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The Influence of Vegetation on the Properties of the Soils of Sikkim

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The influence of different vegetal sources (*Tectona grandis, Shorea robusta, Pinus roxburgii, Cryptomeria japonica* and *Cinnamom cardamom*) of different ages (40–50 years) on the physicochemical characteristics of the soils of Sikkim in the altitude ranges of 300–1690m above m.s.l was studied. Green foliage, litter and raw humus were analysed for their chemical elements present in the ash in order to understand the changes taking place during the formation of litter from green foliage and then to raw humus. It was observed that in the course of transformation of green foliage to litter and then to humus, some of the elements (CaO, MgO, K_2O, Na_2O and P_2O_5) were leached out with the accumulation of others (SiO_2 and Fe_2O_3). The soil under conifer was more acidic but exchangeable bases were higher under broad-leaved (*Tectona grandis* and *Shorea robusta*) species.

Key Words: Organic matter transformation, Changes in soil properties, Forest soils of Sikkim

Introduction

Vegetation influences the soil development because of the close relationship between soil and plant communities and the mutual influence of one on the other (Banerjee et al. 1984, 1985, 1986, Singh et al. 1985). A unique characteristic of most forest ecosystems is the development of a distinct forest floor through litter fall. The forest floor is undoubtedly the most distinctive feature of forest soils that contributes greatly to their unique soil properties. The nature and content of organic debris returned to the forest floor and varied with vegetation affect the physicochemical properties of soils.

In a part of south and west Sikkim Forest Divisions, several plantations of different species were raised in the past after clearing the natural forest in areas with more or less uniform geology and gentle to rolling topography. Since the plantations are old enough (40 to 50 years), a study was undertaken to know the nature and extent of variations in soil properties under the different vegetations with special reference to the decomposition and interaction of organic matter returned to the floor of the plants.

Materials and Methods

Five sites were selected for this investigation in Sikkim Forest Division between 300 and 1690 m above m.s.l. and within 88°20′ to 88°25′E and 27°20′to 28°30′N. These areas fall in the lower and middle hills of the Eastern Himalayan Region with undulating topography and occasional slopes of 10 to 20%. The area receives 2500–2700 mm average annual rainfall and experiences 17°C and 10°C mean maximum and minimum temperatures (table 1) respectively. The parent materials, in most cases, are gneiss mixed with mica schist. The litter fall, by and large, is heavy, particularly under conifers, to form a thick mat every year. The cool climate coupled with heavy rainfall decompose the organic debris to form raw humus of 2–3 cm thickness. The underlying soils are deep to very deep with well developed profiles, are well drained and noncalcareous.

Plant samples were collected from five locations under pure stands of *Tectona grandis* (Teak), *Shorea robusta* (Sal), *Pinus roxburgii* (Chir pine), *Cinnamom cardamom* (Cardamom) and *Cryptomeria japonica* (Dhupi). Leaves which attained maximum growth but were still uniformly green were collected from different canopy positions and mixed thoroughly to obtain composite samples. The samples of leaves, litter and raw humus were dried and powdered for analysis. The samples were ignited in muffle furnace at 500°C for 3 hr and the ashes dissolved in dilute

hydrochloric acid (N/10) and silica separates out. CaO, MgO, Na_2O, K_2O, Fe_2O_3 and P_2O_5 were estimated in the extracts (Black 1965).

Soil profiles were exposed at each of the above sites and representative soil samples were collected from each horizon and subhorizon for laboratory investigation. *p*H (1:2.5 soil water suspension), cation exchange capacity, exchangeable cations and organic carbon were estimated following the standard methods (Jackson 1973). Humus extraction was made by treating the soils with 0.5(M) NaOH and fractionating into humic and fulvic acids (Banerjee & Mukherjee 1975). Exchangeable H^+ and Al^{3+} were estimated from KCl extract of the soil according to the method described by Mclean (1965).

Results and Discussion

Green leaves

The ash content of green leaves varied from 2.50 to 11.52% on dry weight basis (table 2). Teak had the highest ash content (11.52%) and Chir pine the lowest (2.5%). The mineral content of leaves varied considerably from species to species: SiO_2 — 10.40–15.85%, CaO — 18.60–38.04%, MgO — 8.03–12.50%, Na_2O — 0.22–1.41%, K_2O — 14.59–19.15%, P_2O_5 — 3.27–10.65% and Fe_2O_3 — 1.50–4.14%. These values are in close resemblance with those obtained by Dhir (1970) in the green leaves of different tree species in the North-western Himalayas. Lutz and Chandler (1946) concluded that, except for nitrogen, the annual return of major nutrients was greater in hard wood than in conifer litter. The greater amounts in the hard wood leaves reflect generally higher concentration of nutrients rather than larger amounts of litter. It was observed that maximum litter return was by Dhupi followed by Chir pine, Teak and Sal.

Forest Litter

The amount of organic matter which may be measured in or on the soil at any given time is the conventional way of characterising the soil organic status. As indicated previously the maximum litter return was from Dhupi and minimum from Cardamom. The form of the litter component is determined by the species from which it originates. The concentration of plant nutrients in litter material is important because of its influence both on the rate of decomposition of the litter and on the amounts of nutrients liberated during decomposition. However, if the rate of decomposition is slow, the litter may have a pronounced physical effect by allowing rapid entry of water into the soil as well as facilitating gas exchange. Although organic matter has long been known to' influence soil properties, it is increasingly apparent that certain chemical constituents, especially of fresh origin exert a profound influence on processes of soil weathering and soil profile development. It is generally expected that the ash content of the fresh litter should be higher than that of green leaves because in the process of conversion of the green leaves to litter, a portion of their dry matter is usually lost (Dhir 1970). However, contrary to the general expectation, the analytical data (table 2) show slightly lower values in almost all the cases (3.0–8.0%). The chemical composition of forest litter, as can be expected differs with standing crop species (table 2). In almost all the cases, SiO_2 and Fe_2O_3 contents generally increased and CaO, MgO, P_2O_5, K_2O and Na_2O decreased with respect to green leaves. This may be due to selective leaching of some elements leaving behind some others during the process of conversion of green leaves to litter. The results are in accordance with those obtained by Dhir (1970) who showed that during the transformation of green leaves to litter the order of leaching was $K_2O > P_2O_5 > Na_2O > MgO > CaO > SiO_2 = Fe_2O_3$. Latter and Cragg (1967) studying *Funcus* litter found more than 50% loss of all inorganic ions with potassium, phosphorus, magnesium and calcium losses being most marked.

Table 1 *Temperature data (°C) in middle and lower hills*

Month	Middle hill		Lower hill	
	Mean maximum	Mean minimum	Mean maximum	Mean minimum
Jan.	8.0	4.0	12.6	7.1
Feb.	10.0	5.2	14.5	8.4
Mar.	11.5	6.0	17.6	10.2
Apr.	14.6	9.0	20.6	11.1
May	16.1	10.0	24.8	15.3
Jun.	17.2	11.1	27.2	16.8
Jul.	17.4	11.6	26.4	15.6
Aug.	17.4	11.4	26.0	14.9
Sept.	17.6	10.0	24.2	13.0
Oct.	15.5	9.8	22.8	11.8
Nov.	13.0	7.6	16.3	9.6
Dec.	9.3	4.8	13.2	7.8

Raw Humus Layer

The raw humus layers formed by the decomposition of forest litter and immediately over the mineral part of the soil were generally dark and friable with earthy feeling (field observation). Ash content of these layers ranged from 44.0 to 72.5%, which is 5.5 to 22 times

Table 2 *Elementary analysis of the ash (as % of the ash content)*

Species	Ash	SiO_2	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5
GREEN FOLIAGE								
Teak	11.52	15.30	2.48	38.04	8.38	0.22	19.15	5.74
Sal	4.10	15.00	2.60	28.25	8.20	0.53	16.54	4.20
Chir pine	2.50	14.40	1.50	20.80	9.37	1.41	17.75	10.65
Dhupi	6.80	15.85	4.14	18.60	8.03	0.42	14.59	5.50
Cardamom	5.00	10.40	1.50	26.30	12.50	1.16	18.36	3.27
LITTER								
Teak	8.00	26.10	6.15	28.54	4.34	0.10	11.10	1.23
Sal	3.50	22.85	6.59	19.59	4.68	0.27	10.16	1.10
Chir pine	3.00	16.66	5.91	16.58	2.31	1.06	8.10	5.91
Dhupi	5.74	21.40	6.04	10.38	2.24	0.39	7.10	1.66
Cardamom	3.13	12.59	4.03	20.53	4.40	0.42	9.68	1.42
RAW HUMUS								
Teak	44.00	46.70	13.61	8.82	4.53	0.27	13.15	0.46
Sal	72.50	60.23	10.25	6.38	1.38	0.38	11.50	0.15
Chir pine	64.50	56.04	13.05	3.45	0.45	1.25	11.23	1.07
Dhupi	65.40	60.25	9.93	2.38	1.43	0.87	10.27	1.07
Cardamom	65.40	63.75	10.38	2.76	2.00	0.59	10.73	1.05

that of the litter and 4 to 27 times that of the green leaves (table 2). The ash content in the humus layer under Sal was quite high (72.5%) which may be due to the mixing up of some mineral matter from the surface mineral horizon. However, nearly 63% ash was found in the humus layer under *Abies pindrow* (Dhir 1970). The higher ash content in humus layer over that of litter and green leaves can be attributed again to loss of dry matter in the course of transformation from litter to raw humus and subsequent mineralisation. The chemical changes during the initial stage of litter breakdown consist in decomposition of soluble carbohydrates, starches, pectic substances and soluble nitrogenous compounds (Burges 1967). A considerable proportion of inorganic ions in the fallen leaves is rapidly lost by leaching which is evidenced by the fact that in the course of transformation from litter to humus, SiO_2, Fe_2O_3, K_2O and Na_2O increase but CaO, MgO and P_2O_5 decrease considerably clearly indicating high degree of leaching of the latter and accumulation of the former. It has been observed (Wright 1956, Remezev 1961, Latter & Cragg 1967) that CaO, MgO and P_2O_5 are heavily leached out from litter but K_2O is comparatively less mobile. Fe_2O_3 and SiO_2 are highly immobile in oxidised and hydrated states and are thus left behind. During the formation of raw humus from litter the order of leaching as observed by Dhir (1970) was: $CaO > MgO = P_2O_5 > K_2O = Na_2O > SiO_2 > Fe_2O_3$.

Except in Pedon 4, the *p*H of the upper horizons (table 3) of the mineral layers was higher in all the pedons. This may be attributed to the release of bases which go down to the upper layers of the mineral soil and combine to form complexes through replacement of H^+. Nykvist (1959) showed that material leached from the litter layers became less acidic with time due to the presence of bases released through decomposition. Initial rise in *p*H was also found by Mattson and Koulter-Anderson (1954).

The content of organic carbon in each pedon varied from 0.35 to 4.77%—the highest (1.50–4.77%) under Dhupi and lowest (0.35–1.93%) under teak (table 3). The highest amount of organic matter under Dhupi is correlated with the highest amount of litter fall. Moreover, in the soils under Dhupi at higher altitude and at low temperature (table 1) and low *p*H there is slow formation of new humic substances from decomposed plant origins and also is the slow breakdown and mineralisation of newly formed humic substances with the resultant accumulation of higher amount of organic matter. On the other hand, in the soils of lower altitudes under Teak, as the temperature is comparatively higher (table 1) there is a periodic

Table 3 *Physicochemical characteristics of the soils*

Depth (cm)	pH (1:2.5)	Org. C (%)	C E C (me/100g)	Exchangeable bases (me/100g)				Base saturation (%)	Exch. acidity (me/100g)		Mechanical separater (%)		
				Ca^{2+}	Mg^{2+}	K^+	Na^+		H^+	Al^{3+}	Sand	Silt	Clay
PEDON 1, *under* ***Tectona grandis*** *(altitude 300m), Typic Udipsamment*													
0–20	5.2	1.39	12.29	4.24	2.27	0.28	0.49	59.2	0.12	0.11	83.6	5.9	10.5
20–35	4.9	0.72	7.77	1.43	1.43	0.22	0.18	41.9	0.01	0.22	76.2	12.4	11.4
35–75	4.8	0.35	6.61	0.42	1.27	0.18	0.19	31.2	0.01	0.22	78.2	11.8	10.0
PEDON 2, *under* ***Shorea robusta*** *(altitude 390m), Typic Udipsamment*													
0–10	5.3	2.52	16.49	3.50	2.82	0.78	0.19	44.2	0.01	0.22	82.8	8.8	8.4
10–19	4.8	1.02	12.99	1.43	2.54	0.51	0.20	36.0	0.24	0.22	68.4	16.0	15.6
19–65	4.8	0.54	8.47	0.47	0.84	0.33	0.21	21.8	2.14	0.45	62.8	18.8	18.4
PEDON 3, *under* ***Pinus roxburgii*** *(altitude 540m), Typic Udipsamment*													
0–6	5.2	2.10	9.97	2.80	2.38	0.71	0.06	49.6	Tr	0.72	84.2	5.0	10.8
6–20	5.0	1.26	7.98	1.93	2.45	0.36	0.06	60.1	0.41	2.08	65.2	18.2	16.6
20–75	4.7	0.67	6.80	1.29	1.41	0.27	0.07	44.7	0.14	2.56	63.0	17.2	19.8
PEDON 4, *under* ***Cryptomeria japonica*** *(altitude 1680m), Typic Dystrochrept*													
0–9	4.0	4.77	23.43	0.79	0.58	0.29	0.22	8.0	5.11	3.61	74.4	8.6	17.0
9–45	4.1	1.66	15.74	0.31	2.59	0.18	0.38	22.0	2.93	2.26	58.6	22.8	19.2
45–100	4.1	1.50	15.39	0.37	0.14	0.17	0.21	5.8	1.77	2.71	54.2	27.2	18.6
PEDON 5, *under* ***Cinnamom cardamom*** *(altitude 1690m), Typic Dystrochrept*													
0–27	4.1	3.99	19.43	0.68	0.53	0.23	0.21	8.5	2.99	3.61	76.4	9.2	14.4
27–77	4.1	2.03	15.74	0.31	0.68	0.18	0.31	9.4	2.95	2.71	60.0	22.6	17.4
77–110	3.9	0.54	4.71	0.15	0.37	0.14	0.22	18			33.6	52.0	14.4

moisture deficit which promotes the rapid breakdown and mineralisation of humic substances as a result of increased microbial activity and intensive oxidation. The net result is the accumulation of a lower amount of organic matter (Mukhopadhyay & Banerjee 1985). It may be mentioned here that under Dhupi mor-humus is formed but under other species it is either mull or mild mull-like moder type.

Exchangeable bases distributed throughout the profile contained predominantly Ca^{2+} (0.15–4.24 me/100g) and Mg^{2+} (0.14–2.82 me/100g). Total exchangeable bases as well as % base saturation were highest under Teak, obviously because Teak is a calcicolous plant and uptake and return of the base ions (table 2) will be more under this species in comparison to others. Na^+ and K^+ contents were somewhat low (0.06–0.49 and 0.14–0.78 me/100g respectively). The low per cent base saturation in the surface soil under Dhupi (table 3) and the high contents of H^+ and Al^{3+} lower the *p*H. These H^+ and Al^{3+} are released from humus with subsequent replacement by the bases from leaf samples. The highest litter fall under Dhupi produces larger amount of organic acids through microbial decomposition for a sufficiently long time and the bases thus released replace the H^+ and Al^{3+} of the organic acids. The analysis of humus, humic acid carbon and fulvic acid carbon (table 4) further corroborate the aforesaid observations. The humus content ranges from 0.28 to 2.37% and the highest amount of humus, rather humic acid carbon and fulvic acid carbon was under Dhupi. However, the degree of humification was lower in these soils showing a lower humic acid/fulvic acid ratio. The surface soils of Pedons 1, 2 and 3 of lower hills had comparatively lower organic matter as well as humus, humic acid and fulvic acid carbon as compared to Pedons 4 and 5 of higher hills. This variation may be due to the altitude and the nature of vegetation community. The lower humic acid/fulvic acid ratio particularly in Pedons 4 and 5 suggests that mobility of fulvic acid is higher than that of humic acid and with depth the fulvic acid tends to predominate.

Table 4 *Content and composition of humus constituents*

Depth (cm)	Humus C (%)	Humic acid C (%)	Fulvic acid C (%)	HA_c/FA_c
PEDON 1				
0–20	0.417	0.080	0.337	0.23
20–35	0.390	0.053	0.337	0.15
35–75	0.285	0.051	0.234	0.21
PEDON 2				
0–10	0.973	0.503	0.407	1.23
10–19	0.549	0.212	0.337	0.62
19–65	0.338	0.129	0.209	0.61
PEDON 3				
0–6	0.840	0.520	0.320	1.62
6–20	0.470	0.270	0.200	1.35
20–75	0.320	0.200	0.120	1.66
PEDON 4				
0–9	1.520	0.725	0.795	0.91
9–45	0.893	0.423	0.470	0.89
45–100	0.919	0.402	0.517	0.77
PEDON 5				
0–27	2.031	0.922	1.109	0.83
27–77	1.026	0.476	0.556	0.84
77–110	0.364	0.053	0.235	0.22

Translocation of humus down the profile is not pronounced and, as such, no zone of enrichment was noticeable in the profile. The high acidic condition coupled with high rainfall might be responsible for the mobility of fulvic acid in the profile.

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