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Soil physico-chemical attributes of Bangabandhu Jamuna eco-park, Sirajganj, Bangladesh

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Abstract

The soil physical and chemical properties (*viz*., moisture content, maximum water-holding capacity, pH, organic carbon, organic matter, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, zinc, copper, and manganese) of Bangabandhu Jamuna Eco-Park (BGEP), Sirajganj, Bangladesh was analyzed during 2021-2022. It was evident that the soils of the study area were slightly acidic in nature, where the pH values ranged from 5.88 to 6.69. The average moisture content and maximum water holding capacity of soils varied from 4.55% to 15.41% and 32.55% to 40.42%, respectively. The maximum moisture content 15.41% was recorded in Site D and the minimum value 4.55% was recorded in Site B, whereas the highest maximum water-holding capacity 40.42% was recorded in Site C and the lowest value 32.55% was recorded in Site B. The maximum organic carbon content of 2.41% was recorded at site D and the minimum value was 1.77% at Site B. The average values of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, zinc, copper, and manganese ranged from 0.09 to 0.12%, 7.01 to 8.20 μg/g, 0.13 to 0.17 meq/100g, 9.31 to 12.14 meq/100g, 1.27 to 1.94 meq/100g, 2.44 to 3.44 μg/g, 1.17 to 2.98 μg/g, 0.17 to 0.89 μg/g and 1.25 to 1.74 μg/g, respectively. The values of physical and chemical properties were also found to vary among surface (0-16 cm), sub-surface (17-32 cm) and substratum (33-48 cm) layers of soil. Significant correlation was found among the recorded soil parameters. A comprehensive finding of the current status of the physico-chemical attributes of soils in this important eco-park has been obtained, which will help in the eco-friendly management and development of this eco-park.

Key words: Soil, Physico-chemical attributes, Bangabandhu Jamuna eco-park.

INTRODUCTION

Bangladesh is a small South Asian nation with a huge population and limited natural resources. Most people have a high degree of dependency on the forest for their livelihoods, which results in the degradation of forest ecosystems and the depletion of natural resources (Muhammed *et al*., 2008b). Soil is a fundamental integral part of natural resources that is usually unconsolidated into variable depth, massively differentiated into a few horizons of organic constituents and inorganic minerals, which have differences from parental material in terms of morphology, physical, chemical, and biological characteristics and constitutions (Jenny, 1914). Forest floor has distinct features, mainly consists of decomposing organic matter and litter, which supports a dynamic phase for the development of characteristics in soil flora and fauna (Prichett and Fisher, 1987). Soil's physical and chemical properties determine the overall composition of the plant

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community and the regeneration potential of plants (Sigdel *et al.*, 2015) which results in variations in plant productivity and vegetation growth. Therefore, proper and intimate knowledge of soil properties and their distribution is an essential pre-requisite for developing local and national level land management plans for forestry, agriculture, and other uses (Mandal, 2013). Soil properties depend on many environmental factors like elevation, slope, landscape, climate, microclimate, topography, geographical distribution, and vegetation (Chen *et al.*, 1997).

A distinctive difference has been seen in forest and other soils due to developmental processes. Forest soils are highly characterized by higher porosity, permeability, more stable soil aggregates, and greater water-holding capacity in comparison with other soils (Sozykin, 1939). Besides, soil acts as a foundation for any natural resources, agricultural practices, and the development of any infrastructure. Soil is an integral part of the ecological cycle, such as the nutrient and water cycles. Soil is also a phenomenal reservoir of carbon. But the status of forest soils and their biodiversity is worsening day by day due to natural calamities and human intervention. In these circumstances, the government of Bangladesh has established a number of protected areas for the protection and conservation of vegetation and wildlife, as well as their natural habitats, including soil. BGEP is the newest eco-park in Bangladesh, established in 2008. Since its establishment, no detailed information on the physico-chemical attributes of soils is available. So, an initiative was undertaken to study the physical and chemical properties of the soils in this eco-park to know the present condition and nutrient status of the soils for sustainable management and eco-friendly conservation of this eco-park.

MATERIALS AND METHODS

Description of the study area: BGEP is located in the South Sirajganj forest range in the Rajshahi forest division under the Brahmaputra-Jamuna floodplain biogeographic zone (Nishat *et al*., 2002). It is adjacent (western part) to Bangabandhu Jamuna Bridge and about 12 km south of Sirajganj Sadar upazila. It is located in the northern part of the national highway-N405 Elenga road. The currently notified area of the eco-park covers an area of 124 acres (50.20 ha). The area of beats is located under the south Sirajganj range of the Rajshahi division (BFD, 2008). Its GPS coordinates are under 24°24′3.59″N latitude and 89°44′45.59″E longitude. About 28-30 acres of this eco-park are under the supervision of the Bangladesh Army and have small tree cover (in Fig.1).

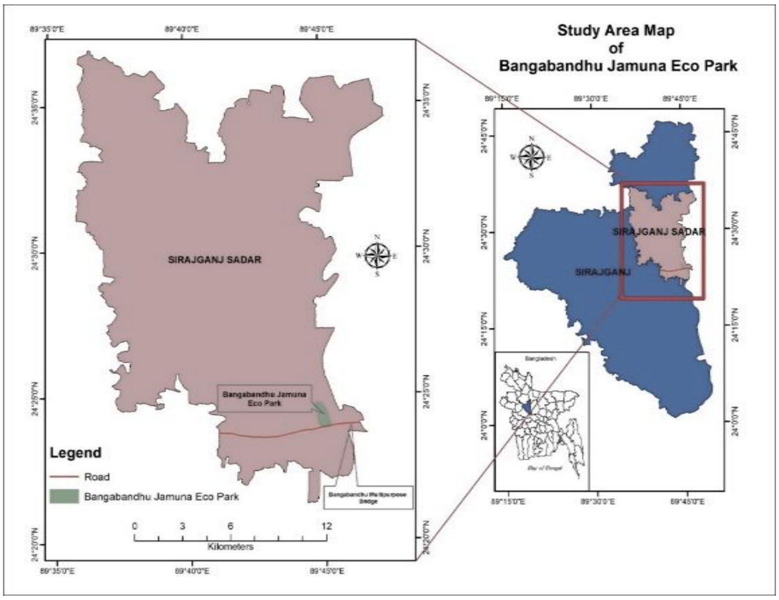

Fig. 1. Map showing the study area of BGEP under Sirajganj district

The study area was divided into five different sites on the basis of topographic features, geospatial location, habitat distribution, and vegetation composition. The sites were recognized as- Site-A (*Albizia* dominated low land, 24°24′3.59″N, 89°44′52.8″E); Site-B (*Casuarina*-*Eucalyptus* mixed forest, 24°24′21″N, 89°44′45.59″E); Site-C (Marginal forest near east part of Jamuna river, 24°24′3.58″N, 89°45′7.1″E); Site-D (Deep center forest region, 24°24′32.3″N, 89°44′56.3″E); and Site-E (*Casuarina* dominated high land, 24°23′56.4″N, 89°45′7.1″E). For the analysis of soil samples from different sites, a dry season was selected for the collection of fresh soil samples, which was done on April, 2022.

Collection and processing of soil samples: Soils were randomly collected from five different sites. Soils were collected from three different vertical layers, such as- Surface layer (S, 0-16 cm), Sub-surface layer (SS, 17-32 cm) and Substratum layer (ST, 33-48 cm) of each site. Soil samples were taken into different polybags according to soil layers. After taking soil from each sub-site, soils were mixed properly to make a composite soil sample (CSS), and soils were collected from each sample into another polybag according to soil layers (Shukla and Chandal, 1993; Ahmed *et al*., 2010). In this way, composite soil samples were collected from each selected site. Collected samples were divided into two parts. One was taken into air-tied polybags to prevent the loss of moisture contents and other part was kept into another polybag to evaluate the chemical properties of soils. Air-tied soils were used for analyzing the physical properties. Other soils were dried in air. Air-dried soils were ground and passed through 2 mm sieve. Messed soils were prepared for the chemical analysis.

Analysis of soil samples: Field moisture content (MC) and maximum water holding capacity (MWC) of soils were determined using the Gravimetric method. The pH of soils was evaluated by electro-chemically by using standard HANNA model-302 glass electrode pH meter; Organic Carbon (OC) was analyzed by using Walkley and Black's (1934) wet oxidation method and Organic Matter (OM) was calculated by multiplying percent of organic carbon by conventional factor 1.724. Total Nitrogen (TN) was determined by Kjeldahl's method, which was described by Jackson (1973); Phosphorus (P) was determined by the method of Bray and Kurtz (1945) and was evaluated by spectrophotometer; Sulphur (S) was extracted by 500 mg PL^{-1} (Fox *et al.*, 1964) and calculated Turbidimetrically (Hunt, 1980). Potassium (K) was determined by using a Flame Photometer (Gallenkamp) and Calcium (Ca), Magnesium (Mg), Copper (Cu), and Manganese (Mn) were analyzed by using an Atomic Absorption Spectrophotometer (Pye-Unicam).

Statistical Analysis: Mean values and standard deviation were used to differentiate between values of different parameters and calculated by using MS Excel (version 2019). The correlation matrix was determined by using the standard Karl Pearson method (1900) in MS Excel (version 2019).

RESULTS AND DISCUSSION

Physical properties of the soil: Physical properties of the soil collected from Bangabandhu Jamuna Eco-Park are depicted in Table 1. Among the physical properties-moisture contents of soils were found to be maximum (15.41%) in Site D and minimum (4.55 %) in Site B. The sequence of variation of moisture contents was: Site D > Site E > Site C > Site A > Site B. The average value of moisture content was higher (14.36%) in surface and lower (6.41 %) in substratum layer of soil and the sequence of variation was: S > SS > ST. The maximum water holding capacity of soils were found to be maximum (40.42%) in Site C and minimum (32.55%) in Site B. Variation of moisture content followed the sequence: Site C > Site D > Site A > Site E > Site B. The average value of maximum water holding capacity was higher (41.75%) in surface and lower (31.71%) in substratum layer of soil and the sequence of variation was: S > SS > ST (Table 1 and Fig. 2). So, the study showed that the physical properties of soils were varied amongst different layers of soil in different selected sites of this study area.

Table 1. Physical properties of soil collected from three layers of soil from five sampling sites at BGEP

Physical Property	Soil Layer *	Site					Mean
		A	B	C	D	E	
Moisture Content (%)	S	8.67	6.69	15.80	22.58	18.08	14.36±5.91
	SS	4.43	3.70	11.19	14.78	10.14	8.85±4.20
	ST	3.81	3.25	8.30	8.88	7.82	6.41±2.38
	Mean	5.64±2.65	4.55±1.87	11.76±3.78	15.41±6.87	12.01±5.38	9.87±4.13
Maximum Water Holding Capacity (%)	S	39.24	35.11	49.78	46.19	38.43	41.75±6.03
	SS	36.86	32.41	40.69	39.59	33.83	36.67±3.57
	ST	35.10	30.12	30.78	31.18	31.41	31.71±1.95
	Mean	37.07±2.08	32.55±2.5	40.42±9.5	38.98±7.52	34.56±3.57	36.72±2.86

* S- Surface, SS- Sub-surface, ST- Substratum

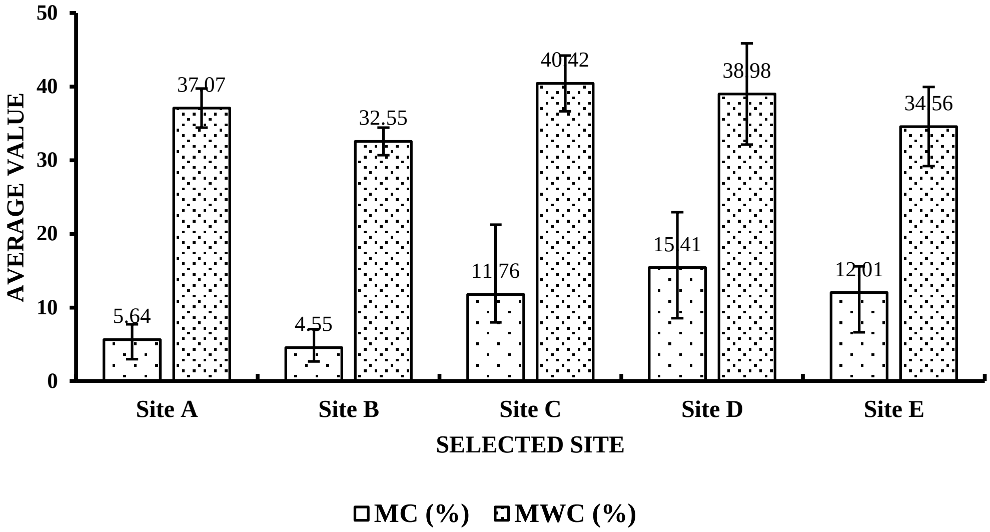

Fig. 2. Physical properties of soils in five selected sites at BGEP

Chemical properties of the soil: The chemical properties of the soil collected from BGEP are depicted in Table 2. The study showed that the soils of all sites were found to be slightly acidic in nature and the values ranged from 5.88 to 6.69. The sequence of pH values existed as: Site B > Site A > Site C > Site D > Site E. Average pH values varied from 5.78 to 6.82 in different layers where the lowest value of pH was found on the surface of soil and the highest value was found in substratum with the following sequence: ST > SS > S (Table 2 and Fig. 3).

Amongst the chemical properties of soils, the average value of organic matter was found maximum (1.39%) in site D and minimum (1.02%) in Site B following the sequence: Site D > Site C > Site E > Site A > Site B. The organic matter content was always higher (1.83%) in surface, followed by a gradual decline in deeper soil and was lowest (0.83%) in the substratum of soils following the sequence: S > SS > ST. The average value of organic carbon content was found maximum (2.41%) in site D and minimum (1.77%) in Site B following the sequence: Site D > Site C > Site E > Site A > Site B. The organic matter was always higher (3.14%) in surface soil followed by a gradual decline in deeper soil and was lower (1.43%) in the substratum of soils following the sequence: S > SS > ST (Table 2 and Fig. 3).

Amongst the macro-nutrients of soils, the average values of Nitrogen ranged from 0.09 to 0.12% and showed the sequence of variation as: Site D > Site C > Site E > Site A & B. Available Nitrogen was found higher (0.16%) in surface and the values gradually decreased with depth and the sequence of changing was: S > ST > SS. Average total Nitrogen was 0.12%. The values of available Phosphorus ranged from 7.01 to 8.20µg/g and the sequence of changing was: Site A > Site D > Site C > Site B > Site E. Phosphorus content was found higher (11.71µg/g) in surface and lower (5.32µg/g) in substratum layer of soils and the sequence did not show the similar pattern found in Nitrogen content and the sequence was: S > SS > ST. Average Phosphorus content was 7.51μg/g. The value of available Potassium was ranged from 0.13 to 0.16meq/100g and the sequence of changing was: Site C > Site D > Site E & Site A > Site B. Potassium content was found higher (0.20meq/100g) in surface and lower (0.11meq/100g) in substratum layer of soils and the sequence of changing was: S > SS > ST. Average Potassium content was 0.14meq/100g (Table 2 and Fig. 3).

The values of available Calcium ranged from 9.31 to 12.14 meq/100g and the sequence of changing was: Site C > Site D> Site A > Site E > Site B. Calcium content was found higher (13.71 meq/100g) in surface and lower (8.30 meq/100g) in substratum layer of soil and the sequence of changing was: S > SS > ST. Average Calcium content was 10.35 meq/100g. The values of available Magnesium ranged from 1.27 to 1.94 meq/100g and the sequence of changing was: Site D > Site C > Site A > Site E > Site B. Magnesium content was higher (1.83 meq/100g) in surface and lower (1.37 meq/100g) in substratum layer of soils and the sequence of changing was: S > SS > ST. Average Magnesium content was 1.56 meq/100g. The values of available Sulfur ranged from 2.44 to 3.44 μg/g and the sequence of changing was: Site C > Site A > Site D > Site B & E. Sulfur content was found higher (4.15 μg/g) in surface and lower (2.05 μg/g) in sub-surface and the sequence of changing was: S > ST > SS. Average Sulfur content was 2.84 μg/g (Table 2 and Fig. 3).

Amongst the micro-nutrients of soils- the values of available Zinc ranged from 1.17 to 2.98 μg/g and the sequence of changing was: Site E > Site B > Site D > Site A > Site C. Zinc content was found higher (1.91 μg/g) in surface and lower (1.67 μg/g) in substratum layer and the sequence of changing was: S > SS > ST. Average Zinc content was 1.78 μg/g. The values of available Copper ranged from 0.17 to 0.89 μg/g and the sequence of changing was: Site D > Site E > Site A > Site B > Site C. Copper content was found higher (0.59 μg/g) in surface and lower (0.17 μg/g) in substratum layer and the sequence of changing was: S > SS > ST. Average Copper content was 0.39 μg/g. The values of available Manganese ranged from 1.25 to 1.74 μg/g and the sequence of changing was: Site E > Site D > Site C > Site A > Site B. Manganese content was found higher (1.95 μg/g) in surface and lower (0.94 μg/g) in substratum and the sequence of changing was: S > SS > ST. Average Manganese content was 1.45 μg/g (Table 2 and Fig. 3).

Table 2. Chemical properties of soil collected from three layers of soil in five sampling sites (including macro and micro nutrients) at BGEP

Chemical Property	Soil Layer *	Site					Mean
		A	B	C	D	E	
Organic Matter (%)	S	2.61	3.03	3.44	3.58	3.03	3.14±0.38
	SS	1.03	1.93	1.51	1.99	1.58	1.61±0.39
	ST	1.93	0.34	1.58	1.65	1.65	1.43±0.62
	Mean	1.86±.0.79	1.77±1.35	2.18±1.09	2.41±1.03	2.09±0.82	2.06±0.91
Total Nitrogen (%)	S	0.13	0.15	0.17	0.18	0.15	0.16±0.02
	SS	0.05	0.10	0.08	0.10	0.08	0.08±0.02
	ST	0.10	0.02	0.08	0.08	0.08	0.12±0.03
	Mean	0.09±0.04	0.09±0.07	0.11±0.05	0.12±0.05	0.10±0.04	0.12±0.04
pH	S	5.83	6.15	6.46	5.30	5.18	5.78±0.55
	SS	6.85	6.90	6.53	6.10	6.10	6.49±0.39
	ST	7.22	7.01	6.87	6.65	6.37	6.82±0.33
	Mean	6.63±0.72	6.69±0.47	6.62±0.22	6.02±0.68	5.88±0.62	6.36±0.60
Phosphorus (µg/g)	S	13.52	11.35	9.55	13.59	10.52	11.71±1.80
	SS	5.28	5.97	4.54	6.41	5.31	5.50±0.72
	ST	5.80	3.82	7.30	4.51	5.17	5.32±1.33
	Mean	8.20±4.61	7.04±3.88	7.13±2.51	8.17±4.79	7.01±3.05	7.51±3.32
Potassium (meq/g)	S	0.17	0.14	0.22	0.24	0.21	0.20±0.04
	SS	0.12	0.13	0.17	0.14	0.12	0.14±0.02
	ST	0.12	0.13	0.10	0.11	0.11	0.11±0.01
	Mean	0.14±0.03	0.13±0.01	0.17±0.06	0.16±0.07	0.14±0.06	0.14±0.04
Calcium (meq/g)	S	14.01	12.23	17.47	12.84	11.98	13.71±2.25
	SS	7.81	8.63	10.47	9.75	8.68	9.07±1.04
	ST	8.79	7.06	8.49	8.68	8.52	8.30±0.71
	Mean	10.21±3.3	9.31±3.65	12.14±4.7	10.43±2.1	9.72±1.95	10.35±2.83
Magnesium (meq/g)	S	1.85	1.39	2.10	2.46	1.33	1.83±0.48
	SS	1.29	1.34	1.72	1.81	1.29	1.49±0.25
	ST	1.22	1.09	1.71	1.56	1.31	1.37±0.25
	Mean	1.45±0.35	1.27±0.16	1.84±0.22	1.94±0.46	1.31±0.02	1.56±0.38
Sulfur (µg/g)	S	5.16	2.96	6.20	3.19	3.26	4.15±1.45
	SS	3.61	2.22	1.41	1.60	1.41	2.05±0.93
	ST	1.45	2.14	2.72	2.72	2.65	2.33±0.55
	Mean	3.41±1.86	2.44±0.45	3.44±2.48	2.50±0.82	2.44±0.94	2.84±1.36
Zinc (µg/g)	S	2.23	0.41	0.75	2.75	3.38	1.91±1.28
	SS	0.71	3.29	2.44	1.80	0.72	1.79±1.12
	ST	0.61	2.20	0.33	0.30	4.86	1.67±1.95
	Mean	1.18±0.91	1.97±1.45	1.17±1.12	1.61±1.24	2.98±2.10	1.78±1.39
Copper (µg/g)	S	0.43	0.13	0.09	1.51	0.84	0.59±0.59
	SS	0.27	0.31	0.29	0.87	0.40	0.42±0.25
	ST	0.16	0.12	0.13	0.31	0.15	0.17±0.08
	Mean	0.29±0.14	0.19±0.11	0.17±0.11	0.89±0.60	0.46±0.35	0.39±0.39
Manganese (µg/g)	S	1.96	0.81	0.95	2.43	3.62	1.95±1.15
	SS	1.09	2.19	1.99	1.17	0.90	1.46±0.58
	ST	1.02	0.76	1.28	0.94	0.72	0.94±0.23
	Mean	1.35±0.52	1.25±0.81	1.41±0.53	1.51±0.80	1.74±1.62	1.45±0.82

* S- Surface, SS- Sub-surface, ST- Substratum

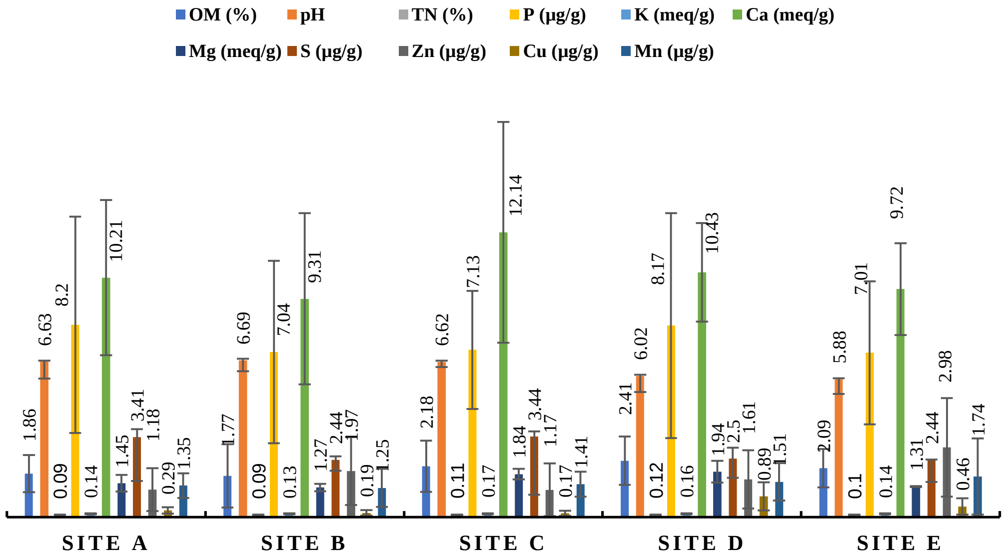

Fig. 3. Chemical properties of soils in five selected sites at BGEP

Correlation: The present study showed that, Organic matter (OM) content was significantly and positively correlated with Moisture content (MC) of soils at 1% level of significance. Total Nitrogen (TN) was significantly and positively correlated with Moisture content (MC) of soil at 5% level of significance. Calcium (Ca) and Magnesium (Mg) were significantly and positively correlated with Maximum water holding capacity (MWC) of soils at 5% level of significance (Table 3).

It was also evident that Manganese is negatively correlated with pH of soils at the 5% level of significance. Potassium (K) is positively correlated with Magnesium (Mg) of soils at a 5% level of significance. Total Nitrogen (TN) is positively correlated with Magnesium (Mg) at a 5% level of significance and with Potassium (K) at 1% level of significance (Table 3).

It was evident that the overall nutrient status of the soils of BGEP was very poor except for moderate values of Calcium (Ca) and Phosphorus (P). Hadi *et al.* (2013) found the average value of Moisture content was 20.65% and the average value of Maximum water holding capacity was 51.49% in Tilagarh Eco-Park, Sylhet. Haider *et al.* (2012) found the average value of pH (4.71), Organic matter (1.18%), Total Nitrogen (0.05%), Phosphorus (3.13 µg/g) and Potassium (0.15 meq/g) in Moulvibazar hill forest. Hadi *et al.* (2013) found the average value of pH (4.61), Organic matter (2.64%), Total Nitrogen (0.32%), Phosphorus (6.24 µg/g) and Potassium (0.18 meq/g) in Tilagarh Eco-Park, Sylhet.

Table 3. Correlation among different physical and chemical parameters of soils (Pearson Correlation) of BGEP

Parameter	MC	MWC	pH	OM	TN	P	K	Ca	Mg	S	Zn	Cu	Mn
MC	1	.60	-.74	.97**	.93*	.12	.87	.42	.72	-.19	.14	.73	.67
MWC		1	-.01	.70	.72	.42	.81	.89*	.91*	.61	-.64	.26	.05
pH			1	-.63	-.51	-.05	-.33	.22	-.13	.60	-.67	-.78	-.91*
OM				1	.98*	.26	.91	.49	.83	.10	-.03	.76	.53
TN					1	.22	.96**	.54	.89*	-.08	-.13	.70	.37
P						1	.09	.03	.43	.25	-.53	.53	-.13
K							1	.74	.91*	.11	-.25	.47	.28
Ca								1	.74	.71	-.60	-.12	-.05
Mg									1	.29	-.56	.49	.02
S										1	-.76	-.48	-.36
Zn											1	.18	.70
Cu												1	.50
Mn													1

****=** Correlation is significant at 1% level; ***=** Correlation is significant at 5% level.

Legend: MC= Moisture content, WHC= Maximum water holding capacity, OM= Organic matter, TN= Total Nitrogen, K= Potassium, Ca= Calcium, Mg= Magnesium, S= Sulfur, Zn= Zinc, Cu= Copper, Mn= Manganese.

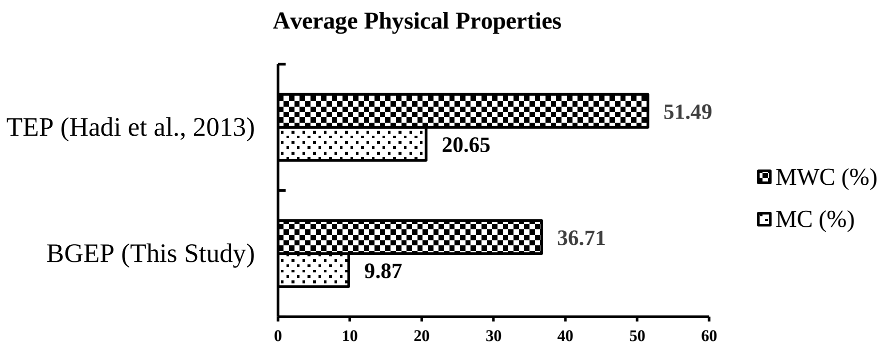

Fig. 4. A comparison of the physical properties of soil at BGEP and Tilagarh Eco-Park (TEP).

Conclusions and Suggestions: Bangabandhu Jamuna Eco-Park was developed with a vision to protect the river bank of Jamuna Bridge. The soils of this eco-park are mostly sandy in nature. From the time when tree species were planted here, the quality and status of soils started to change due to different soil-forming processes. Higher numbers of upper ground undergrowth plant species are largely contributing to those processes. As the better health of the soil can support higher floral diversity, it is necessary to develop proper management guidelines to protect and conserve the soils of any ecosystem, especially any eco-park like this one. A massive region of this eco-park has no vegetation cover, so an appropriate plantation of desired plants is needed in those regions. Besides, fast-growing leguminous indigenous species may be planted within this eco-park to increase soil fertility and plant productivity. Introducing suitable soil-covering plants to enrich soil fertility and to conserve soil, especially in deforested areas, is highly recommended.

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