities and lines depending on the contents of Fe_2O_3, Al_2O_3 and SiO_2. The natural evolution of these soils might have proceeded in different ways. The tropical red ferrallitic soils might have turned into red lessivated and later by kaolinization and mottling to concretionary type and further by dehydration and compaction to laterites. The transitions between these stages were closely related to the alterations of vegetation covers, the intensity of disturbance and over all, effect of fire (Balagopalan 1993). Most of the soils in the plantations had been subjected to intensive erosion, thereby skeletonising. They are generally loose, friable, granular and porous on the surface but turn slightly compact, massive and less porous with depth in the natural forests.

Methodology

Soil pits up to a depth of 60 cm were dug in the evergreen and moist deciduous forests, grassland, and teak and cashew plantations. Altogether 45 soil pits were dug, of which 16 (8 each) were from the evergreen and moist deciduous forests,

20 from the teak plantation, 5 from the cashew plantation and 4 from the grassland. Soil samples were collected from layers at 0 - 20, 20 - 40 and 40 - 60 cm depths. Samples were air dried and sieved. Analyses were carried out on 2 mm sieved samples for particle-size separates, pH (1:2 soil:water suspension), organic carbon, exchangeable bases, exchange acidity, cation exchange capacity, extractable N, P, K, Ca and Mg (Jackson 1958, Black 1965). Gravel contents (particles > 2 mm) were also determined. Soil properties in different layers are given in Tables 1 and 2. Analyses of variance of soil properties (Snedecor & Cochran 1975) between vegetation types are presented in Table 3.

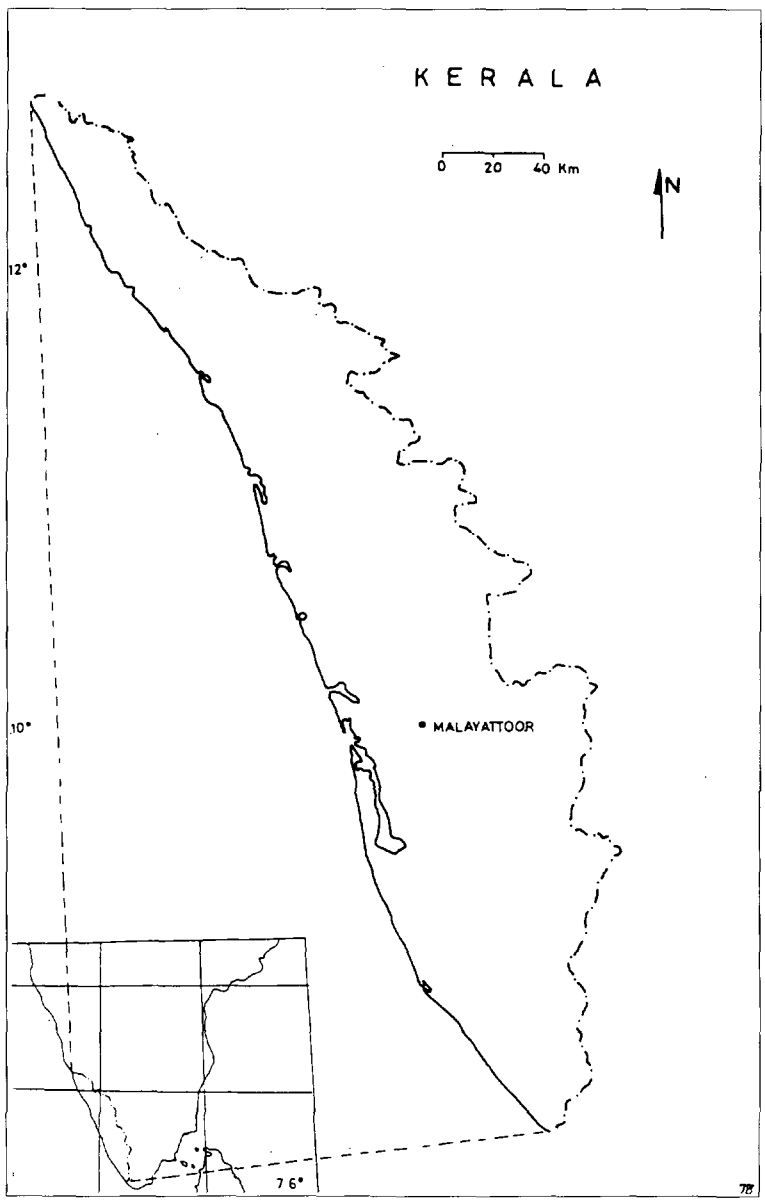

Figure 1. Location of study area

Results and discussion

Soil properties in the evergreen forest

In general, the clay content increased while sand, pH, organic carbon, exchange acidity, cation exchange capacity, extractable N, P, K and Mg decreased with depth (Table 1). There was no change in silt content while gravel, exchangeable bases and extractable Ca followed no pattern. The soil was sandy loam and moderately acid.

Soil properties in the moist deciduous forest

Sand, organic carbon, exchangeable bases, extractable N, P, K, Ca and Mg contents and cation exchange capacity values decreased whereas gravel, silt and clay contents increased with depth (Table 1). There was no change in pH value while exchange acidity followed no trend. The soil was loamy sand and moderately acid. It was also found that there was dense development of feeder roots and the microclimate was relatively stable in the natural forests.

Soil properties in the teak plantation

Organic carbon, exchangeable bases, exchange acidity, extractable N, K, Ca, Mg and cation exchange capacity decreased while gravel, silt and clay contents increased with depth (Table 1). There was no trend for sand, pH and extractable P values. The soils were loamy sand and moderately acid.

Soil properties in the cashew plantation

Silt, clay and extractable Ca and Mg increased while sand, organic carbon, exchange acidity, extractable K and cation exchange capacity decreased with depth (Table 1). There was no trend for gravel, exchangeable bases, extractable N, P values whereas soil pH remained the same in the three layers. The soil was sandy loam and moderately acid.

The content of crystallized forms of iron compounds was high in the plantation. This was evident by the presence of iron concretions in most of the pits. These concretions also indicated the onset of the initial stages of laterisation .

Soil properties in the grassland

Sand, organic carbon, exchange acidity, extractable N, K and Ca and cation exchange capacity decreased whereas clay and pH values increased with depth (Table 1). No pattern was observed for gravel, silt, exchangeable bases, extractable P and Mg contents. The soil was sandy loam and moderately acid. The occurrence

Table 1. Mean values of soil properties in the different layers in the different forest ecosystems

Properties	Vegetation types/layers (cm)														
	Evergreen forest			Moist deciduous forest			Cashew plantation			Teak plantation			Grassland		
	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60
Gravel (%)	21	20	22	16	17	20	22	21	24	17	20	22	12	18	14
Sand "	80	77	75	87	86	85	80	74	73	83	75	78	82	77	76
Silt "	11	11	11	10	11	11	10	12	12	10	12	13	10	12	11
Clay "	9	12	14	3	4	4	10	14	15	6	9	10	8	11	13
pH	5.2	5.0	5.0	5.5	5.5	5.5	5.3	5.3	5.3	5.4	5.3	5.4	5.0	5.2	5.4
OC (%)	2.16	1.35	1.08	2.39	1.65	1.26	1.99	1.41	0.94	1.92	1.19	0.91	2.32	1.30	0.90
EB (me/100 g)	8	7	8	15	8	7	2	3	2	14	12	12	12	9	10
EA "	6.8	6.5	6.0	8.0	8.4	7.5	7.3	6.3	5.3	8.9	7.8	6.5	8.9	6.0	5.8
N (ppm)	197	116	91	213	132	101	184	190	81	171	102	73	201	104	74
P "	10	8	8	6	4	4	6	5	6	7	5	6	10	6	6
K "	415	260	209	605	403	304	458	344	220	367	201	197	465	365	160
Ca "	33	17	18	85	30	21	22	28	28	54	30	29	48	32	26
Mg "	14	7	7	24	9	8	11	11	12	19	13	13	16	13	13
CEC[c mol(+)/kg]	15.2	13.7	13.5	23	17	14	9.7	9.2	7.3	23.1	20	18.4	20.9	15.3	15.8

OC = Organic carbon; EB = Exchangeable bases; EA = Exchange acidity; CEC = Cation exchange capacity .

of fire is a common phenomenon in the plantations and grassland especially during summer months.

Soil properties in the different forest ecosystems - a comparative approach

In the physical properties, the soil in the cashew plantation had the highest gravel and clay contents, and lowest sand content and exchange acidity value, while in the moist deciduous forest, these values were reversed, except for the gravel content which was highest in the grassland. Teak soil had the maximum silt content whereas in the other three, the silt contents were similar and lower. Acidity was highest in the evergreen forest and lowest in the moist deciduous forest soils. Organic carbon, extractable N and K contents were highest in the moist deciduous forest and lowest in the teak plantation soils. The soil in the teak plantation had the highest exchangeable bases content and cation exchange capacity value and that in the cashew plantation had the lowest. Extractable P content was lowest in the moist deciduous forest soil and highest in the grassland soil. The evergreen forest soil contained the lowest Ca and Mg contents while these were found to be highest in the moist deciduous forest and teak plantation soils respectively (Table 2).

It could be seen that the soil properties varied considerably between vegetational types. Excluding gravel, silt, extractable P, Ca and Mg, all other properties were found to differ significantly between the five vegetation types (Table 3). The vegetation changes and other management practices have therefore influenced the soil and eventually, its functions as a supplier of nutrients and water.

The structural and functional adaptations of the natural forests to the climatic and edaphic environment are relatively efficient to maintain and conserve a viable, perpetual ecosystem when compared to the plantations. In the natural forests, it could be seen that the top soil had a more favourable structure and a comparatively high organic matter content.

The soils were red, leached with mottled horizons in the plantations. Concretions of iron were also seen in most of the pits in the plantations. The general tendency was towards laterisation which would be enhanced by alteration in the vegetation cover and other environmental impacts.

It was observed that the changes in the vegetation composition and structure also resulted in changes in the soils. The soils in the plantations were found to be highly deteriorated in the sense that organic matter and N decreased and the levels of most nutrients continued to decrease when compared with those of the natural forests.

The decrease in soil organic matter in the plantations may be explained by the low rate of addition and incorporation of fresh and partially decomposed litter (Balagopalan 1993).

It was also observed that the plantations of teak and cashew have not caused any change in the soil acidity. A dense development of feeder roots in the litter and topsoil, often with very intense mycorrhiza development, relatively high organic matter content in the top soil, which substantially increases the nutrient retention

Table 2. Mean values of soil properties in the 0 - 60 cm layer in the different vegetation types

Vegetation types	Properties													
	Gravel	Sand	Silt	Clay	pH	Org. carbon	Exch. bases	Exch. acidity	Extractable N	P	K	Ca	Mg	CEC
	(.....%.....)					(%)	(me/100 g soil)		(.....ppm.....)					[c mol(+)/kg]
Evergreen forest	21	78	11	11	5.0	1.53	8	6.4	135	6	295	14	9	14.4
Moist deciduous forest	18	86	11	3	5.5	1.78	10	8.0	149	4	437	27	14	18.0
Teak plantation	19	80	12	8	5.4	1.32	13	7.8	114	6	250	22	15	20.8
Cashew plantation	22	76	11	13	5.3	1.46	3	6.3	128	6	341	17	11	9.3
Grassland	15	78	11	11	5.2	1.51	10	7.4	127	7	330	21	14	17.4

CEC = Cation exchange capacity.

capacity, various N fixing mechanisms, and a favourable top soil structure, which prevents losses by surface erosion, are some important adaptations to the soil condition in the natural forest (Lundgren 1978). Another fact is that the amount of organic matter and nutrients stored in the living vegetation is very high in relation to the annually circulated amount, and this reduces the risk of high losses during seasons of excessive rainfall. It is quite unlikely that a monoculture plantation will possess the same spectrum of N-fixing mechanism as a natural forest (Balagopalan 1993).

Table 3. Analyses of variance of soil properties between the vegetation types

Source	Degrees of freedom	Sum of squares	F ratio
Gravel			
Between groups	4	170.1967	2.2431 ns
Within groups	41	777.7381	
Total	45	947.9348	
Sand			
Between groups	4	435.5818	9.0858 **
Within groups	41	491.3964	
Total	45	926.9783	
Silt			
Between groups	4	8.2529	1.6077 ns
Within groups	41	52.6167	
Total	45	60.8696	
Clay			
Between groups	4	399.4630	10.7789 **
Within groups	41	379.8631	
Total	45	779.3261	
pH			
Between groups	4	0.8763	5.3870 **
Within groups	41	1.6674	
Total	45	2.5437	
Organic carbon			
Between groups	4	1.2473	3.2991 *
Within groups	41	3.8753	
Total	45	5.1226	
Exchangeable bases			
Between groups	4	463.9866	7.1090 **
Within groups	41	668.9917	
Total	45	1132.9783	
Exchange acidity			
Between groups	4	18.6577	3.1306 *
Within groups	41	61.0884	
Total	45	79.7461	

(continued)

Table 3 (continued)

Extractable nitrogen			
Between groups	4	7765.0696	3.2419 *
Within groups	41	24551.3000	
Total	45	32316.3696	
Extractable phosphorus			
Between groups	4	23.4237	1.7161 ns
Within groups	41	139.9024	
Total	45	163.3261	
Extractable potassium			
Between groups	4	210934.6900	4.1439 **
Within groups	41	521746.0274	
Total	45	732680.7174	
Extractable calcium			
Between groups	4	2509.7582	2.6444 ns
Within groups	41	9728.0679	
Total	45	12237.8261	
Extractable magnesium			
Between groups	4	220.9196	1.4839 ns
Within groups	41	1525.9500	
Total	45	1746.8696	
Cation exchange capacity			
Between groups	4	634.6968	6.9385 **
Within groups	41	937.6112	
Total	45	1572.3080	

ns = not significant; *, * * significant at p ≐ 0.05 and 0.01 respectively.

Fears of soil changes under plantations have been repeatedly and increasingly expressed during the last decades and comparatively few studies have been carried out to elucidate the problem (Lundgren 1978). The scarcity of factual information on this point is striking. In the present study it could be seen that biological uniformity, the repeated exposure of soils to sun and rain and the effects of associated management practices have made the soils in the plantations less fertile. Scientific management measures are required to preserve and enhance the fertility of the land.

Conclusion

The study of soils in the evergreen and moist deciduous forests, grassland, cashew and teak plantations in the Malayattoor Forest Division, Kerala, India, revealed that they were less compact in the evergreen forest and had a favourable structure. Soils were sandy loam in the evergreen forest, grassland and cashew plantation while those in the moist deciduous forest and teak plantation were loamy sand.

They were very moderately acid in all the five vegetation types. The soil properties in the five ecosystems varied significantly. The soils in the plantations were found to be deteriorated.

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