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Some Chemical Properties of Soils from Two Agroecological Regions of Bangladesh: Region 5 – Lower Atrai Basin and Region 6 – Lower Purnabhaba Floodplain

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Bangladesh has been divided into 30 Agroecological Regions (AEZs) and the applied agricultural research has currently been conducted on this basis. An experiment was undertaken to elucidate chemical properties of fourteen soils collected from AEZ 5 of the Lower Atrai Basin and six soils from AEZ 6 of the Lower Purnabhaba Floodplain. The soils belonged to five soil series of Laskara, Tarash, Manda, Malanchi and Gangachara in AEZ 5 and one soil series of Jaonia in AEZ 6. Particle–size distribution, pH, active acidity, lime requirement, electrical conductivity (EC), organic carbon and total nitrogen, available sulfur and phosphorus, cation exchange capacity (CEC), exchangeable calcium, magnesium, sodium and potassium, and non–exchangeable potassium were determined following the standard methods.

Most of the soils from AEZ 5 were medium–textured (loam to silty loam) except the Tarash–1 and Tarash–2 soils which were in the same category as the soils from AEZ 6 of fine–texture (silty clay loam, silty clay and clay). The fineness of texture was related to the position of soils in the lower elevation and accumulation of clay. The latter group of the soils had, in general, higher values of organic matter, lime requirement, total nitrogen, CEC, and some exchangeable cations. But, the values for pH, EC, available sulfur and phosphorus were not related to the difference between two groups of the soils. Soil test values were compared with the Bangladesh soil standards for crop requirement.

INTRODUCTION

Bangladesh is one of the greatest deltas of the world having a wider range and greater complexity of land. Population density is high and is increasing while the agricultural land is decreasing rapidly due to construction of homestead, factories, roads, highways, etc. As an agro–based country, Bangladesh needs to produce more crops to feed the ever–growing population. Proper management of soil is an important aspect to sustain its productivity. For research planning and better crop production, the basic data on physical and chemical properties of soils are important.

Physiographically the soils in Bangladesh are classified into three major units: Tertiary hills (12%), Pleistocene terraces (8%), and Holocene floodplains (80%). Based on the mode of formation and morphological appearance, soils are grouped into 21 general soil types of the Bangladesh soil classification system, which have been correlated with USDA Soil Taxonomy and FAO–UNESCO soil classification system (Saheed, 1984).

Again, Bangladesh has been divided into 30 Agroecological Regions (popularly known as AEZs) based on physiography, inundation land types, soils, and agroclimate (FAO–UNDP, 1988). Agricultural research, and technology generation and transfer, etc. are now going on the AEZ basis. The present work was focused on the soils of the two AEZs of the Lower Atrai Basin (AEZ 5) and the Lower Purnabhaba Floodplain (AEZ 6) which were not given due attention previously.

AEZ 5 of the Lower Atrai Basin comprises the low–lying area between the Barind Tract and Ganges River Floodplain. It includes the *Chalan Bil* area. Most of this region lies in Naogaon and Natore Districts. Small areas extend into Rajshahi, Bogra and Sirajgang Districts. Total area of this AEZ is 851 km^2. Smooth, low–lying basin land occupies most of the region. Areas bordering the Ganges, Lower Atrai and Little Jamuna Floodplains have some ridges penetrating into the basin; and the relief is locally irregular near river channels. AEZ 6 of the Lower Purnabhaba Floodplain is located in the western part of Naogaon District and includes little areas of Chapainawabgonj Districts. Total area of this region is 129 km^2 only. Basins and *bils* separated by low floodplain ridges occupy the whole area of this AEZ (FAO–UNDP, 1988).

The objective of the present study was to elucidate the physical and chemical properties of soils of these two AEZs in order to ascertain their potentiality for efficient use of the land resources, and better soil and crop management.

MATERIALS AND METHODS

Soils used

Major soil series of the AEZs under study were identified from the semi–detailed soil survey reports of different Upazilas covering the area. In AEZ 5, five soil series were found to occur: Laskara, Tarash, Manda, Malanchi, and Gangachara. Considering their extent of

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occurrence, 4 samples were collected from each of Tarash and Gangachara, 3 from Laskara, 2 from Manda, and 1 from Malanchi series. In AEZ 6, only one soil series (Jaonia) was found to occur. Six samples were collected from this AEZ considering the difference in location and land type. Thus, in total, twenty soil samples were collected from a depth of 0–15 cm. General features of these soils are presented in Table 1. The soil samples were dried at room temperature, crushed, mixed thoroughly, sieved with a 2–mm sieve and preserved in plastic bags for subsequent laboratory analyses.

Analytical procedures

Particle–size analysis was carried out by the hydrometer method as outlined by Bouyoucos (1927). The textural classes were then determined by plotting the results on a triangular diagram designed by Marshall (1947) following the USDA system. The pH was determined by a glass–electrode pH meter in the soil suspension having a soil:water ratio of 1:2.5, after 30–min shaking. The electrical conductivity (EC) was measured by a EC meter in the soil suspension having a soil:water ratio of 1:5, after 30–min shaking.

To determine active acidity (exchangeable Al), soil was extracted with 1 M KCl. The filtrate was titrated against 0.01 M NaOH while stirring using phenolphthalein as an indicator. Lime requirement was calculated from this value. The lime requirement was also determined using the widely followed method given by

Table 1. General information of the soils

AEZ	Soil series	Land type[1)]	Parent material	General soil type[2)]	Location	Crop
Lower Atrai Basin	Laskara–1	MHL	Tista alluvium	Non–calcareous Dark Grey Floodplain Soil	Singhradanra Raninagor Naogaon	T. Aus, T. Aman, mustard, sesame, sesbania
	Laskara–2	MLL	Tista alluvium	Non–calcareous Dark Grey Floodplain Soil	Singhradanra Raninagor Naogaon	Mixed Aus and Deepwater Aman, Boro
	Laskara–3	MHL	Tista alluvium	Non–calcareous Dark Grey Floodplain Soil	Kalikapur Atrai Naogaon	T. Aus, T. Aman, Boro, gram,
	Tarash–1	MHL	Atrai alluvium	Non–calcareous Dark Grey Floodplain Soil	Sinda Raninagor Naogaon	T. Aus, T. Aman, Boro, sesbania,
	Tarash–2	MLL	Atrai alluvium	Non–calcareous Dark Grey Floodplain Soil	Lohachora Raninagor Naogaon	Mixed Aus and Deepwater Aman, Boro
	Tarash–3	MLL	Atrai alluvium	Non–calcareous Dark Grey Floodplain Soil	Kalikapur Atrai Naogaon	Mixed Aus and Deepwater Aman, Boro
	Tarash–4	MLL	Atrai alluvium	Non–calcareous Dark Grey Floodplain Soil	Ahsangonj Atrai Naogaon	Mixed Aus and Deepwater Aman, Boro
	Manda–1	HL	Tista alluvium	Non–calcareous Dark Grey Floodplain Soil	Akdala Hapinia Naogaon	Aus, Aman, Boro, jute, wheat, potato, sweet potato, maize, brinjal, vegetables
	Manda–2	HL	Tista alluvium	Non–calcareous Dark Grey Floodplain Soil	Chackbilaki Raninagor Naogaon	Aus, Aman, Boro, jute, wheat, potato, sweet potato, maize, brinjal, vegetables
	Malanchi	HL	Tista alluvium	Non–calcareous Dark Grey Floodplain Soil	Hapania Naogaon	Aus, Aman, Boro, jute, wheat, potato, sweet potato, maize, brinjal, vegetables
	Gangachara–1	HL	Tista alluvium	Non–calcareous Dark Grey Floodplain Soil	Hapania Naogaon	Aus, Aman, Boro, wheat, cotton, vegetables, fruits
	Gangachara–2	MHL	Tista alluvium	Non–calcareous Dark Grey Floodplain Soil	Chackbilaki Raninagor Naogaon	Aus, Aman, Boro, wheat, cotton, vegetables, fruits
	Gangachara–3	HL	Tista alluvium	Non–calcareous Dark Grey Floodplain Soil	Ahsangonj Atrai Naogaon	Aus, Aman, Boro, wheat, cotton
	Gangachara–4	MHL	Tista alluvium	Non–calcareous Dark Grey Floodplain Soil	Ahsangonj Atrai Naogaon	Aus, Aman, Boro, wheat, sunflower, gram, lentil, onion, tomato, vegetables, fruits

Table 1. General information of the soils (contd)

AEZ	Soil series	Land type[1)]	Parent material	General soil type[2)]	Location	Crop
Lower Purnabhaba Floodplain	Jaonia–1	LL	Purnabhaba alluvium	Acid Basin Clay	Radhanagor Gomostapur Chapainawabgonj	Deepwater Aman, Boro, khesari[3)]
	Jaonia–2	MLL	Purnabhaba alluvium	Acid Basin Clay	Radhanagor Gomostapur Chapainawabgonj	Deepwater Aman, Boro, khesari
	Jaonia–3	LL	Purnabhaba alluvium	Acid Basin Clay	Nitpur Porsa Naogaon	Deepwater Aman, Boro, khesari
	Jaonia–4	MLL	Purnabhaba alluvium	Acid Basin Clay	Nitpur Porsa Naogaon	Deepwater Aman, Boro, khesari
	Jaonia–5	LL	Purnabhaba alluvium	Acid Basin Clay	Aihai Sapahar Naogaon	Deepwater Aman, Boro, khesari
	Jaonia–6	MLL	Purnabhaba alluvium	Acid Basin Clay	Aihai Sapahar Naogaon	Deepwater Aman, Boro, khesari

1) Land type: HL, highland; MHL, medium highland; MLL, medium lowland; LL, lowland. HL: land which is above the normal flood level; MHL, MLL and LL: land which is normally flooded up to a depth of about 90 cm, 90–180 cm deep and 180–270 cm deep, respectively, during the monsoon season.
2) Soil classification based on the Bangladesh system.
3) Scientific name is *Lathyrus sarivum*.

Shoemaker *et al.* (1961). In this method, soil, water and an extracting buffer solution were mixed in 1:1:2 ratio. They were stirred for 15 minutes and the pH of the suspension was measured with a pH meter. The amount of lime required against the measured pH value was found out from a correlation table for increasing the soil pH to a desired level.

The organic carbon content was determined by the wet oxidation method as outlined by Nelson *et al.* (1982) and the organic matter content was calculated by multiplying the organic carbon content with a conventional factor of 1.724.

The total nitrogen content was determined by the micro–Kjeldahl digestion method. Digestion was made with concentrated H_2SO_4 with addition of catalyst mixture (K_2SO_4:$CuSO_4 \cdot 5H_2O$:Se in the ratio of 10:1:0.1). Nitrogen in the digest was estimated by distillation with 40% NaOH followed by titration of the distillate trapped in the H_3BO_3 solution against 0.005 M H_2SO_4 (Bremner and Mulvaney, 1982). The available sulfur content was determined by the calcium chloride (0.15%) extraction method (Williams and Steinbergs, 1959). The available phosphorus content was determined by the two different methods as given by Olsen *et al.* (1954) and Bray and Kurtz (1945).

Cation exchange capacity (CEC) was determined by the sodium saturation method as described by Chapman (1965). Exchangeable calcium, sodium and potassium were extracted from soil using 1 M CH_3COONH_4 and their concentrations in the extract were directly determined by a flame photometer. In addition, the non–exchangeable potassium content was determined by the boiling HNO_3 method (Knudsen *et al.,* 1982). Exchangeable magnesium was extracted by DTPA solution and its concentration in the extract was determined directly by an atomic absorption spectrophotometer (AAS).

RESULTS AND DISCUSSION

Particle–size distribution

Data on the particle–size distribution and the USDA textural class of the soils presented in Table 2 indicated that the contents of sand, silt and clay varied widely with soil series and also with samples in the same soil series. The soils collected from AEZ 5 of the Lower Atrai Basin was mostly medium–textured (loam and silt loam) except the Tarash–1 and Tarash–2 soils which were identified as silty clay loam and silty clay, respectively. On the other hand, all six soils from AEZ 6 of the Lower Purnabhaba Floodplain were fine–textured (clay and silty clay).

On the basis of the clay content, the soils collected from AEZ 5 could be grouped into three: high (>40%) in the Tarash–1 and Tarash–2 soils, medium (20–40%) in the soils of the Malanchi and Laskara series and low (<20%) in the other soils. While, the soils of AEZ 6 contained high to very high amounts of clay (44–68%). The higher clay contents were mostly related to the position of soils on the lower topography where clay has been deposited through run–off water over the time.

It appears from the results in Table 2 that the silt content had higher values for most of the soils especially from AEZ 5. Soils like silt loam and clay loam textures have higher agricultural values being less susceptible to becoming loose and open (Weir, 1989). The soil having the silt loam texture can easily be kept in a state good for tilth, favourable for germination of seeds and easy for

Table 2. Particle–size distribution and texture of the soils

AEZ	Soil series	Particle–size distribution (%)			Texture
		Sand	Silt	Clay	
Lower Atrai Basin	Laskara–1	42	34	24	loam
	Laskara–2	36	36	28	loam
	Laskara–3	14	66	20	silt loam
	Tarash–1	22	34	44	silty clay loam
	Tarash–2	20	30	50	silty clay
	Tarash–3	24	60	16	silt loam
	Tarash–4	32	54	14	silt loam
	Manda–1	40	50	10	silt loam
	Manda–2	36	56	8	silt loam
	Malanchi	16	62	22	silt loam
	Gangachara–1	20	66	14	silt loam
	Gangachara–2	22	70	8	silt loam
	Gangachara–3	22	64	14	silt loam
	Gangachara–4	24	66	10	silt loam
Lower Purnabhaba Floodplain	Jaonia–1	16	20	64	clay
	Jaonia–2	26	30	44	silty clay
	Jaonia–3	16	16	68	clay
	Jaonia–4	18	20	62	clay
	Jaonia–5	16	34	50	silty clay
	Jaonia–6	14	28	58	silty clay

root penetration, and has the considerable water–holding capacity. The silt loam soil may be highly productive if managed properly. On the other hand, higher clay gives the soil higher fertility condition with the good water–retention capacity which is congenial for transplanted rice cultivation.

Soil reaction (pH)

Data on the soil pH are presented in Table 3. The pH of the soils from AEZ 5 ranged from 5.2 to 6.1, i. e. the soils were slightly acidic to acidic in reaction. The pH range of the soils from AEZ 6 was in between 4.8 and 5.2 which were mostly acidic in nature. For some crops the soil reaction could be a problem as Tamhane *et al.* (1970) reported that the most soil nutrients were available to plants in a pH range from 6.5 to 7.5. So, pH should be kept between 6.5 and 7.5 by the soil and crop managements including application of lime.

Active acidity

The values of active acidity of the soils, which is equivalent to the amount of exchangeable aluminum adsorbed on colloids, were found in a narrow range between 0.2 and 0.5 $cmol_c\ kg^{-1}$ (Table 3). The active

Table 3. Soil pH, active acidity and lime requirement of the soils

AEZ	Soil series	pH	Active acidity ($cmol_c\ kg^{-1}$)	Lime requirement ($t\ ha^{-1}$) on the basis of	
				Active acidity	Shoemaker method
Lower Atrai Basin	Laskara–1	5.2	0.4	0.89	4.62
	Laskara–2	5.5	0.3	0.67	4.62
	Laskara–3	5.4	0.3	0.67	6.07
	Tarash–1	5.9	0.2	0.45	7.51
	Tarash–2	5.5	0.3	0.67	11.6
	Tarash–3	5.9	0.3	0.67	3.40
	Tarash–4	5.5	0.2	0.45	6.07
	Manda–1	5.3	0.3	0.67	4.62
	Manda–2	5.3	0.3	0.67	3.40
	Malanchi	6.0	0.2	0.45	7.53
	Gangachara–1	5.5	0.3	0.67	6.07
	Gangachara–2	6.1	0.2	0.45	0.00
	Gangachara–3	5.7	0.2	0.45	3.40
	Gangachara–4	5.8	0.3	0.67	3.40
Lower Purnabhaba Floodplain	Jaonia–1	5.2	0.4	0.89	18.7
	Jaonia–2	4.8	0.5	1.13	17.3
	Jaonia–3	4.9	0.4	0.89	28.7
	Jaonia–4	4.9	0.4	0.89	27.2
	Jaonia–5	5.1	0.3	0.67	14.6
	Jaonia–6	5.2	0.3	0.67	13.1

acidity of the soils from AEZ 5 was mostly 0.2 or 0.3 $cmol_c$ kg^{-1}, except the Laskara–1 soil (0.4 $cmol_c$ kg^{-1}), whereas the soils from AEZ 6 had values from 0.3 to 0.5 $cmol_c$ kg^{-1}. It was observed that soils having the lower pH values had the higher active acidity values. From the correlation matrix (Table 7) it was found that active acidity was significantly correlated with CEC.

Lime requirement

As the soils were found to be mostly acidic in reaction, lime requirement was estimated using two different methods. According to the estimate based on the active acidity values, the soils of AEZ 5 required lime ($CaCO_3$) at the rate of 0.45 or 0.67 t ha^{-1}, except the Laskara–1 soil that required the amount of 0.89 t ha^{-1}. The six soils of AEZ 6 required somewhat higher amounts of lime ranging from 0.67 to 1.13 t ha^{-1} (Table 3).

According to the Shoemaker method, the lime requirement of the soils from AEZ 5 was as follows: ranging from4.62 to 6.07 t ha^{-1} for the Laskara series; 3.40 to 11.6 t ha^{-1} for the Tarash series; 3.40 to 4.62 t ha^{-1} for the Manda series; 7.53 t ha^{-1} for the Malanchi series; and 0.00 to 6.07 t ha^{-1} for the Gangachara series. While, lime requirement of the Jaonia series of AEZ 6 ranged from 13.1 to 28.7 t ha^{-1}, which was much higher than that for the soils of AEZ 5.

The above results indicated that the two methods were greatly different in the lime requirement of the soils and that the estimates by the Shoemaker method were much higher than the estimates based on the active acidity.

Electrical conductivity

Data on the electrical conductivity are presented in Table 4. The values ranged from 0.03 to 0.08 dS m^{-1} in the AEZ 5 soils and from 0.03 to 0.06 dS m^{-1} in the AEZ 6 soils and indicated non–saline nature of these soils. No significant difference was observed among the soils of the two AEZs or among the soils of the same soil series.

Organic matter content

The organic matter content of the AEZ 5 soils ranged from 10.9 to 24.2 g kg^{-1} while that of the AEZ 6 soils ranged from 16.8 to 25.2 g kg^{-1} (Table 4). The soils having the high to very high clay contents mostly had the organic matter content around or more than 20 g kg^{-1}. According to the grading of BARC (1997) the organic matter content of these soils was evaluated to be mostly in the medium level. The values were above the usually very low levels of the organic matter content, mainly due to the lower topographic position of the soils. From the correlation matrix (Table 7) it was found that the organic matter content was significantly correlated with the clay and total nitrogen contents, CEC, and the exchangeable calcium and magnesium contents.

Total nitrogen content

The total nitrogen content of the soils from AEZ 5 varied from 0.8 to 1.4 g kg^{-1} while that of the AEZ 6 soils had the higher contents of 1.3 to 1.5 g kg^{-1}. The total nitrogen content of the soils from AEZ 5 was evaluated to be in the low to very low level while that of the soils from AEZ 6 to be in the low level according to the grading of BARC (1997). Portch and Islam (1984) also found that 100% of the soils studied were deficient in available nitrogen, which was similar to the present findings. The total nitrogen content was found to be significantly correlated with the clay and organic matter contents and CEC of the soils (Table 7).

Table 4. Electrical conductivity, organic matter and total nitrogen contents, and C/N ratio of the soils

AEZ	Soil series	Electrical conductivity (dS m^{-1})	Organic matter (g kg^{-1})	Total nitrogen (g kg^{-1})	C/N ratio
Lower Atrai Basin	Laskara–1	0.08	14.9	0.8	10.2
	Laskara–2	0.04	18.7	1.2	9.2
	Laskara–3	0.07	18.3	1.4	7.6
	Tarash–1	0.06	23.7	1.1	12.2
	Tarash–2	0.06	24.2	1.4	10.0
	Tarash–3	0.07	12.6	0.7	10.0
	Tarash–4	0.04	14.7	0.7	12.8
	Manda–1	0.03	17.5	1.4	7.2
	Manda–2	0.03	10.9	0.8	8.1
	Malanchi	0.05	19.2	0.8	13.2
	Gangachara–1	0.04	17.5	1.0	10.6
	Gangachara–2	0.07	15.2	1.0	9.3
	Gangachara–3	0.04	18.5	0.8	12.7
	Gangachara–4	0.06	22.8	1.0	13.9
Lower Purnabhaba Floodplain	Jaonia–1	0.04	21.3	1.3	9.5
	Jaonia–2	0.06	19.0	1.4	7.9
	Jaonia–3	0.03	25.2	1.5	9.7
	Jaonia–4	0.04	21.4	1.3	9.6
	Jaonia–5	0.06	23.2	1.3	10.0
	Jaonia–6	0.04	16.8	1.3	7.5

C/N ratio

The C/N ratio of the soils ranged from 7.2 to 13.9 with an average of 10.0 (Table 4). Brady (2002) stated that the C/N ratio in agricultural top soils varied from 8.1 to 15.1. Most of the soils in the present study were found to have the C/N ratio within this range.

Available sulfur content

The available sulfur content of the different soil series of AEZ 5 ranged from 16.3 to 32.6 mg kg^{-1} while that of the soils of AEZ 6 ranged from 12.9 to 198 mg kg^{-1} (Table 5). The Jaonia–3, Jaonia–4 and Jaonia–6 soils contained very high amounts of available sulfur, and in the other soils the available sulfur content was evaluated to be in a low to optimum range for crop production (BARC, 1997). The higher amount of available sulfur could be resulted from oxidation of sulfides during air–drying of the samples.

Available phosphorus content

The available phosphorus contents of the six soil series estimated by the Olsen and Bray & Kurtz methods are shown in Table 5. According to the Olsen method the available phosphorus content ranged from 5.0 to 57.0 mg kg^{-1} for the soils of AEZ 5 and from 6.5 to 8.6 mg kg^{-1} for the AEZ 6 soils. The available phosphorus contents of the soils were of the low level in all locations for the Jaonia series, and varied from medium to optimum levels for the Laskara series, from very low to high levels for the Tarash series, from low to optimum levels for the Manda series and from low to optimum levels for the Gangachara series, and it was observed to be in the high level for the soil of the Malanchi series (BARC, 1997). In the Bray & Kurtz method, it was found that the contents of available phosphorus were higher than those by the Olsen method in the most cases. Both results were significantly correlated with each other (Table 7).

Cation exchange capacity (CEC)

The CEC of the soils of the six soil series was as follows: 20.4 to 21.9 cmol$_c$ kg^{-1} for the Laskara series,15.4 to 28.4 cmol$_c$ kg^{-1} for the Tarash series, 10.9 to 12.4 cmol$_c$ kg^{-1} for the Manda series, 12.4 cmol$_c$ kg^{-1} for the Malanchi series, 16.4 to 20.4 cmol$_c$ kg^{-1} for the Gangachara series and 26.8 to 31.3 cmol$_c$ kg^{-1} for the Jaonia series (Table 6). The CEC was estimated in the high level for the soils of the Tarash, Gangachara and Laskara series, in the medium level for the soils of the Manda and Malanchi series and in the high to very high level for the soils of the Jaonia series (BARC, 1997). The higher CEC values denote the comparatively high chemical activity of a soil, and it was found that the CEC was significantly correlated with active acidity and the contents of clay, organic matter, total nitrogen, and exchangeable calcium, magnesium and potassium in the present study (Table 7).

Exchangeable calcium content

The exchangeable calcium contents of the soils of the six different soil series of AEZ 5 and AEZ 6 are presented in Table 6. It was observed that the exchangeable calcium content for the Laskara, Tarash, Manda, Malanchi, and Gangachara series of AEZ 5 varied from 4.50 to 9.00, 5.50 to 14.8, 1.94 to 2.20, 3.50, and 2.50 to 3.26 cmol$_c$ kg^{-1}, respectively, while that for the Jaonia series of AEZ 6 varied from 12.7 to 14.0 cmol$_c$ kg^{-1}. The exchangeable calcium content was found to be in the very high level in all locations for the Jaonia series; it was to be in the medium to very high level for the Laskara series, the optimum to very high level for the Tarash series, the low level for the Manda series, the

Table 5. Available sulfur and phosphorus contents of the soils

AEZ	Soil series	Available sulfur (mg kg^{-1})	Available phosphorus (mg kg^{-1})	
			Olsen method	Bray and Kurtz method
Lower Atrai Basin	Laskara–1	32.6	9.2	12.5
	Laskara–2	18.8	9.1	14.5
	Laskara–3	22.8	18.9	13.5
	Tarash–1	18.4	6.3	7.6
	Tarash–2	18.0	5.0	7.9
	Tarash–3	17.6	24.9	19.5
	Tarash–4	18.1	21.9	20.2
	Manda–1	16.3	22.9	22.8
	Manda–2	17.9	6.5	10.1
	Malanchi	17.5	24.2	20.7
	Gangachara–1	16.8	27.8	27.9
	Gangachara–2	17.8	57.0	40.2
	Gangachara–3	31.8	18.8	18.3
	Gangachara–4	20.9	15.8	17.9
Lower Purnabhaba Floodplain	Jaonia–1	13.5	7.4	7.9
	Jaonia–2	12.9	7.4	10.2
	Jaonia–3	156	7.7	10.7
	Jaonia–4	176	6.5	9.9
	Jaonia–5	34.3	8.6	10.6
	Jaonia–6	198	7.7	9.3

Table 6. Cation exchange capacity (CEC), and exchangeable calcium, magnesium, potassium and sodium, and non–exchangeable potassium contents of the soils

AEZ	Soil series	CEC	Exchangeable				Non–exchangeable
			Ca	Mg	K	Na	K
		($cmol_c\ kg^{-1}$)					
Lower Atrai Basin	Laskara–1	20.9	4.50	5.46	0.27	0.55	4.5
	Laskara–2	21.9	9.00	6.92	0.19	0.74	5.9
	Laskara–3	20.4	6.24	6.04	0.24	0.62	7.0
	Tarash–1	24.4	14.8	7.80	0.18	0.68	4.6
	Tarash–2	28.4	13.0	8.20	0.27	0.74	4.9
	Tarash–3	15.4	7.50	7.32	0.22	0.49	7.5
	Tarash–4	16.4	5.50	4.66	0.14	0.49	5.7
	Manda–1	10.9	2.20	3.78	0.10	0.43	5.4
	Manda–2	12.4	1.94	2.92	0.07	0.31	5.0
	Malanchi	12.4	3.50	5.78	0.10	0.87	6.2
	Gangachara–1	16.9	2.50	9.24	0.10	0.49	7.5
	Gangachara–2	16.4	3.26	7.06	0.08	0.68	7.7
	Gangachara–3	19.4	2.70	5.52	0.11	0.62	6.4
	Gangachara–4	20.4	3.04	6.16	0.08	0.55	6.1
Lower Purnabhaba Floodplain	Jaonia–1	26.8	14.0	8.80	0.44	0.62	3.5
	Jaonia–2	29.3	13.7	8.46	0.46	0.68	5.7
	Jaonia–3	30.3	12.7	9.24	0.36	0.68	7.8
	Jaonia–4	31.3	13.5	8.90	0.33	0.56	6.4
	Jaonia–5	28.3	14.0	8.70	0.50	0.56	7.5
	Jaonia–6	28.2	13.7	8.34	0.48	0.68	3.3

medium level for the Malanchi series, and the low to medium level for the Gangachara series (BARC, 1997). From the correlation matrix (Table 7) it was found that the exchangeable calcium content was significantly correlated with the clay content, CEC, and the exchangeable magnesium and potassium contents.

Exchangeable magnesium content

Like the exchangeable calcium content, the exchangeable magnesium content of the soils of the two AEZs was in the very satisfactory level (Table 6). In general, the soils of AEZ 6 had higher amounts of exchangeable magnesium than did the most AEZ 5 soils. Variation of the exchangeable magnesium content was mainly due to the clay content and CEC of the soils, although the significant correlation was also observed with the organic matter, total nitrogen, and exchangeable calcium and potassium contents (Table 7).

Exchangeable sodium content

The exchangeable sodium content of the AEZ 5 soils ranged from 0.31 to 0.87 $cmol_c\ kg^{-1}$ while that of the AEZ 6 soils varied from 0.56 to 0.68 $cmol_c\ kg^{-1}$ (Table 6). The exchangeable sodium content for these soil series was less than that for soil series in the coastal area because of inundation by fresh water.

Exchangeable potassium content

As shown in Table 6, the exchangeable potassium content of the soils of AEZ 5 varied with soil series mainly based on the clay content: higher for the Laskara and Tarash series (0.14 to 0.27 $cmol_c\ kg^{-1}$) and lower for the Manda, Malanchi and Gangachara series (0.07 to 0.11 $cmol_c\ kg^{-1}$). The first group had exchangeable

Table 7. Correlation matrix between physical and chemical properties of the soils

	Clay	pH	AA	CEC	OM	N	P_1	P_2	S	K	Ca
Clay	1										
pH	−0.606**	1									
AA	0.520*	−0.831**	1								
CEC	0.898**	−0.599**	0.563**	1							
OM	0.647**	−0.197	0.173	0.672**	1						
N	0.689**	−0.612**	0.517*	0.670**	0.652**	1					
P_1	−0.621**	0.626**	−0.507*	−0.593**	−0.403	−0.403	1				
P_2	−0.679**	0.592**	−0.478*	−0.635**	−0.402	−0.437	0.967**	1			
S	0.617**	−0.481*	0.282	0.557*	0.220	0.375	−0.303	−0.311	1		
K	0.839**	−0.705**	0.644**	0.825**	0.376	0.631**	−0.543*	−0.616**	0.477*	1	
Ca	0.921**	−0.480*	0.437	0.884**	0.592**	0.646**	−0.598**	−0.683**	0.441	0.838**	1
Mg	0.740**	−0.274	0.394	0.773**	0.595**	0.511*	−0.185	−0.216	0.406	0.650**	0.733**

** and * mean correlation significant at the 0.01 and 0.05 levels, respectively (2–tailed).
Clay: clay percentage AA: active acidity CEC: cation exchange capacity OM: organic matter content N: total N content
P_1: available P determined by the Olsen method P_2: available P determined by the Bray and Kurtz method
S: available S content K: exchangeable K content Ca: exchangeable Ca content Mg: exchangeable Mg content

potassium in the medium to optimum level and the second group had the low level in respect of crop production (BARC, 1997). While, the exchangeable potassium content of the soils of AEZ 6 having the higher clay content was highest (0.33 to 0.50 $cmol_c\ kg^{-1}$) to be evaluated in the high to very high level.

Non–exchangeable potassium content

The non–exchangeable potassium content of the AEZ 5 soils ranged between 4.5 and 7.7 $cmol_c\ kg^{-1}$ while that of the AEZ 6 soils ranged between 3.3 and 7.8 $cmol_c\ kg^{-1}$ (Table 6). No definite trend was found for variation among the soils. However, relatively good amounts of non–exchangeable potassium were found in all soil series.

Correlation matrix

The correlation matrix for physical and chemical properties determined in the present study is given in Table 7. It was understood that the clay content was the most fundamental property to control chemical properties of soils in AEZs 5 and 6. The clay content is most important for efficient land use and better soil and crop management in these agroecological regions.

CONCLUSIONS

The soils of AEZ 5 were mostly medium–textured and had the lower values of organic matter, lime requirement, total nitrogen, CEC, and some exchangeable cations than did the soils of AEZ 6 which were fine–textured having the higher content of clay. Other chemical properties also varied among the soils irrespective of AEZs and soil series. Deficiencies of different nutrients were found to occur. Hence, soil fertility should be improved based on the results obtained in the present study.

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