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Characterizing soils under different land use patterns in *Terai* region of West Bengal

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Summary

A study under four different eco-systems (forest land, agricultural land, tea garden and fallow land) was conducted under *Terai* situation of West Bengal to characterise the soils with important physico-chemical properties and also to find out the available nutrient status in soils with the increasing depth. It was observed that the available N-P-K of the soils and the exchangeable (Ca^{+2} + Mg^{+2}), electrical conductivity (EC), oxidisable organic carbon (OC) and total C-H-N-S in soil significantly varied with the depth of soils in most of the cases. The soils were acidic in reaction and non-saline in character. The available N-P-K and OC of soils of forest, agricultural and tea-garden differed with the uncultivated fallow. The survey of the regions showed that the buildup of nutrients (N-P-K, Ca^{+2} + Mg^{+2}) varied with the changing ecosystems as reflected by the C/N, C/S and C/H ratio of the soils.

Key words : Ecosystem, Nutrients, Physico-chemical

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Introduction

The *Terai* region of West Bengal is characterised by biomass production, well supported complimentary climatic factors, particularly high rainfall for luxuriant vegetative growth and regeneration rate. Availability of abundant phyto-biomass, both above and below ground in the form of forests and other allied sources has made the region a unique place in India. Since vegetation or biomass is one of the most important sources to enrich soil with organic matter, a general belief is that the soils of *Terai* region will be very high in carbon content. Land use / land cover change and type of land use practices have considerable influences on changing the soil properties. The conversion of natural forests to other forms (agricultural land, tea gardens) may have effect on changing the important nutrients (Ca^{+2}, Mg^{+2}, N, P, K, S) in soils and also the carbon stock of the region. The change in soil organic carbon content from 36.02 g/kg to 25.76 g/kg (1982-2003) on transformation of forest to cultivated land (Jiang *et al.*, 2006). The introduction of cultivation and pasture in some forest ecosystems resulted the changes in soil physico-chemical and biological properties (Houghton and Skole, 1990). It was observed that soils of the organically cultivated field (OCF) had higher moisture, total organic carbon, nitrogen, microbial biomass C and N, compared to fallow grassland at the neighboring plot (Chandra *et al.*, 2010). It was also observed that the total phosphorus (P) in soil varied

significantly under the food crop system and plantation of tea (Tehienlkoua and Zech, 2003). It was reported that soil properties are being influenced (Sidhu *et al*., 2014,) by the management practices and change of cropping pattern in the indo gangetic plain (IGP). Soil organic carbon, total nitrogen, available nitrogen, soil microbial biomass carbon and phosphorus increases with time with the increase of plantation establishment (Wang *et al*., 2011 and Zhu *et al*., 2010). Furthermore, studies were taken to assess the impact of conversion of native ecosystem into arable land on labile pool to assess the role of soil as sink for carbon under different management practices and land uses (Leite *et al*., 2003 and Verma *et al*., 2010). The influence of aggregation of soils under different cropping system (Manna *et al*., 2007 and Hati *et al*., 2007) and loss of carbon-rich macro-aggregates due to cultivation (Hati *et al*., 2008) were also observed.

Emission of carbon dioxide from soil is influenced by oxidation of soil organic matter, root and microbial respiration (Al-kaisi *et al*., 2008 and Sainju *et al*., 2008). Reasonable amount of information on soil organic carbon status and carbon stock has been generated for main land India (Bhattacharyya *et al*., 2009). Based on these background, the present study was conducted to assess the changes in the physico-chemical properties of the soils under different ecosystems.

Resource and Research Methods

Experimental sites and soil sampling :

Considering the different climatic conditions and land use pattern under the *Terai* agro-ecosystems, the selection of the sites for collecting soils was done on the basis of different land use and land cover (e.g. agricultural, fallow, tea garden and forest land) situations. Field survey was conducted in identified agricultural and fallow lands at Kharibari (Darjeeling district), Binnaguri, Kumargram (Jalpaiguri district) and Balarampur (Cooch Behar district) under the northern province of West Bengal. The soils were collected in the year 2014 from tea gardens of Darjeeling and Jalpaiguri districts and soils from forest land cover were collected from Mahananda Sanctuary, Gorumara National Park, Chilapata Forest and Buxa Tiger Reserve Forest of West Bengal.

The soils were collected at four to five uniform spots from each land use/land cover site at 0-20 cm, 20-40 cm and 40-60 cm depths during 2014. At each site, three sub-samples were drawn and pulled together to form one composite soil sample. After removing all stubbles, residues and unwanted substances, composite soil sample collected from each site and depth were homogenized and air dried at room temperature, ground in wooden mortar, sieved through 2 mm sieve and preserved with care in covered plastic containers for further analysis.

Physico-chemical analyses of soil :

The collected soil samples were processed to determine the important physico-chemical properties by the standard procedures. The pH, EC, CEC and exchangeable (Ca^{+2} + Mg^{+2}) of soils were measured by the method of Jackson (1973). The soil available nitrogen, phosphorus and potassium were determined by the methods of Subbiah and Asija (1956), Bray and Kurtz (1945) and Hanway and Heidel (1952), respectively. The oxidisable organic carbon was estimated following Walkley and Black (1934). The total C,H,N,S of soils were determined in the CHNS analyser (Elementar Vario EL3).

Statistical analysis :

Least significant difference(LSD) and correlation analysis were performed using SPSS software (version 6.0) to study the underlying relationships among different soil properties.

Research Findings and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under the following heads :

Characterization of soils under study :

Forest ecosystems :

The soils were collected from four sites (Gorumara, Mahananda, Buxa and Chilapata) of the region. The important soil properties of the samples from forest ecosystems are given in Table 1. In all the sampling sites, the soil was acidic in reaction (average pH 5.15). A general trend of increasing the pH with the depth of the soils was observed. The range of pH in soils varied from 4.77 to 5.62. The ECs of the collected soils showed the non-saline characteristics having an average of 0.05 dSm^{-1}. The (Ca^{+2} + Mg^{+2}) content in soils was low in this zone (average 3.48 meq/l) which indicated the acidic nature of the soil. The oxidisable organic carbon (average 1.59 %) showed variation at different depths of soils. The available nitrogen (kg ha^{-1}) was high (238.34) in

Gorumara forest and lowest in Chilapata forest (194.43) at the surface soils (0-20 cm). Besides, significant variations of CEC with soil depths was observed at different sites of the forest ecosystems. The available nitrogen (N) trend to decrease with the depth of the soil. The lowest value of N (119.17 kg ha^{-1}) was at 40-60 cm depth of soils under the Chilapata forest. The available phosphorus under the forest ecosystem varied at different locations under study. A general trend of decreasing the available P with the depth of soil (except at the Mahananda and Chilapata forest ecosystems) was observed. The average Bray-extractable P was 86.09 kg ha^{-1}. In the Chilapata forest ecosystem the exchangeable (Ca^{+2} + Mg^{+2}) should have a positive correlation with the available P in soil at different depths. A general trend of lowering of K content with the soil depths was observed under this ecosystem. The average K content was 108.70 kg ha^{-1}. The maximum K content was at soils of the Gorumara and minimum at the Mahananda forest. The total (%) C-N-S decreased with the increasing depths of the soil having the average content (%) 2.07, 0.18 and 0.52, respectively. The total H (%) in general decreased with the depth for the soils of Mahananda, Buxa and Chilapata, while increased at Gorumara soils. Comparatively a lower C/N was observed in soil of Boxa than the others (Gorumara, Mahananda and Chilapata) land situations.

Agricultural land :

The soils were collected from four locations

Table 1 : Important properties of soils under the forest ecosystem

Forest soils (L_1)	Depth (cm)	pH (1:2.5)	EC (dSm^{-1})	Ca^{+2}+Mg^{+2} (meq/l)	CEC (meq/100g)	OC (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Total C (%)	Total H (%)	Total N (%)	Total S (%)	C/N	C/S	C/H
Gorumara (S_1)	0-20 (D_1)	5.13	0.10	5.40	26.37	2.51	238.34	92.93	206.45	2.63	0.31	0.24	0.99	12.26	2.75	8.76
	20-40(D_2)	5.05	0.02	3.13	15.40	2.07	200.70	59.84	162.03	2.84	0.38	0.23	0.68	12.58	4.31	7.47
	40-60(D_3)	5.15	0.01	3.00	18.20	2.38	165.16	39.59	128.80	2.68	0.40	0.20	0.61	12.15	4.39	6.51
Mahananda (S_1)	0-20 (D_1)	5.02	0.01	0.80	17.87	2.42	200.70	87.32	76.53	2.98	0.27	0.25	0.44	12.05	7.80	11.08
	20-40(D_2)	5.23	0.04	1.00	17.87	1.51	163.07	55.68	34.72	2.47	0.27	0.21	0.39	12.31	8.04	9.79
	40-60(D_3)	5.62	0.05	1.53	7.43	0.72	148.44	131.25	39.95	1.71	0.15	0.15	0.42	11.54	5.41	12.32
Buxa (S_1)	0-20 (D_1)	4.79	0.03	4.93	31.80	1.55	213.25	25.31	180.69	2.03	0.52	0.22	0.42	9.29	5.66	3.90
	20-40(D_2)	4.77	0.01	3.60	30.27	1.21	200.70	20.43	138.88	1.62	0.50	0.17	0.30	9.69	8.34	3.27
	40-60(D_3)	4.88	0.10	3.20	29.90	1.14	192.34	14.28	124.69	1.48	0.50	0.15	0.27	9.79	9.66	2.95
Chilapata (S_1)	0-20 (D_1)	5.32	0.10	2.00	19.13	1.47	194.43	156.02	101.17	1.83	0.32	0.16	0.62	11.49	4.67	5.97
	20-40(D_2)	5.36	0.06	2.47	14.23	1.09	137.98	167.95	57.87	1.37	0.26	0.12	0.61	12.08	4.06	5.42
	40-60(D_3)	5.49	0.06	10.67	14.80	0.96	119.17	182.42	52.64	1.18	0.25	0.10	0.44	11.35	3.66	4.79
Mean		5.15	0.05	3.48	20.27	1.59	181.19	86.09	108.70	2.07	0.34	0.18	0.52	11.38	5.73	6.85

Table 2 : Important properties of soils under the agro- ecosystem

Cultivated soils (L_2)	Depth (cm)	pH (1:2.5)	EC (dSm^{-1})	Ca^{+2}+Mg^{+2} (meq/l)	CEC (meq/100g)	OC (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Total C (%)	Total H (%)	Total N (%)	Total S (%)	C/N	C/S	C/H
Binnaguri (S_2)	0-20 (D_1)	5.26	0.02	3.80	15.57	1.16	202.79	45.92	174.35	1.39	0.25	0.16	0.69	8.70	2.05	5.66
	20-40 (D_2)	5.55	0.01	5.40	17.77	1.05	152.62	35.80	141.12	1.24	0.22	0.14	0.72	8.60	1.71	5.62
	40-60 (D_3)	5.62	0.07	3.60	15.57	0.78	142.17	40.68	103.41	0.98	0.16	0.13	0.74	7.96	1.39	6.34
Balarampur (S_2)	0-20 (D_1)	7.35	0.02	5.13	33.47	0.91	140.07	26.76	86.99	0.81	0.25	0.15	0.56	6.76	1.98	3.96
	20-40 (D_2)	7.92	0.38	3.47	30.30	0.48	106.62	27.66	107.15	0.81	0.22	0.10	0.56	8.01	1.68	3.87
	40-60 (D_3)	8.06	0.03	5.60	22.27	0.40	62.72	24.95	85.87	0.82	0.21	0.08	0.56	9.80	1.68	3.91
Kumargram (S_2)	0-20 (D_1)	6.14	0.16	10.80	30.67	0.78	133.80	23.86	137.01	0.92	0.23	0.13	0.33	7.19	2.90	4.09
	20-40 (D_2)	6.56	0.07	10.20	26.57	0.63	125.44	21.51	133.65	0.76	0.22	0.11	0.30	7.18	2.68	3.50
	40-60 (D_3)	6.66	0.06	6.47	17.50	0.44	87.81	24.95	96.69	0.56	0.13	0.09	0.27	6.42	2.26	4.39
Kharibari (S_1)	0-20 (D_1)	5.18	0.19	3.53	35.87	1.63	188.16	42.31	254.61	1.87	0.52	0.21	0.13	9.01	14.97	3.59
	20-40 (D_2)	5.18	0.37	2.87	33.73	1.53	186.07	32.54	240.05	1.93	0.55	0.20	0.15	9.62	15.02	3.55
	40-60 (D_3)	5.36	0.13	9.07	43.50	1.33	146.35	24.95	250.13	1.70	0.55	0.17	0.13	9.92	15.00	3.11
	Mean	6.24	0.13	5.83	26.90	0.93	139.55	30.99	150.92	1.15	0.29	0.14	0.43	8.26	5.28	4.30

(Binnaguri, Balarampur, Kumargram and Kharibari) under agricultural field, the properties of which are given in Table 2. The soil samples collected from Binnaguri, Kumargram and Kharibari were acidic, while the soils of Balarampur were towards neutral. The average pH was 6.24 for the soils of agricultural land and in general, there was a trend of increasing pH with the soil depth. The ECs of the soil samples showed the non-saline character with an average value of 0.13 dSm^{-1}. The exchangeable (Ca^{+2} + Mg^{+2}) of the soils of Balarampur and Kumargram were relatively higher than the soils of Binnaguri and Kharibari. The variation may be due to the acidic reaction of the soils and indiscriminate application of liming materials in the field. The oxidisable organic carbon generally decrease with the depth of the soils, being the average of 0.93 per cent. The available nitrogen in soils (0-20 cm depth) was in the order Binnaguri > Kharibari > Balarampur > Kumargram and the content tends to decrease with the increasing depth of the soil. The significant variation of the available P with the depth of the soil was observed. The mean P content of 30.99 kg ha^{-1} of the soils might be due to the fixation of the phosphate under the acidic condition of the soils. The mean exchangeable K was 150.92 kg ha^{-1} in the agricultural field. The exchangeable K in Kharibari soil was highest followed by Binnaguri, Kumargram and Balarampur soils. The exchangeable K decreased with the depth of the soils collected from Binnaguri and Kumargram. In most of the soils, the total C-H-N-S decreased in the sub-surface layers with an

Table 3 : Important properties of soils under the fallow land situation

Fallow land (L_3)	Depth (cm)	pH (1:2.5)	EC (dSm^{-1})	Ca^{+2}+Mg^{+2} (meq/l)	CEC (meq/ 100g)	OC (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Total C (%)	Total H (%)	Total N (%)	Total S (%)	C/N	C/S	C/H
Binnaguri (S_3)	0-20 (D_1)	4.78	0.06	2.00	20.23	1.56	175.62	74.67	113.87	2.00	0.30	0.20	0.75	9.71	2.62	6.42
	20-40 (D_2)	5.10	0.08	1.40	18.43	1.04	163.07	67.98	85.12	1.35	0.24	0.14	0.74	9.43	1.87	5.64
	40-60 (D_3)	4.99	0.01	2.47	19.43	1.11	163.07	101.60	82.88	1.32	0.22	0.14	0.64	9.45	2.26	5.95
Balarampur (S_3)	0-20 (D_1)	6.76	0.52	10.20	24.17	0.72	119.17	37.60	275.52	0.77	0.20	0.11	0.51	6.75	1.63	3.89
	20-40 (D_2)	6.77	0.02	5.80	21.33	0.40	75.26	72.14	258.72	0.46	0.12	0.08	0.55	5.60	0.90	3.62
	40-60 (D_3)	6.99	0.02	7.60	22.60	0.28	56.45	101.97	219.52	0.33	0.12	0.08	0.52	4.19	0.76	2.82
Kumargram (S_3)	0-20 (D_1)	6.07	0.07	6.20	7.13	0.51	123.35	49.18	125.81	0.65	0.08	0.10	0.26	6.51	2.74	9.23
	20-40 (D_2)	6.18	0.06	9.47	16.40	0.44	108.71	41.04	137.76	0.51	0.07	0.10	0.29	5.12	1.76	7.76
	40-60 (D_3)	6.21	0.06	6.73	16.93	0.52	140.07	34.17	148.59	0.65	0.11	0.13	0.29	5.19	2.42	5.84
Kharibari (S_3)	0-20 (D_1)	5.17	0.93	3.53	23.30	2.05	313.60	56.23	149.33	2.68	0.54	0.30	0.32	8.90	8.97	4.98
	20-40 (D_2)	4.84	0.21	2.87	19.47	1.72	213.25	47.37	122.08	2.11	0.46	0.23	0.12	9.43	9.35	4.63
	40-60 (D_3)	4.97	0.18	9.07	31.30	1.56	198.61	45.02	226.61	1.80	0.44	0.20	0.14	9.01	10.26	4.14
	Mean	5.74	0.19	5.61	20.06	0.99	154.19	60.75	162.15	1.22	0.24	0.15	0.43	7.44	3.80	5.41

Table 4 : Important properties of soils under the tea gardens

Tea gardens (L_4)	Depth (cm)	pH (1:2.5)	EC (dSm^{-1})	Ca^{+2}+Mg^{+2} (meq/l)	CEC (meq/100g)	OC (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Total C (%)	Total H (%)	Total N (%)	Total S (%)	C/N	C/S	C/H
Moraghat (S_4)	0-20 (D_1)	4.26	0.48	2.73	28.13	1.90	225.79	241.90	214.29	2.40	0.35	0.24	0.70	9.98	3.57	6.84
	20-40 (D_2)	4.57	0.01	3.13	27.40	1.35	177.71	46.46	137.39	1.66	0.32	0.16	0.63	10.37	2.97	5.18
	40-60 (D_3)	4.59	0.01	3.07	24.67	1.22	175.62	42.31	135.89	1.48	0.28	0.14	0.57	10.38	2.88	5.19
Ellenbari (S_4)	0-20 (D_1)	4.35	0.02	1.47	21.03	1.59	175.62	301.56	119.47	1.75	0.19	0.19	0.49	9.57	4.47	9.52
	20-40 (D_2)	4.56	0.02	1.40	16.33	1.26	175.62	120.77	104.91	2.17	0.26	0.20	0.47	10.65	5.20	8.50
	40-60 (D_3)	4.73	0.01	1.40	12.73	1.19	194.43	68.34	116.11	1.42	0.18	0.14	0.41	10.12	4.02	7.85
Nimti (S_4)	0-20 (D_1)	4.32	0.44	3.87	37.90	1.78	236.25	30.55	501.01	2.27	0.44	0.22	0.27	10.28	6.23	5.16
	20-40 (D_2)	5.35	0.09	2.13	37.50	1.27	175.62	18.26	329.65	1.53	0.42	0.15	0.30	10.10	5.50	3.65
	40-60 (D_3)	5.39	0.01	3.40	32.93	1.27	173.53	18.62	255.73	1.57	0.41	0.14	0.33	11.35	5.69	3.86
Kumargram (S_4)	0-20 (D_1)	5.03	0.15	7.80	22.13	0.85	133.80	52.43	185.92	0.99	0.16	0.15	0.25	6.78	4.05	6.52
	20-40 (D_2)	5.18	0.08	5.80	26.40	0.78	148.44	27.84	182.93	0.91	0.17	0.13	0.27	7.03	3.79	5.44
	40-60 (D_3)	5.03	0.07	7.20	26.10	0.49	146.35	18.98	114.99	0.55	0.15	0.10	0.25	5.30	2.30	3.55
	Mean	4.78	0.12	3.62	26.10	1.25	178.23	82.34	199.86	1.56	0.28	0.16	0.41	9.33	4.22	5.94

average distribution (%) of C-H-N-S as 1.15 – 0.29 – 0.14 – 0.43, respectively. The C/N was found in the order as Kharibari > Binnaguri > Kumargram > Kumargram. The average C/N of the agricultural field was 8.26.

Tea garden :

The soils were collected from tea gardens of Moraghat, Ellenbari, Nimti and Kumargram areas and their important properties are shown in Table 4. The soils were acidic with an average pH of 4.78 and ECs of 0.12 dSm^{-1}. The exchangeable (Ca^{+2} + Mg^{+2}) in soils of Kumargram was relatively higher than Moraghat, Ellenbari and Nimti soils. The variation may be due to the lowering of the soil pH and improper application of liming materials in the field (Ray and Mukhopadhyay, 2012). A general trend of decrease of the organic carbon

Table 5 : Interactions among soil properties and different ecosystems

	pH (1:2.5)	EC (dSm^{-1})	Ca^{+2}+Mg^{+2} (meq/l)	CEC (meq/100g)	OC (%)	Available N(kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Total C (%)	Total H (%)	Total N (%)	Total S (%)	C/N	C/S	C/H
Land (L)															
L_1	5.15	0.0485	3.48	20.27	1.59	181.19	86.09	108.70	2.09	0.340	0.180	0.520	11.38	5.73	6.85
L_2	6.24	0.1254	5.70	26.90	0.93	139.55	30.99	150.92	1.17	0.290	0.140	0.430	8.26	5.28	4.30
L_3	5.74	0.1863	5.61	20.06	0.99	154.19	60.75	236.82	1.22	0.240	0.150	0.430	7.44	3.80	5.41
L_4	4.78	0.1167	3.62	26.11	1.25	178.23	82.34	199.86	1.56	0.280	0.160	0.410	9.33	4.22	5.94
LSD (P=0.05)	0.022	0.0006	0.129	0.067	0.003	2.718	0.390	0.814	0.022	0.009	0.004	0.078	0.194	1.188	0.357
Sites (S)															
S_1	5.00	0.0744	3.26	20.60	1.51	181.89	74.14	140.47	1.82	0.290	0.180	0.710	10.13	2.73	6.30
S_2	6.11	0.0960	3.78	20.62	0.99	134.85	88.00	164.45	1.41	0.200	0.150	0.490	8.95	3.63	6.76
S_3	5.61	0.0955	5.92	26.29	0.96	159.24	26.85	192.52	1.22	0.300	0.140	0.300	8.18	4.66	4.80
S_4	5.18	0.2110	5.44	25.83	1.29	177.18	71.17	198.86	1.59	0.360	0.170	0.290	9.16	8.01	4.64
LSD (P=0.05)	0.022	0.0006	0.129	0.067	0.003	2.718	0.390	0.814	0.022	0.009	0.004	0.078	0.194	1.188	0.357
Depths (D)															
D_1	5.31	0.2055	4.85	24.67	1.46	188.42	84.03	223.44	1.77	0.310	0.190	0.480	9.01	4.82	6.22
D_2	5.51	0.0966	4.11	23.09	1.11	156.93	53.96	155.38	1.50	0.290	0.150	0.440	9.22	4.83	5.43
D_3	5.61	0.0557	4.85	22.24	0.99	144.52	57.13	143.41	1.27	0.270	0.130	0.410	9.07	4.63	5.22
LSD (P=0.05)	0.020	0.0005	0.112	0.059	0.003	2.356	0.337	0.705	0.020	0.008	0.004	NS	0.168	1.031	NS
L × S															
LSD (P=0.05)	0.048	0.0010	0.258	0.135	0.006	5.439	0.781	1.629	0.045	0.018	0.008	0.157	0.387	2.378	0.716
L × D															
LSD (P=0.05)	0.042	0.0010	0.222	0.115	0.003	4.709	0.677	1.410	0.039	0.016	0.007	NS	0.334	NS	0.621
S × D															
LSD (P=0.05)	0.042	0.0010	0.222	0.115	0.003	4.709	0.677	1.410	0.039	0.016	0.007	NS	0.334	NS	NS
L × S × D															
LSD (P=0.05)	0.081	0.0019	0.444	0.230	0.008	9.418	1.353	2.819	0.079	0.031	0.015	NS	0.671	NS	1.238

NS=Non-significant

Table 6 : Correlation co–efficients among different soil properties and nutrient pools

Soil properties	pH	EC	Organic C	(Ca^{+2} + Mg^{+2})	CEC
Available N	-0.733**	0.419**	0.809**	-0.432**	0.201*
Available P	-0.292**	0.001	0.216**	-0.253**	-0.342**
Available K	-0.001	0.696**	0.144	0.199*	0.439**
Total C	-0.639**	0.217**	0.948**	-0.577**	0.085
Total N	-0.630**	0.400**	0.891**	-0.442**	0.191*
Total S	0.017	-0.149	0.136	-0.230**	-0.263**
C : N	-0.493**	-0.073	0.705**	-0.607**	-0.044
C : S	-0.334**	0.238**	0.399**	-0.166*	0.400**
C : H	-0.281**	-0.178*	0.285**	-0.388**	-0.617**

* and ** indicate significance of values at P=0.05 and P=0.01, respectively

with the depth of soils was observed. The available nitrogen, phosphorus and K also varied with the depth of the soils with an average value of 178.23, 82.34 and 199.86 kg ha^{-1}, respectively. The total C-H-N-S also varied with the soil depth in this region. The average C/N of the tea garden soils was 9.33.

Fallow land :

The soils were collected from the uncultivated fallow land of Binnaguri, Balarampur, Kumargram and Kharibari sites and were characterised with important soil properties (Table 3). All the soils were acidic in reaction (average pH 5.74) and ECs as 0.19 dSm^{-1}. A general trend of increasing the (Ca^{+2} + Mg^{+2}) content was observed with the soil depth having an average of 5.61 meq/l. This may be due to the sub-surface deposition of (Ca^{+2} + Mg^{+2}) with leaching water. The average organic carbon content (0.99 %) was observed in this region while the mean available N-P-K (kg ha^{-1}) were 154.19, 60.75 and 162.15 kg ha^{-1}, respectively in soils (Table 3). The total available C-H-N-S (%) in soils were 1.22, 0.24, 0.15 and 0.42, respectively. The variation of C/N with the soil depth was observed with an average of 7.44 in soils under the fallow land situation.

While comparing the CEC of the soils in all the ecosystems (Table 1 to Table 4), it was observed that the CEC of soils of Agriculture> Tea garden> Forest> Fallow. This may be due to the difference in the degree of input of nutrients under different ecosystems.

The available N and P content (Fig. 1) in forest land, fallow land and tea garden soils were quite comparable than under agricultural land. The available K content in soils was found to be in the order as fallow land > tea garden > agriculture land > forest land.

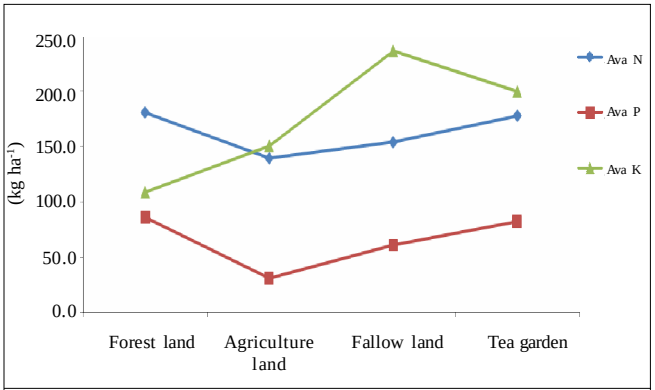

Fig. 1 : Change in available N-P-K (kg/ha) with different ecosystems

A significant positive interaction among the different ecosystems and soil properties (Table 5) was observed, although, the total S and C/H were statistically at par with the soil depths and locations under different ecosystems. This might be due to the insufficient use of sulphur aided nutrients into the soils of these ecosystems.

From the correlation study(Table 6), it was observed that soil pH had a significant negative correlation with available N, available P, total carbon, C : N, C : S and C : H. The EC of soil had a positive correlation with available N, available K and negative with C : H. The oxidisable organic C had a significant positive correlation with available N, available P, total C, total N, C : N, C : S and C : H. The (Ca^{+2} + Mg^{+2}) of the soil had a significant negative correlation with available N, available P, total C, total N, total S, C : N, C : S, C : H and positive with available K . The significant negative correlation between CEC and available P, total S, C : H and positive correlation between available N and available K, total N and C : S was observed.

Conclusion :

From the study, it was observed that land use and management practices had a significant role to play on changing the available N, P and K status and also the (Ca^{+2} + Mg^{+2}) and organic carbon content in soils. The properties of the soils under the fallow land varied significantly with the other ecosystems (tea garden, agriculture and forest). The comparison of the status of the physico-chemical properties at different ecosystems emphasizes the need for proper management of the soils to refrain from soil erosion, reduction in soil fertility and land degradation.

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