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Soil Properties and Fertility Status of Terai Soils of West Bengal as Influenced by Different Land Use

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Abstract

Agro-ecosystem functioning and sustained land productivity are closely associated with land use induced change. We compared changes in soil properties and fertility status of four major land uses viz. barren, cultivated, forest and tea plantations, in the terai region of West Bengal. Among the physico-chemical properties studied, distinct difference was observed in the pH of the soils, with tea and forest soils being more acidic. This was related to the exchangeable calcium and magnesium content of the soils. More clay content was associated with cultivated soils which were pedogenically in advanced stage of weathering which also influenced the water holding capacity of these soils. However organic carbon was more in tea and forest soils as compared to barren or cultivated soils which was also deflected in the cation exchange capacity and total nitrogen content of the soils. Cycling of organic matter was more rapid in the cultivated soils and greater amount of mineral nitrogen was observed in cultivated soils. All the soils were sufficient in micronutrient status because of the acidic pH. Cultivated and tea soils had higher micronutrients because of external additions. Fungi dominated tea soils and bacteria dominated forest soils. Greater amount of actinomicetes were found in soils left barren.
Key words : Land use, Soil properties, Soil fertility.

The terai agro-climatic zone is a well-marked distinct physiographic unit of the state of West Bengal. The sub-mountain tract lying at the top hills of the Himalayas is characterized by deep steep sided valleys, separated by terraced high lands, while the flat alluvial terrain towards the south locally referred to, as terai constitutes the plain zone. Based on the old system of classification the soils of the terai zone can be broadly classified into Teesta alluvium, terai and brown forest soils. However, according to the modern system of classification terai soils are association of Dystrochrepts and Haplaquepts of the order Inceptisols and Udifluvent/Udorthent/Ustorthent of the order Entisol. A number of soil series have also been established in this region. But a given soil series cannot be considered to have a static set of characteristics. Drooger and Bouma (1) distinguished between soil genoform and soil phenoform, the former has been defined as the genetically defined soil series and the latter indicates differences in a certain genoform as a result of different land use history. Land use and related management practices influences soil properties and therefore soil functioning (2). In the terai zone of West Bengal, 50% of the area is net sown followed by 14% area under forests, 9% occupied by plantation crops and 4% area under barren and 1% falls under fallow and cultivable wastes (3). Long-term effect of such land use may cause many environmental and soil factors to interact resulting in different soil conditions. The paper sets to investigate the divergence in soil properties of soils derived form pedogenically similar parent material due to difference in land use.

Methods

Sixteen surface soil samples (0—15 cm) representing fallow (4), cultivated (4), forest (4) and tea (4) soil from terai region of West Bengal were studied. The pH and EC were measured in water using 1:2.5

Table 1. Physico-chemical properties of soils differing in land use.

		Barren	Cultivated	Forest	Tea plantation
pH	Range	5.30—6.72	4.93—5.75	4.84—5.43	4.57—4.96
	Median	6.01	5.14	5.01	4.82
	SD	0.58	0.35	0.28	0.20
EC (dS/m)	Range	0.03—0.12	0.04—0.14	0.01—0.03	0.04—0.13
	Median	0.03	0.09	0.03	0.07
	SD	0.05	0.05	0.01	0.04
Sand (%)	Range	57.88—74.88	51.44—65.88	62.88—79.88	59.88—69.60
	Median	64.24	53.14	76.24	67.92
	SD	7.14	6.84	7.79	4.37
Silt (%)	Range	15—28	16—27	11—22	13—20
	Median	24.00	24.98	13.00	18.50
	SD	5.74	4.98	5.19	3.32
Clay (%)	Range	10.12—14.12	18.12—24.56	9.12—15.12	12.04—20.12
	Median	11.76	20.38	10.76	16.26
	SD	1.73	2.85	2.62	4.04
Max WHC (%)	Range	39.4—49.9	41.8—55.6	37.7—58.8	41.8—52.6
	Median	48.00	51.12	41.53	48.48
	SD	4.69	5.81	9.81	4.54
CEC (Cmol(+)/kg)	Range	4.68—8.19	3.3—4.45	3.28—9.99	3.6—8.55
	Median	5.14	3.89	6.03	7.60
	SD	1.62	0.53	3.06	2.21
Organic C (g/kg)	Range	4.6—14.8	4.1—13.8	13.0—20.4	6.9—14.0
	Median	10.30	6.90	16.25	11.80
	SD	0.51	0.43	0.39	0.33

soil : solution ratio. Texture was estimated by the hydrometer method, maximum water holding capacity by Keen and Rockzowski's method, nitrate and ammonium form of nitrogen was extracted with 2 M KCl and then analyzed by distillation method. Available P was extracted by Bray IP extractant and then determined colorimetrically. Available K, available Ca+Mg, and available Na were extracted by neutral normal ammonium extractable. Organic carbon was estimated by wet digestion using chromic acid; total nitrogen by sulfuric-salicylic acid digestion and then by steam distillation method; for total P and K a di-acid digestion method was followed. The cation exchange capacity (CEC) was measured by the ammonium saturation method using IN NH_4OAc. Available micronutrients were extracted using DTPA and analyzed in atomic absorption spectrophotometer. The microbial status was enumerated by serial dilution and incubation in appropriate growth medium.

Results and Discussion

Physico-Chemical Properties

The important physico-chemical properties are presented in Table 1. All soils were acidic in reaction and the pH in barren, cultivated, forest and tea soils varied between 5.30 to 6.72 (mean 6.01), 4.93 to 5.75 (mean 5.24), 4.84 to 5.43 (mean 5.07) and 4.57 to 4.96 (mean 4.79) respectively. The general acidic reaction of all soils is probably due to leaching of bases resulting from high rainfall (> 2,000 mm/annum). The average pH trend was barren > cultivated > forest > tea soils. Good drainage condition maintained in tea soils resulting in rapid leaching and enhancement of the weathering process giving rise to high Al levels, thereby lowering the pH. Paul and Ghosh (4) reported that pH of terai soils are a function of aluminium saturation of effective CEC. Forest soils receive a continuous supply of organic matter and low pH has been reported in soils under forest (5). Cultivated soils receiving a lot of fertilizers had an intermediate pH and barren soils which neither receive organic matter or inorganic salt addition exhibited the highest pH. The electrical conductivity of the soils was in general low because of the light soil texture and leaching of soluble bases. The mean EC values in barren, cultivated, forest and tea soils were 0.05, 0.09, 0.02 and 0.08 dS/m,

Table 2. Total and available nutrient status of soils differing in land use.

		Barren	Cultivated	Forest	Tea plantation
Total N (%)	Range	0.088—0.162	0.083—0.163	0.086—0.159	0.100—0.131
	Median	0.13	0.10	0.11	0.12
	SD	0.03	0.04	0.04	0.01
Total P (%)	Range	0.039—0.117	0.034—0.112	0.019—0.063	0.024—0.092
	Median	0.05	0.08	0.05	0.07
	SD	0.04	0.04	0.02	0.03
Total K (%)	Range	1.26—2.10	1.04—2.31	0.66—1.52	1.3—2.61
	Median	1.40	1.55	1.20	1.51
	SD	0.38	0.52	0.38	0.60
NH_4^+ -N (mg/kg)	Range	9.09—20.01	9.09—23.56	5.46—12.74	7.28—12.74
	Median	14.56	16.38	10.92	9.09
	SD	4.70	6.13	3.49	2.29
NO_3^- -N (mg/kg)	Range	9.09—16.38	5.46—16.38	3.64—7.28	3.64—14.56
	Median	13.65	11.83	6.37	5.46
	SD	3.11	4.55	1.74	5.15
Available P (mg/kg)	Range	3.55—244.5	6.3—236	3.90—92	8.62—96.12
	Median	8.40	89.63	42.38	50.88
	SD	118.93	115.66	43.64	38.99
Available K (mg/kg)	Range	60—115.5	49.5—130.5	60—91.5	73.5—127.5
	Median	66.75	81.75	75.75	96.00
	SD	25.71	34.65	13.56	24.78
Exchangeable	Range	2.702—6.345	1.645—2.067	0.705—2.115	0.822—1.762
Ca + Mg (Cmol(+)/kg)	Median	3.41	1.88	1.65	1.35
	SD	1.62	2.01	0.57	0.53

respectively. The higher EC values under cultivated and tea soils is probably because of more fertilizer addition.

The mean clay content varied from around 11 to 20%, the lower values being representative of barren and forest soil and the higher side of the range for cultivated and tea soil. The clay content reflected the degree of weathering, tea and cultivated soils being more weathered than forest and barren soils. The mean maximum water holding capacity of barren, cultivated, forest and tea soil were 46.3, 49.9, 44.9 and 47.8% on the dry soil basis. The maximum water holding capacity was positively correlated to finer soil fraction silt ($r = 0.71^{**}$) and clay ($r = 0.39$). Organic carbon content varied from 0.46 to 1.39 (mean 1.00), 0.41 to 1.38 (mean 0.79), 1.30 to 2.04 (mean 1.65) and 0.69 to 1.40 (mean 1.11) percent in barren, cultivated, forest and tea soils, respectively. Highest organic carbon content was observed in forest soil that may be due to the continuous recycling of forest litter. The barren and tea soils that are little disturbed showed similar organic C status. Continuous tillage operations and turning over of soil results in organic matter depletion and hence lowest organic C was observed in cultivated soils. The barren soil in which grass grows and tea soils, which are little disturbed, had similar organic carbon status. Organic carbon content stabilize the soil by improving aggregation and water holding capacity (6) and thereby increase productivity.

Data pertaining to cation exchange capacity (CEC) is presented in the Table 1. The CEC ranged from 4.68 to 8.19 (mean 5.78), 3.3 to 4.45 (mean 3.88), 3.28 to 9.99 (mean 6.33) and 3.6 to 8.55 (mean 6.84) me/100 g soil in barren, cultivated, forest and tea soil respectively. Significant positive correlation of cation exchange capacity with organic matter ($r = 0.66^{**}$). The results clearly indicate the importance of organic matter in these soils affecting CEC.

Nutrient Status

The available nutrient status (N, P, K, Ca + Mg) of four different land uses is presented in the Table 2.

Table 3. Available micronutrients and microbial status of soils differing in land use.

		Barren	Cultivated	Forest	Tea plantation
Zn (ppm)	Range	0.42—14.07	0.21—2.26	0.14—0.67	0.67—4.84
	Median	1.17	0.80	0.27	1.06
	SD	6.60	0.98	0.24	1.97
Fe (ppm)	Range	32.99—119.08	86.53—200	61.08—109.4	92.71—154.34
	Median	57.24	112.62	89.17	128.97
	SD	37.07	49.59	25.58	28.01
Cu (ppm)	Range	2.11—3.77	1.17—4.85	1.41—2.48	1.82—3.34
	Median	3.39	3.42	1.98	3.00
	SD	0.73	1.53	0.51	0.68
Mn (ppm)	Range	9.1—18.65	12.27—21.41	5.93—18.54	6.56—17.28
	Median	12.21	13.40	6.67	9.95
	SD	4.58	4.26	6.07	4.59
Bacteria	Range	13.3—49.6	8.3—49.5	200—303	1.9—8.5
(× 10^6/g soil)	Median	28.30	16.05	223.00	4.05
	SD	15.13	18.39	45.89	3.20
Fungi	Range	10.30	3.5—29	10.3—25.3	63—405
(× 10^3/g soil)	Median	14.65	15.95	18.15	209.00
	SD	9.42	10.42	6.64	177.97
Actinomycetes	Range	11.7—133	12.6—37.3	19—28	17.5—29.3
(× 10^5/g soil)	Median	58.95	29.50	22.50	22.95
	SD	58.80	10.43	4.24	4.85

The 2M KCl extractable nitrogen status of these four land use are expressed in NH_4^+ -N and NO_3^- -N form. The available NH_4^+ form of N varied from 9.09 to 20.01 (mean 14.55) mg/kg in barren soil, 9.09 to 23.65 (mean 16.37) mg/kg in cultivated soils, 5.46 to 12.74 (mean 10.01) mg/kg in forest soils and 9.09 to 12.74 (mean 9.55) mg/kg in tea soils. The soils under barren, cultivated, forest and tea cultivation contained available NO_3^- form of N from 9.09 to 16.38 (mean 16.38), 5.46 to 16.38 (mean 11.37), 3.64 to 7.28 (mean 5.91), and 3.64 to 14.56 (mean 7.28) mg/kg of soil, respectively. The NH_4^+ -N content was in general higher than NO_3^- -N in all soils. The lower content of NO_3^- -N may be due to rapid plant uptake, delayed nitrification at low pH and or leaching of NO_3^- from the profile. The available N content in barren and cultivated soil was higher than tea and forest soil. Both forms of N are negatively correlated to organic carbon (r = -0.31 for NH_4^+ and –0.41 for NO_3^- -N, respectively) and NH_4^+ -N was positively correlated to clay content (r = 0.31). Thus, the source of soil N might be the mineralization of organic carbon (7) and weathering of illitic type of clay, present in these soils. Available N content (NH_4^+ + NO_3^-) in the cultivated soil was higher than tea or forest soil probably due to continuous N fertilizer addition and rapid turn over of organic matter brought about by tillage operations.

The available P content varied from low to high under soil from different uses. Available P content in soil varied from 3.55 to 244.5 (mean 62.2), 6.3 to 236.0 (mean 105.4), 3.9 to 92.0 (mean 45.2) and 8.62 to 96.12 (mean 51.6) mg/kg under barren, cultivated, forest and tea cultivation, respectively. The available K status varied from low to medium. The available K content in barren, cultivated, forest and tea soils varied from 60.0 to 115.5 (mean 77.25), 49.5 to 130.5 (mean 85.8), 60.0 to 91.5 (mean 75.7) and 73.5 to 127.5 (mean 98.2) mg/kg of soil, respectively. The available K content was correlated (Table 4) to EC of the soil (r = 0.55*). The available K content of barren and forest soil represents the native soil K status with no external additions. The much higher values observed in cultivated and tea soils are probably a result of external additions.

(Ca + Mg) content in these soil are low. (Ca + Mg) content varied from 2.702 to 6.345 (mean 3.965), 1.645 to 2.467 (mean 1.967), 0.705 to 2.115 (mean 1.527) and 0.822 to 1.762 (mean 1.321) me/100 g soil under barren, cultivated, forest and tea cultivation (Table 2). The low content of (Ca + Mg) may be due to the light texture of the soil and occurrence of high rainfall, which causes rapid leaching of basic cations (8).

Table 4. Relationship among soil properties, total and available nutrients.

Parameter	*R* value
Maximum water holding capacity vs Silt	0.71**
Maximum water holding capacity vs Clay	0.39
CEC vs Organic carbon	0.66**
NO3-N vs Organic carbon	-0.31
NH_4^+ -N vs Organic carbon	-0.41
NH_4^+ -N vs Clay	0.31
Available K vs EC	0.55*
pH vs Ca+Mg	0.94**
Total N vs Organic carbon	0.64**
Total N vs clay	0.55*
Total P vs Ca + Mg	-0.14
Total K vs clay	0.47
Total K vs Silt	0.56*

It is positively correlated to pHw (*r* = 0.94**) suggesting that improvement of (Ca + Mg) status by liming would improve the pH. The range and mean of Na content (Table 2) of all the land uses were 0.90—1.05 (mean 0.97) me/100 g soil for barren, 0.90—1.01 (0.97) me/100 g soil for cultivated soil, 0.80—0.86 (0.83) me/100 g soil for forest soil and 0.84—0.93 (0.88) me/100 g soil for tea soil.

Total Nutrient Status

Total nitrogen content in barren, cultivated, forest and tea soil varied from 0.088 to 0.162 (mean 0.126), 0.083 to 0.163 (mean 0.112), 0.086 to 0.159 (mean 0.116) and 0.104 to 0.131 (mean 0.118) %, respectively (Table 2). Total N content was positively correlated to organic carbon (*r* = 0.64**) and CEC (*r* = 0.55*). Gupta et al. (2001) reported positive relation between total N and organic matter. Since greater than 90% of total soil N exists in organic combinations, the significant positive correlation is obvious.

The total P content varied from 0.039 to 0.117 (mean 0.064), 0.034 to 0.112 (mean 0.075), 0.019 to 0.063 (mean 0.043) and 0.024 to 0.092 (mean 0.065)% under barren, cultivated, forest and tea soils respectively (Table 2). Total P was negatively correlated to (Ca + Mg) content (*r* = -0.14) suggesting that due to the acid character of the soil P may get fixed in Fe and Al forms. Total K content in these soils varied widely from 1.26 to 2.1 (mean 1.54), 1.04 to 2.31 (mean 1.61), 0.66 to 1.52 (mean 1.14) and 1.3 to 2.61 (mean 1.73) percent (Table 2) for barren, cultivated, forest and tea soil, respectively. Total K content was positively correlated to the clay (*r* = 0.47) and silt content of the soils (*r* = 0.56*). Similar findings were reported by Boruah and Nath (9). Since the source of soil K is dominantly the clay and silt fraction and since the soils of terai region have dominantly illitic and kaolinitic type of clay (10) the results are in conformity.

Micronutrient Status

The average DTPA extractable zinc content (Table 3) in barren, cultivated, forest and tea soils was 4.21, 0.81, 0.34 and 1.91 ppm respectively. Considering 1 ppm Zn as critical limit, all cultivated and forest soils are deficient in available zinc. The average DTPA extractable Fe content was 66.64, 127.94, 87.21 and 126.25 ppm respectively for barren, cultivated, forest and tea soils respectively. All soils had Fe content much higher than the critical limit of 4.5 ppm. Cultivated and tea soils had much higher Fe content than barren or forest soils. The average Cu content was 316, 3.21, 1.96 and 2.79 ppm respectively for barren, cultivated, forest and tea soils respectively. Considering 0.2 ppm as the critical limit, all soils were sufficient supplied with copper. The available Mn content was high in all soils considering 1 ppm DTPA extractable Mn as the critical limit. The average DTPA extractable Mn was 13.04, 15.12, 9.45 and 10.93 ppm respectively for barren, cultivated, forest and tea soils respectively.

Microbial Status

Average bacterial count in barren, cultivated, forest and tea soils was 29.88, 22.48, 237.25 and 4.63 × 10^6 per gram soil (Table 3) respectively. Forest soils contain highest number of bacteria that may be due to higher organic carbon content. Tea soil contains less number of bacteria probably because tea plant grows well in acid soil condition and bacteria cannot survive well under acidic range of pH (Table 4). The average fungal population was 17.33, 16.1, 17.98 and 221.5 × 10^3 per gram soil for barren, cultivated, forest and tea soils respectively. Tea soils having lowest pH also showed the predominance of fungal population. The population of actinomycetes followed the pattern barren > cultivated > forest = tea soils. Barren soils having highest pH content which favors higher population of actinomycetes. Forest aoils and tea soils showed less actinomycetes population probably due to lower pH condition of those soils.

Conclusion

Terai soils of eastern India are similar pedogenically, having developed form the same parent material and under similar climatic conditions. But differences in land use and related management practices (implying differences in plant species, soil tillage, drainage and use of organic and inorganic manures and fertilizers and amendments) influenced soil properties and therefore soil functioning (2). Long term effect of such land use has caused many environmental and soil factors to interact resulting in different soil conditions. Thus within a genoform a number of phenoforms have developed according to land use viz. barren, cultivated, forest and tea plantation.

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