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NATURE AND PROPERTIES OF SOILS AT DIFFERENT DEPTHS IN LOWLAND RICE ECOSYSTEM

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Abstract

A study was conducted to evaluate the nature and properties of soil at different depths in lowland rice ecosystem of Zakiganj, Kulaura, Baniachong and Sarail Upazila of Bangladesh. The total 24 soil samples were collected from the above four sites covering six soil depth, viz. 0-10 cm, 10-20 cm, 20-40 cm, 40-60 cm, 60-80 cm and 80-100 cm. The mean value of pH was found 5.08 to 6.85 at the depth 0-40 cm and having much lower value in 40-100 cm depth at different sites. It indicates that soil of the sites are acidic in nature. The NPK and S content in studied areas were very low. Based on physico-chemical properties, the study revealed that soil nutrient levels are low in the study sites. The findings also indicate that upper soil layers (0-40 cm) are higher in potential fertility compared to the deeper layers (40-100 cm). Similar trends were observed in Baniachong and Sarail sites, where the upper soil layers exhibited higher fertility than the lower layers. However, an exception was found in Kulaura site hence the deeper soil layers (40-100 cm) had higher levels of soil organic carbon (SOC) and cation exchange capacity (CEC) than the upper layers. This difference is likely due to the clay illuviation in the lower depths where the prevalence of silty clay texture under imperfectly drained conditions of the soil. The above results underscored need to protect the surface and subsurface soil depths with proper management and care.

Key words: Soil properties; Lowland; Rice ecosystem; Soil depth level.

INTRODUCTION

Soil is the basis for agriculture, beyond it provides ecological functions, balancing nutrients and water cycles, biomass production, biodiversity preservation and carbon sequestration (Vogel *et al*. 2018). Soil holds more than three times as much carbon as the atmosphere and terrestrial vegetation, thus playing an important role in global climate change and agricultural production (Lal 2004, Li *et al.* 2017). Soil organic carbon (SOC) storage is the key function of agricultural soil, as it interacts with other functions, e.g. soil fertility, nutrient cycling etc. (Lal *et al.* 2007). It is also reported by Heenan *et al.* (2004) that SOC in cropland is strongly dependent upon crop and soil management practices. The content of SOC is affected by a range of factors such as climate (Homann *et al.* 2007), topography (Tan *et al.* 2004), biota (Wu *et al*. 2009), parent material (Sleutel *et al.* 2007, Wagai *et al.* 2008), time (Schlesinger 1990) and land management (Blumfield *et al.* 2006). Many of these factors are mutually interactive (Sollins *et al.* 1996). In a nut shell, it may be said that SOC controls the physical, chemical, biological and ecological properties of soils. Uddin *et al.* (2019) observed that in the agricultural soils of Bangladesh, SOC levels are generally low, reflecting the intensity of agriculture and land management practices. It has already been reported that the soil fertility level is very poor in some ecologically vulnerable areas of Bangladesh.

Ahmmed *et al.* (2018) reported that the soils of Bangladesh are deficient in organic matter, nitrogen, phosphorus, potassium, sulphur, zinc and boron etc. There is a continuous pressure on the upper soil specifically 0-40 cm depths because of more food production to feed the millions of people in the country. In such a situation, the local farmers are continuously using chemical fertilizers specifically nitrogenous fertilizer. As a result, soil health is deteriorating due to nutrient mining. Torres-Sallan *et al*. (2017) noted that most of the stable carbon is located at depths below 30 cm specifically in soils that are subject to clay illuviation. In this circumstance, it is prerequisite to know the present soil properties at 0-40 cm depths to take the safe strategy of soil nutrient reserve and their depletion in the soil system. In the view of the above theme, the following objectives were undertaken to complete the present research to assess the potential nutrient status of the soil in the lowland rice ecosystem to identify the soil properties at 0-40 cm depths in contrast to 40-100 cm depths and to make a recommendation on the possible ways to restore the soil properties and these precious resources in a sustainable manner.

MATERIAL AND METHODS

A study was conducted to evaluate the properties of soils in the lowland rice ecosystems across four sites, namely upazila of Zakiganj, Kulaura, Baniachong and Sarail. A total of 24 soil samples were collected from these sites at various depths. Soil samples were placed in polythene bags immediately after extraction, sealed with strings and labeled with the sample number, location, depth and date. These bags were then kept inside another polythene bag for added protection. The samples were air-dried for three days at 40°C by spreading them in a thin layer over clean paper. Visible roots and debris were removed, and the drying process was accelerated by exposing the samples to sunlight. Larger aggregates were gently crushed into finniest ones using a wooden hammer. The samples were then screened through a 2 mm stainless steel sieve and preserved in plastic containers, properly labeled with soil name, sample number and date etc.

Soil pH was determined in a soil-water suspension (1:2.5 w/v) using a pH meter, following Page *et al*. (1982). Soil Organic Carbon (SOC) was assessed by following the Walkley and Black method (Nelson and Sommers 1982). Total soil nitrogen (TSN) was calculated using the Kjeldahl method (Bremner and Mulvaney 1982). Total phosphorus was estimated colorimetrically by developing a yellow color with Vanadomolybdate, as described by Jackson (1962). Total potassium was determined using a flame photometer, as described by Page *et al.* (1982). Total sulfur was ascertained by the Turbidimetric method, as described by Page *et al.* (1982). Cation Exchange Capacity (CEC) was determined by following the ammonium acetate extraction method (Sumner and Miller 1996). Exchangeable calcium, magnesium and sodium was estimated using an atomic absorption spectrophotometer (VARIAN AA 240) following Page *et al.* (1982). Exchangeable potassium was estimated using a flame photometer by extracting the soil with 1*N* ammonium acetate at pH 7 (Page *et al.* 1982). Particle size of soil was carried out by the hydrometer method, as described by Gee and Bauder (1986). Soil bulk density was assessed using the core method, as described by Blake and Hartge (1986).

RESULTS AND DISCUSSION

Zakiganj site

The study site Zakiganj belongs to 24°54'15.4" N latitude and 92°18'45.9" E longitude. The distribution of silt fraction ranges from 45% to 59%, with an average of 50% at a depth 40 cm. The clay fraction varies between 35% and 52%, averaging 42.33%, while the sand fraction is minimal.

Bulk density ranged from 1.38 to 1.61 g/cc, with a mean value of 1.53 g/cc (Table 1). The soil pH varied from 4.82 to 5.22, averaging 5.08, and is classified as strongly acidic according to Ahmmed *et al.* (2018). This low pH may result from the extensive use of nitrogenous fertilizers for cultivating high-yielding variety (HYV) rice crops. Soil organic carbon (SOC) content varied from 0.50% to 0.96%, with an average of 0.79%, categorized as

Table 1. Physico-chemical properties of lowland soils of Zakiganj site of Sylhet sadar upazila.

Soil properties	Depths (cm)			Mean at	Depths (cm)			Mean at
	0-10	10-20	20-40	0-40 cm	40-60	60-80	80-100	40-100 cm
Sand (%)	20.0	1.0	1.0	7.33	15.0	10.0	12.0	11.0
Silt (%)	45.0	47.0	59.0	50.33	45.0	60.0	51.0	52.0
Clay (%)	35.0	52.0	40.0	42.33	40.0	30.0	37.0	36.0
Bulk density (g/cc)	1.61	1.38	1.59	1.53	1.37	1.44	1.50	1.44
pH	5.22	4.82	5.20	5.08	5.28	4.64	4.8	4.91
Organic carbon (%)	0.96	0.90	0.50	0.79	0.50	0.24	0.26	0.33
Total N (%)	0.12	0.06	0.04	0.07	0.03	0.04	0.02	0.03
Total P (%)	0.07	0.06	0.06	0.07	0.05	0.05	0.07	0.062
Total K (%)	0.07	0.06	0.07	0.07	0.19	0.08	0.07	0.11
Total S (%)	0.15	0.20	0.20	0.18	0.18	0.15	0.18	0.17
CEC (meq/100 g)	61.43	49.43	56.43	55.76	64.45	46.01	18.02	42.83
Exchangeable Ca (meq/100 g)	5.51	4.91	5.96	5.46	4.90	2.95	3.32	3.72
Exchangeable Mg (meq/100 g)	4.29	3.52	4.10	3.97	3.80	1.08	3.02	1.00
Exchangeable K (meq/100 g)	0.30	0.31	0.32	0.31	0.35	0.27	0.21	0.29
Exchangeable Na (meq/100 g)	0.24	0.24	0.22	0.23	0.21	0.20	0.20	0.20

low by Ahmmed *et al.* (2018). The low SOC might be insufficient input of fresh organic material as fertilizers. Zhuang *et al.* (2007) stated that SOC levels depend on the balance between organic carbon and nitrogen gain/loss. Total nitrogen (N) ranged from 0.04% to 0.12%, with a mean value of 0.07%, indicating very low nitrogen content due to the low organic matter content. The phosphorus (P) ranged from 0.064% to 0.074%, with an average of 0.067%, denoting low phosphorus levels. Similarly, total potassium (K) varied from 0.056% to 0.068%, with a mean of 0.066%, also indicating low potassium content. Sulfur (S) contained at Zakiganj site ranged from 0.15% to 0.19%, with an average of 0.18%, which is considered low. The cation exchange capacity (CEC) ranged from 49.43 to 61.43 meq/100 g, averaging 55.76 meq/100 g, which exposed higher level of CEC, as reported by Ahmmed *et al.* (2018). This high value of CEC is due to the silty clay nature of the soils. Exchangeable calcium (Ca) ranged from 4.91 to 5.96 meq/100 g, with an average of 5.46 meq/100 g, exceeding the critical limit of 2.0 meq/100 g for wetland rice soils. Exchangeable magnesium (Mg) varied from 3.52 to 4.92 meq/100 g, averaging 3.97 meq/100 g, also above the critical limit of 0.5 meq/100 g for wetland rice soils expressing high magnesium levels. The potassium (K) ranged from 0.30 to 0.32 meq/100 g, with an average of 0.31 meq/100 g, higher than the critical limit of 0.12 meq/100 g for wetland rice soils, indicating high potassium levels. Exchangeable sodium (Na) ranged from 0.22 to 0.24 meq/100 g, with an average of 0.23 meq/100 g, the findings approved low content of Na. The soil properties at 0-40 cm depths showed higher nutrient values as compared to the soil depths at 40-100 cm. So, it may be concluded that upper most soil layer (0-40 cm soil depths) is more fertile than the 40-100 cm soil depths at Zakiganj site.

Kulaura site

The geo-coordinates of the Kulaura site are 24°24'44.6" N latitude and 91°25'07" E longitude. The soil properties of Kulaura are presented in Table 2. The upper depth of soil at 0 to 40 cm, contributed the clay content ranging from 46% to 56%, with an average of 50%. The sand was found 12 to 15% and the silt 12 to 29%, respectively at 0 to 40 cm depth. The values of the result exert the soil's textural class was silty clay. Clay and silt play an important role in stabilizing organic compounds (Bationo and Buerkert 2001). Among these, clays are particularly significant in the direct stabilization of organic molecules (Feller *et al.* 1996). Batjes (1996) and Liu *et al.* (2011) reported that clay has a stabilizing effect where SOC can be trapped in small spaces between clay particles, making them inaccessible to microorganisms and thereby slowing decomposition. Bulk density ranged from 1.59 to 1.71 g/cc, with a mean of 1.67 g/cc (Table 2).

Table 2. Physico-chemical properties of lowland soils of Kulaura Upazila site of Moulvi Bazar District.

Soil properties	Depths (cm)			Mean at 0-40 cm	Depths (cm)			Mean at 40-100 cm
	0-10	10-20	20-40		40-60	60-80	80-100	
Sand (%)	12.0	12.0	15.0	13.0	12.0	15.0	32.0	19.67
Silt (%)	42.0	40.0	29.0	37.0	25.0	19.0	12.0	18.67
Clay (%)	46.0	48.0	56.0	50.0	63.0	66.0	56.0	61.67
Bulk density (g/cc)	1.70	1.71	1.59	1.67	1.61	1.92	1.67	1.73
pH	5.67	5.49	5.65	5.60	5.64	6.32	5.47	5.81
Organic carbon (%)	0.52	0.95	0.95	0.81	0.59	0.40	0.59	0.53
Total N (%)	0.09	0.05	0.07	0.07	0.07	0.14	0.07	0.09
Total P (%)	0.009	0.017	0.017	0.014	0.007	0.007	0.032	0.015
Total K (%)	0.07	0.10	0.17	0.11	0.15	0.175	0.196	0.175
Total S (%)	0.14	0.46	0.14	0.25	0.07	0.139	0.145	0.119
CEC (meq/100 g)	25.44	32.65	21.86	26.65	35.21	42.86	58.72	45.60
Exchangeable Ca (meq/100 g)	3.51	6.02	6.18	5.25	7.42	7.18	10.19	8.26
Exchangeable Mg (meq/100 g)	3.34	4.81	4.77	4.31	4.88	4.49	5.65	5.01
Exchangeable K (meq/100 g)	0.24	0.17	0.21	0.21	0.23	0.19	0.26	0.23
Exchangeable Na (meq/100 g)	0.20	0.17	0.17	0.18	0.20	0.20	0.21	0.20

In comparison to soil at depths of 40-100 cm, the soil properties vary depending on their orientation in the soil profile. Soil pH varied from 5.49 to 5.67, with a mean value of 5.60, which is regarded as near extremely acidic according to Ahmmed *et al.* (2018). Soil organic carbon (SOC) content varied from 0.52 to 0.95%, with an average of 0.81%. According to Ahmmed *et al.* (2018) the SOC value is categorized as low. Total nitrogen (N) ranged from 0.05 to 0.09%, with a mean value of 0.07%, indicating very low nitrogen content Ahmmed *et al.* (2018). This low nitrogen content may be due to insufficient organic matter input. Total phosphorus (P) ranged from 0.009 to 0.017%, with a mean of 0.014%, denoting very low phosphorus content. Total potassium (K) ranged from 0.075 to 0.175%, with a mean value of 0.117%, indicating low potassium content. Total sulfur (S) varied from 0.142 to 0.465%, with an average of 0.252%, which is very low. Cation exchange capacity (CEC) varied from 21.86 to 32.65 meq/100 g, with an average of 26.65 meq/100 g. According to Ahmmed *et al.* (2018), this level of CEC is high in the studied soils, likely due to the silty clay nature of the wetland soils. Exchangeable calcium (Ca) ranged from 3.51 to 6.18 meq/100 g, with an average of 5.25 meq/100 g, which is high compared to the critical limit of 2.0 meq/100 g for wetland rice soils (Ahmmed *et al.* 2018). Exchangeable magnesium (Mg) found ranged 3.34 to 4.81 meq/100 g, with an average of 4.31 meq/100 g, which is significantly higher than the critical limit of 0.5 meq/100 g for wetland rice condition of soils. Exchangeable potassium (K) ranged from 0.17 to 0.24 meq/100 g, with an average of 0.21 meq/100 g, above the critical limit of 0.12 meq/100 g. Exchangeable sodium (Na) was 0.17 to 0.20 meq/100 g, having average of 0.18 meq/100 g, which was relatively low.

Baniachong site

The geo-coordinates of the Habiganj BRRI site belongs between 24°91'41" N latitude and 92°25'07" E longitude. Study showed that the distribution of silt fraction varied, 79 to 87% and average of 81.67% at 40 cm depth level (Table 3), the sand content varied from 12 to 20%, with an average of 16.33%, while the clay content at 40 cm depth was found very low. Bulk density ranges from 1.32 to 1.52 g/cc, with a mean of 1.41 g/cc (Table 3). Soil pH was observed closer to neutral value 6.70 to 7.03, with a mean value of 6.86. Soil organic carbon (SOC) content varied from 0.18 to 0.22% and the average value of 0.20%, may be categorized as very low. This very low level of SOC may result from lower inputs of fresh organic material, such as organic fertilizers. Torres-Sallan *et al.* (2017) gave the impression that climate-smart land management may balance SOC stabilization in top soils for productivity versus sequestration in sub soils for climate mitigation. Total nitrogen (N) ranged from 0.04 to 0.15%, with the mean of 0.08%, indicating very low nitrogen content, on account of low organic matter presence. Total phosphorus (P) was 0.027 to 0.045%, with a mean of 0.038%, denoting low phosphorus content. Total potassium (K) varied from 0.067 to 0.074%, with a mean value of 0.069% and pointed low potassium in soil. Total sulfur (S) obtained 0.062 to 0.080% and possesses the average content 0.071%, which indicated very low. Cation exchange capacity (CEC) ranged from 27.14 to 41.43 meq/100 g, with an average of 35.65 meq/100 g. Analytical result of the study confirmed that this level of CEC is high due to silty nature of the lowland soils. Exchangeable calcium (Ca) varied from 11.94 to 14.39 meq/100 g, with an average of 12.86 meq/100 g, significantly above the critical limit (2.0 meq/100 g) for wetland rice soils. The exchangeable magnesium (Mg) was observed between 4.68 and 5.00 meq/100 g, with an average of 4.79 meq/100 g, also above the critical limit (0.5 meq/100 g) for wetland rice soils. Exchangeable potassium (K) ranged from 0.19 to 0.24 meq/100 g, with an average of 0.21 meq/100 g found above the critical limit (0.12

meq/100 g). The exchangeable sodium (Na) ranged between 0.19 and 0.20 meq/100 g, getting the average value 0.19 meq/100 g which may low performance in the exchange sites.

Table 3. Physico-chemical properties of lowland soils of BRRI site of Baniachong Upazila of Habiganj District.

Soil properties	Depths (cm)			Mean at 0-40 cm	Depths (cm)			Mean at 40-100 cm
	0-10	10-20	20-40		40-60	60-80	80-100	
Sand (%)	12.0	17.0	20.0	16.33	37.0	28.0	28.0	31.0
Silt (%)	87.0	79.0	79.0	81.67	60.0	65.0	65.0	64.0
Clay (%)	1.0	4.0	1.0	2.0	3.0	7.00	7.0	6.0
Bulk density	1.52	1.40	1.32	1.41	1.49	1.51	1.53	1.51
pH	6.7	7.03	6.85	6.86	6.93	6.89	6.20	6.67
Organic carbon (%)	0.22	0.18	0.20	0.20	0.33	0.04	0.11	0.16
Total N (%)	0.15	0.04	0.06	0.08	0.06	0.09	0.06	0.07
Total P (%)	0.04	0.027	0.042	0.04	0.03	0.02	0.05	0.04
Total K (%)	0.07	0.07	0.07	0.07	0.06	0.02	0.05	0.04
Total S (%)	0.08	0.07	0.06	0.07	0.12	0.003	0.16	0.10
CEC (meq/100 g)	38.37	41.43	27.14	35.65	38.57	27.14	25.71	30.47
Exchangeable C (meq/100 g)	11.94	14.39	12.25	12.86	14.74	7.22	6.54	9.5
Exchangeable M (meq/100 g)	4.68	4.69	5.00	4.79	6.33	3.12	3.45	4.3
Exchangeable K (meq/100 g)	0.22	0.19	0.24	0.21	0.26	0.11	0.03	0.14
Exchangeable Na (meq/100 g)	0.20	0.19	0.19	0.19	0.15	0.10	0.05	0.10

Sarail site

Geographically, the Sarail site is situated between 24°05'04.7" N latitude and 91°06'02" E longitude. The silt fraction ranged from 75 to 90%, at Sarail site at a depth of 40 cm, with the average value of 80%. The sand content varied from 4 to 22%, with an average of 15%, while the clay content at 40 cm depth is very low. The bulk density was ranged 1.31 to 1.58 g/cc, with a mean value of 1.48 g/cc (Table 4).

Soil pH ranged from 5.20 to 6.74, with a mean value of 5.52, which is considered near acidic soil in nature. Soil organic carbon (SOC) content ranged from 0.29 to 0.88%, with an average value of 0.54%, categorized as very low by Ahmmed *et al.* (2018). This low SOC level may result from reduced inputs of fresh organic material in the form of organic fertilizers. Total nitrogen (N) content ranged from 0.04 to 0.05%, with a mean value of 0.04%, indicating very low nitrogen levels, likely due to low organic matter. Total phosphorus (P) ranged from 0.030 to 0.045%, with a mean value of 0.03%, denoting low phosphorus content. Total potassium (K) ranged from 0.035 to 0.055%, with a mean value of 0.045%, also indicating low potassium content. Total sulfur (S) ranged from 0.041 to 0.052%, with an average value of 0.047%, which is very low. Cation exchange capacity (CEC) varied from 14.64 to 26.43 meq/100 g, with an average of 19.17 meq/100 g. According to Ahmmed *et al.* (2018), this level of CEC is high in the studied soils. Possibly, the high level of CEC may be due to higher silt contents of the soils. Exchangeable calcium (Ca) ranged from 3.78 to 7.50 meq/100 g, with an average of 5.50 meq/100 g, significantly higher than the critical limit of 2.0 meq/100 g for wetland rice soils (Ahmmed *et al.* 2018). Exchangeable magnesium (Mg) varied from 2.41 to 3.46 meq/100 g, with an average of 2.95

meq/100 g, well above the critical limit of 0.5 meq/100 g for wetland rice soils. Exchangeable potassium (K) ranged from 0.10 to 0.13 meq/100 g, with an average of 0.11 meq/100 g, slightly below the critical limit of 0.12 meq/100 g for wetland rice soils. Exchangeable sodium (Na) varied from 0.10 to 0.12 meq/100 g, with an average of 0.11 meq/100 g, which may be low in the exchange sites.

Table 4. Physico-chemical properties of lowland soils of Sarail site of Brahmanbaria District.

Soil properties	Depths (cm)			Mean at 0-40 cm	Depths (cm)			Mean at 40-100 cm
	0-10	10-20	20-40		40-60	60-80	80-100	
Sand (%)	22.0	4.0	17.0	15.0	15.0	14.0	17.0	15.0
Silt (%)	75.0	90.0	75.0	80.0	80.0	80.0	77.0	79.0
Clay (%)	3.0	6.0	8.0	6.0	5.0	6.0	6.0	6.0
Bulk density (%)	1.55	1.31	1.58	1.48	1.47	1.75	1.58	1.6
pH	6.74	5.20	5.22	5.72	7.23	5.72	5.80	6.25
Organic carbon (%)	0.88	0.46	0.29	0.54	0.15	0.18	0.18	0.17
Total N (%)	0.04	0.05	0.04	0.04	0.01	0.01	0.02	0.01
Total P (%)	0.04	0.03	0.04	0.04	0.06	0.07	0.06	0.06
Total K (%)	0.05	0.03	0.05	0.04	0.06	0.04	0.07	0.06
Total S (%)	0.04	0.05	0.05	0.05	0.03	0.06	0.04	0.04
CEC (meq/100 g)	16.43	14.64	26.43	19.17	15	14.43	16.60	15.34
Exchangeable Ca (meq/100 g)	7.50	5.21	3.78	5.50	5.04	2.20	5.19	4.14
Exchangeable Mg (meq/100 g)	3.46	2.94	2.41	2.95	3.48	1.97	4.03	3.16
Exchangeable K (meq/100 g)	0.10	0.13	0.10	0.11	0.09	0.02	0.08	0.06
Exchangeable Na (meq/100 g)	0.10	0.12	0.12	0.11	0.10	0.05	0.05	0.06

The above all results of physico-chemical properties of wetland soils correlates with the findings of Hossain and Sattar (2002), Atta-Darkwa *et al.* (2020). Talukder and Huda (2021) carried out a study at three different haors of Sunamganj District to evaluate the status and variability of the physico-chemical properties of soils where they found similar trends of soil properties. The SOC, the key indicator of quality which found at 0 to 40 cm depth can be arranged on the basis of higher mean value and the sites in the order of Kulauara 0.81% > Zakiganj 0.79% > Sarail 0.54% > Baniachong 0.20%. The present study also revealed that the soil nutrient reserves at both the level of 0-40 cm and 40-100 cm depths differ due the soil textural nature. The pH value found low which reflects the conditions of soils are in acidic nature. The low pH may result from the extensive use of nitrogenous fertilizers for cultivating high-yielding variety (HYV) of rice crops. The NPK and S content in studied areas were very low. This is due to low or no use of organic materials and also imbalanced use of chemical fertilizers. Hence, the study recommends in improving the soil physico-chemical properties through the implementation of climate smart farming to restore land and soil resources.

This study vividly revealed that 0-40 cm soil depths reserve more potential nutrients than the 40-100 cm soil depths. Based on the physico-chemical properties, the study revealed that soil nutrient levels are low in the study sites. These findings suggest in improving the soil physico-chemical properties through implementation of sustainable land management techniques.

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