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Mineralogical Composition of Some Selected Paddy Soils of Bangladesh

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Soil mineralogy, which largely affects the productivity of soil in low input agriculture, was determined for 28 widely distributed paddy soils from different agroecological regions (AEZs) of Bangladesh. In addition, particle–size distribution was analyzed through fractionation of soil particles into five groups viz. <2, 2–20, 20–53, 53–200 and 200–2000 μm fractions. They represented 3–45, 6–59, 6–41, 3–41 and 0–49% of soil particles, respectively. The 2–20 μm silt fraction appeared to be the dominant fraction for most of our studied soils (17 out of 28 soils). The XRD patterns of the <2 μm clay fraction indicated the presence of five layer silicate (mica, smectite, chlorite, vermiculite and kaolinite) and four complex minerals (quartz, feldspar, goethite and lepidocrocite) and two interstratified minerals (vermiculite–chlorite and mica–chlorite). Mica (20–50%) was the most predominant mineral identified in all the studied soils. Next to mica, chlorite (5–20%) and kaolinite (2–37%) were present in all the soils. Vermiculite (2–16%) was identified in 20 soils while smectite (1–11%) was identified in only 5 soils. In addition, vermiculite–chlorite intergrade (1–11%) and interstratified mica–chlorite (1–13%) was detected both in 11 soils. Other than layer silicates, quartz (4–21%) was the predominant non–silicate mineral identified in all the studied soils. Next to quartz, feldspars was identified in 26 soils with an approximate relative percentage ranges between 3 and 12%. Very small amount of goethite (1–2%) and lepidocrocite (1–3%) were identified only in 4 and 5 soils, respectively. According to the clay mineralogical composition, most of the studied soils were found at the initial stage of weathering, indicating the high potential to sustain low input subsistence agriculture.

Key words: clay mineralogy, paddy soil, Bangladesh

INTRODUCTION

Productivity of paddy soils in low input agriculture like in Bangladesh largely depends on inherent soil fertility due to low soil organic matter content as prevailed by subtropical warm and humid climate, application of inadequate and/or imbalanced mineral fertilizers and poor infrastructure in controlling huge flood and rain water. The mineralogy of these paddy soils is decisive for determining its fertility as well as productivity. The quantity, distribution and composition of mineral soil particles play a pivotal role in soil fertility such as nutrient holding and releasing capacity, soil resistant against detrimental influences of human or nature and resilience against soil degradation (Lal, 1997; Sanchez *et al.*, 2003; Szilas *et al.*, 2005). Generally, soils dominated with highly negatively charged minerals such as smectite and vermiculite have much higher capacity to retain plant–available (exchangeable) cations compared to the medium–charged (mica and chlorite) and low–charged (kaolinite, gibbsite and goethite) minerals.

Paddy soils in Bangladesh are mainly developed on unconsolidated floodplain sediments varying in age, texture and mineralogy deposited under piedmont, meander, estuarine and tidal floodplain conditions (Moslehuddin *et al.*, 1999). Therefore, it is hypothesized that the mineralogical composition of these paddy soils are very heterogeneous. However, knowledge of the mineralogical composition solely on paddy soils in Bangladesh based on large number of soil samples is mainly restricted to the agriculturally important soil series representing some specific physiographic units (Huizing, 1971; Habibullah *et al.*, 1971; Islam and Lotse, 1986; Egashira, 1988; Egashira and Yasmin, 1990; Alam *et al.*, 1993a,b; Khan *et al.*, 1997; Moslehuddin and Egashira, 1997; Moslehuddin *et al.*, 1999) or agroecological regions (AEZs) for an example AEZ 1, 2, 3, 4, 7, 9, 11, 12, 18, 25 and 27 (Islam *et al.*, 2003a,b; Shamsuzzoha *et al.*, 2003; Ripon *et al.*, 2004; Rahman *et al.*, 2005, Moslehuddin *et al.*, 2008a,b, Akter *et al.*, 2015). Based on the above literature, it can be concluded that vermiculite, smectite, mica, chlorite and kaolinite are the most abundant minerals in Bangladeshi paddy soils. Among the studied soils few of them, particularly terrace paddy soils, might be dominated by variable charge minerals while the others are dominated by permanent–charge 2:1 layer silicates clays. Management systems of soils having permanent–charge 2:1 layer silicates are largely different than the soils dominated by variable charge minerals. A small difference in the mineralogical composition may decisively affect various soil properties (Szilas *et al.*, 2005). Therefore more detailed study and comparison of soil mineralogy among paddy soils of Bangladesh is essential to manage them in an efficient and sustainable manner. Thus, the objective of this paper is to show the mineralogical composition and particle size distribution of 28 widely distributed paddy soils from different AEZs in

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MATERIALS AND METHODS

Site description and soils

A set of 28 soils was collected from farmers' fields throughout Bangladesh covering a wide range in texture, AEZ, General Soil Type, cropping pattern and land type (Table 1). Most of the studied farmers' fields were, in details, characterized by Kader *et al*. (2013). The study area is dominated by rice–based cropping patterns and belongs to subtropical monsoon climate with wide seasonal variations in rainfall, moderately warm temperatures and high humidity. The annual mean temperature and precipitation of the study areas were 25.6°C and 2428 mm, respectively (BMD, 2013). Soil samples were collected mostly at the end of 2007 (November and December) and at the beginning of 2008 (January and February) during the gap of two cropping seasons. Surface soil samples (0–15 cm) were collected from 15 locations per field by means of an auger (inner diameter 2.5 cm). These samples were bulked into one composite

Table 1. Soil series name, general soil type, agro–ecological region (AEZ), taxonomic classification, land type and cropping system history of sampled soils

Soil Series	USDA taxonomy	General soil type	AEZ	Land type	Cropping Pattern	Location (Village &District)
Ranisankail	Aeric Albaquepts	Noncalcareous Grey Floodplain Soil	1	MH	P–M–T.A	Koichor, Bogra
Gangachara	Udic Ustochrepts	Noncalcareous Grey Floodplain Soil	3	H	P–J–T.A	Sonahar, Panchagar
Sonatala–1	Aeric Haplaquepts	Noncalcareous Grey Floodplain Soil	9	ML	B–F–T.A	BAU farm, Mymensingh
Silmondi–1	Aeric Haplaquepts	Grey Floodplain Soil	9	ML	V–F–T.A	Katlasen, Mymensingh
Ghatail	Mollic Haplaquepts	Noncalcareous Dark Grey Floodplain Soil	9	L	B–F–F	Batipar, Mymensingh
Balina	Aeric Fluvaquents	Noncalcareous Dark Grey Floodplain Soil	9	VL	B–F–T.A	Nowapara, Mymensingh
Melandaha	Typic Fluvaquents	NoncalcareousDark Grey Floodplain Soil	9	MH	F–F–T.A	Madhupur, Mymensingh
Tarakanda	Aeric Haplaquepts	Noncalcareous Grey Floodplain Soil	9	MH	B–F–F	Mograpara, Narayangonj
Gorargaon	Ultic Ustochrepts	Noncalcareous Dark Grey Floodplain Soil	9	VL	F–F–T.A	Bhaluka, Mymensingh
Dhamrai	Aeric Haplaquepts	Noncalcareous Dark Grey Floodplain Soil	9	ML	M–F–T.A	Vatgao, Dinajpur
Silmondi–2	Aeric Haplaquepts	Grey Floodplain Soil	9	MH	B–F–T.A	Rajendrapur, Netrokona
Sonatala–3	Typic Haplaquepts	Noncalcareous Grey Floodplain Soil	9	MH	F–A–T.A	Arathinyamat, Rangpur
Sulla	Aeric Haplaquepts	Acid Basin Clay	9	VL	B–F–T.A	Netrokona sadar, Netrokona
Silmondi–3	Aeric Haplaquepts	Grey Floodplain Soil	9	ML	B–F–F	Mograpara, Narayangonj
Sonatala–4	Aeric Haplaquepts	Noncalcareous Grey Floodplain Soil	9	H	B–F–T.A	Jamalpur pauroshava, Jamalpur
Sonatala–2	Typic Haplaquepts	Noncalcareous Dark Grey Floodplain Soil	9	ML	B–F–F	Bajitpur, Mymensingh
Silmondi–4	Ultic Ustochrepts	Grey Floodplain Soil	9	ML	B–F–T.A	BADC farm, Tangail
Gopalpur	Aeric Haplaquepts	Calcareous Dark Grey Floodplain Soil	10	MH	B–F–T.A	Jamalpur sadar, Jamalpur
Ishurdi	Udic Ustochrepts	Calcareous Dark Grey Floodplain Soil	12	ML	P–P–M	Vatgao, Dinajpur
Faridganj	Aeric Haplaquepts	Noncalcareous Dark Grey Floodplain Soil	17	MH	B–F–T.A	Larairchar, Chandpur

Table 1: (Continued)

Soil Series	USDA taxonomy	General soil type	AEZ	Land type	Cropping Pattern	Location (Village &District)
Noakhali	Arent	Man–made Land	17	MH	B–F–T.A	Larairchar, Chandpur
Ramgati	Aeric Fluvaquents	Noncalcareous Dark Grey Floodplain Soil	17	ML	B–F–T.A	Giarchar, Laxmipur
Pritimpasa	Typic Haplaquepts	Grey Piedmont Soil	22	MH	B–F–F	Bristol, Kishoregonj
Amnura	Typic Haplaquepts	Deep Grey Terrace Soil	25	MH	B–F–T.A	Dhobadanga, Nilphamari
Noadda–1	Entic Haplumbrepts	Deep Red Brown Terrace Soil	28	H	W–F–T.A	Panchagar sadar, Panchagar
Noadda–2	Aeric Albaquepts	Deep Red Brown Terrace Soil	28	MH	B–F–T.A	BADC farm, Tangail
Karail	Aeric Haplaquepts	Acid Basin Clay	28	ML	V–V–T.A	Netrokona sadar, Netrokona
Kalma	Cumulic Humaquepts	Grey Valley Soil	28	ML	B–F–F	Borbila, Mymensingh

H=High land, MH=Medium highland, ML=Medium lowland, VL=Very lowland
B=Boro, F = Fallow, T. A=Transplant Aman, V=Vegetable, A=Aus, W=Wheat, M=Maize, P=Potato, J=Jute

sample per field and were thoroughly mixed. The field–moist soil was gently broken apart by hand and was air–dried and ground to pass a 2–mm sieve prior to mineralogical analysis.

Particle–size analysis

Particle–size distribution was analyzed through fractionation of soil particles into five groups viz. <2, 2–20, 20–53, 53–200 and 200–2000 μm fractions. For this purpose, soil organic matter was decomposed by 7% hot H_2O_2 treatment followed by stirring with a mechanical stirrer and raising the pH at 10 using 1 M NaOH. Subsequently, the <2 and 2–20 μm fractions were separated by repeated stirring, sedimentation and siphoning while the rest of the size fractions were separated by wet sieving. Each fraction was oven–dried and weighed to determine the particle–size distribution in soils.

Mineralogical characterization

The mineral compositions of the clay fraction were determined by X–ray diffraction using Rigaku RINT 2100 V with Cu Kα radiation at 40 kV and 20 mA, following air–drying and glycerol–solvating of Mg–saturated clay, and air–drying, and heating at 300 and 550°C of K–saturated clay. The XRD data were collected from 3 to 30° 2θ, at a scanning speed of 2° 2θ per minute.

Individual clay minerals were identified based on the XRD patterns of the <2 μm clay fraction. Mica was identified by the presence of the 0.99–1.00 nm peak along with its higher–order reflections at 0.497–0.500 and 0.334 nm. The presence of kaolinite was ascertained by the relatively sharp peaks at 0.714–0.719 and 0.357 nm which were all disappeared by heating at 550°C of the K–saturated clay. Chlorite was identified by the peak at 1.42–1.44 nm and reflections of its higher–orders and by remaining of the 1.42–1.44 nm peak in the treatment of K–saturation and heating at 550°C. Vermiculite was identified by the decrease in the intensity of the 1.42–1.44 nm peak in Mg–saturated specimen with the corresponding increase in the intensity of the 0.99–1.00 nm peak by K–saturation and air–drying. Smectite was noticed by the broad peak around 1.80 nm in the Mg–saturated and glycerol–solvated specimen.

The interstratified mica/vermiculite/smectite (not identified in this study) mineral was noticed on the XRD pattern by the poorly defined diffraction effect between 1.0 and 2.0 nm in the Mg–saturated and glycerol–solvated specimen and by the increase in the intensity of the 1.00 nm peak after K–saturation and air–drying (Egashira, 1988). The presence of the interstratified kaolinite–smectite mineral was suggested by tailing of the 0.7 nm peak toward the higher angles. Chlorite–vermiculite intergrade was detected by the 1.42–1.44 nm reflection in the Mg–saturated clay, which shifted toward 1.00 nm by heating at 300 and 550°C of the K–saturated clay. Goethite, gibbsite, quartz and feldspars which are minerals other than layer silicate minerals were identified by the peaks at 0.416–0.418, 0.484, 0.425 and 0.334, and around 0.32 nm, respectively.

The clay minerals were semi–quantified by the calculation of approximate mineral composition of the clay fraction based on the relative peak intensities of the respective minerals in the XRD charts following Moslehuddin and Egashira (1996).

RESULTS

Particle–size distribution

Particle–size distribution and textural classes of the soils as determined by the USDA system are shown in

Table 2. Particle–size distribution and textural class of sampled soils

Soil series	Particle–size distribution (%)					USDA Textural Class
	<2 μm	2–20 μm	20–53 μm	53–200 μm	200–2000 μm	
Ranisankail	9	6	7	29	49	Loamy sand
Gangachara	14	20	17	36	14	Loam
Sonatala–1	14	59	23	3	1	Silt
Silmondi–1	11	37	30	20	2	Silt loam
Ghatail	35	39	8	4	13	Silty clay loam
Balina	23	36	14	23	5	Silt loam
Melandaha	20	35	8	34	3	Loam
Tarakanda	3	7	6	40	44	Loamy sand
Gorargaon	30	47	7	12	5	Silty clay loam
Dhamrai	26	36	16	19	4	Silt loam
Silmondi–2	21	52	20	5	1	Silt loam
Sonatala–3	17	34	23	25	1	Silt loam
Sulla	38	47	8	7	0	Silty clay loam
Silmondi–3	11	31	18	36	3	Silt loam
Sonatala–4	12	6	39	41	3	Loam
Sonatala–2	25	59	8	8	0	Silt loam
Silmondi–4	25	21	21	32	0	Loam
Gopalpur	13	30	38	18	1	Silt loam
Ishurdi	8	56	21	14	1	Silt loam
Faridganj	5	55	26	14	0	Silt
Noakhali	9	33	19	38	1	Silt loam
Ramgati	19	38	36	6	0	Silt loam
Pritimpasa	22	35	20	18	4	Silt loam
Amnura	12	26	41	15	7	Silt loam
Noadda–1	17	48	23	10	2	Silt loam
Noadda–2	20	32	23	15	10	Silt loam
Karail	45	33	12	4	6	Siltyclay
Kalma	15	52	21	13	0	Silt loam

Table 2. The clay (<2 μm) content in the selected soils varied widely from 3% in the Tarakanda soil to 45% in the Karail soil. The Faridganj, Noakhali, Silmondi 1 & 3, Ishurdi, Tarakanda, Gopalpur, Gangachara, Ranisankail, Amnura, Kalma and Sonatala–4 soils had lower amounts of clay (3 to 15%) while the Karail, Sulla and Ghatail soils had good amounts of clay (35 and 45%). Other soils had moderate amounts of clay ranging between 17and30%. In general, soils located on the higher sites had the lower clay content than those on the lower–elevation sites.

The 2–20 μm silt fraction also varied widely from 6 to 59% and appeared to be the dominant fraction for most of our studied soils. Seventeen out of twenty eight soils had this fraction dominating over all other fractions. The 20–53, 53–200 and 200–2000 μm fractions varied from 6 to 41, 3 to 41 and 0 to 49%, respectively. The amount of coarse sand (200–2000 μm) fraction was found in a low range between 0 and 14% in most of the soils except the Tarakanda (44%) and Ranisankail (49%) soils.

Mineralogy of the clay fraction

The XRD patterns of the <2 μm clay fraction of four selected soils (Ishurdi, Sonatala–3, Pritimpasa and Karail) are reproduced in Fig. 1. XRD analysis revealed that all studied K and Mg–saturated clay fractions were composed of a variable mixture of 2:1 phyllosilicates (peaks at 1.0, 0.500 and 0.333 nm), kaolinite (0.713 and 0.357 nm) quartz (0.425 and 0.333 nm), feldspar (0.320), goethite (0.418 nm) and lepidocrocite (0.627 nm). In a few soils, the presence of open 2:1 phyllosilicates was clear from swelling after glycolation.

The approximate mineralogical composition of the <2 μm clay fraction is summarized in Table 3. The results indicated that mica (accounting 50 and 43% of approximate mineralogical distribution) and chlorite (accounting 23 and 21% of approximate mineralogical distribution) were the most predominant mineral in Ranisankail and Gangachara soils those belong to AEZ 1(Old Himalayan Piedmont Plain) and 3 (Tista Meander Floodplain), respectively. Both soils contain small amount of vermiculite (2–8%) and kaolinite (2%). Only

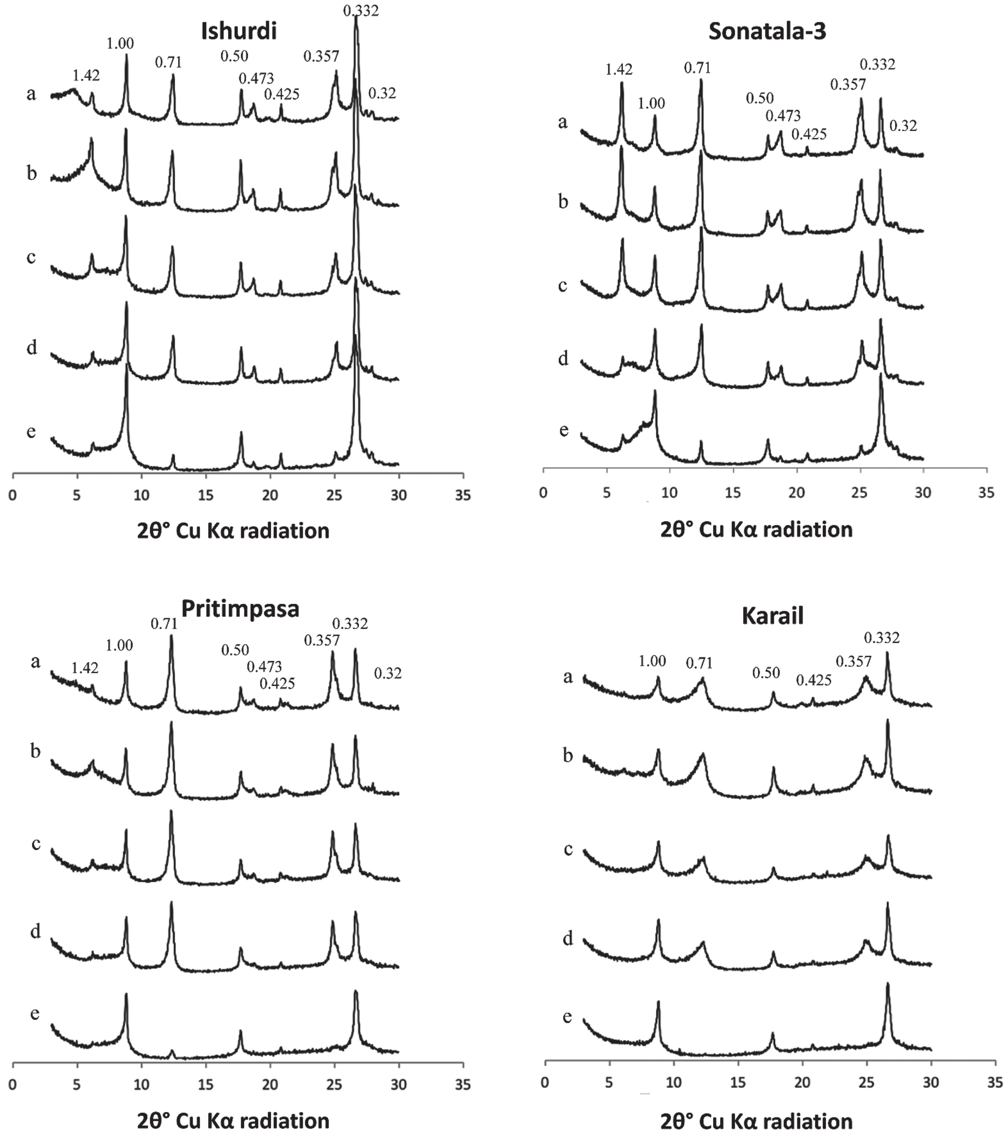

Fig. 1. X–ray diffraction patterns of the <2 μm clay fraction of Ishurdi (upper left), Sonatala–3 (upper right), Pritimpasa (lower left) and Karailsoil (lower right). Spacing is in nm. Treatments: a, Mg–saturation and glycerol– solvation; b, Mg–saturation and air–drying; c, K–saturation and air–drying; d, K–saturation and heating at 300°C; e, K–saturation and heating at 550°C.

Gangachara soil contains 10% mica–chlorite interstratified minerals.

Approximate mineralogical distribution of 15 soils (Sonatala–1, 2, 3, 4, Silmondi–1, 2, 3, 4, Ghatail, Balina, Melandaha, Tarakanda, Gorargaon, Dhamrai, Sulla) belong to AEZ 9 (Old Brahmaputra Floodplain) were found to be predominated by mica ranging between 20 and 45% followed by chlorite ranging between 5 and 25%, and kaolinite ranging between 5% and 21%. Vermiculite was present in almost all these soils except Silmondi–1, Ghatail and Gorargaon. Interstratified vermiculite–chlorite mineral was present in these exceptional three soils instead of vermiculite. Indeed, vermiculite is the end product of weathering of interstratified vermiculite–chlorite mineral.

Two calcareous soils namely Gopalpur and Ishurdi belong to AEZ 10 (Active Ganges Floodplain) and 12 (Low Ganges River Floodplain), respectively, composed of substantial amount of smectite in addition to mica, chlorite, kaolinite and vermiculite. Three soils, developed from Meghna sediments (Faridganj, Noakhali and Ramgati), collected from AEZ 17 (Lower Meghna River Floodplain) composed of mainly mica, chlorite and kaolinite. Noakhali and Ramgati soils have small amount of smectite while only Noakhali soil has a substantial amount of vermiculite among the three studied soils. Faridganj soil has substantial amount of vermiculite–chlorite intergrade instead of vermiculite.

On the other hand, soils originated from marine formation namely, Amnura, Karail, Noadda–1, 2 and Kalma those belong to AEZ 25 (Level Barind Tract) and 28 (Madhupur Tract) composed of substantial amount of kaolinite (and interstratified kaolinite–smectite) in addition to mica and chlorite. Soils collected from piedmont area (Northern and Eastern Piedmont Plains; AEZ 22) namely Pritimpasa composed of substantial amount of

Table 3. Approximate mineralogical composition (%) in clay fraction of sampled soils

Soil Series	Minerals										
	Mc	St	Vt	Ch	Kt	Vt–Ch	Mc/Ch	Qr	Gt	Lp	Fd
Ranisankail	50	0	8	23	2	0	0	9	0	0	8
Gangachara	43	0	2	21	2	0	10	7	0	0	15
Sonatala–1	31	0	6	27	13	0	6	8	0	0	9
Silmondi–1	28	0	0	21	11	11	2	13	0	0	13
Ghatail	20	0	0	21	14	11	0	14	0	1	19
Balina	33	0	8	21	11	0	0	10	0	0	18
Melandaha	40	0	3	17	15	5	3	9	1	0	7
Tarakanda	33	0	2	16	11	9	1	18	0	0	10
Gorargaon	41	0	0	19	12	2	2	15	0	0	10
Dhamrai	41	0	6	21	9	0	3	11	0	0	10
Silmondi–2	30	0	4	21	11	0	0	13	0	3	18
Sonatala–3	27	0	16	25	21	0	0	9	0	0	3
Sulla	45	0	10	5	5	3	0	20	0	0	13
Silmondi–3	36	0	3	20	20	10	2	6	0	0	4
Sonatala–4	36	0	1	20	13	10	13	8	0	0	0
Sonatala–2	27	0	8	18	12	0	0	15	0	2	20
Silmondi–4	27	0	11	22	6	0	0	20	0	0	13
Gopalpur	34	10	5	19	9	3	0	11	0	0	10
Ishurdi	27	11	2	16	13	0	0	19	1	0	12
Faridganj	35	0	0	26	10	10	0	10	0	0	10
Noakhali	34	2	12	22	15	1	5	4	2	0	3
Ramgati	33	1	0	23	9	0	2	14	2	0	16
Pritimpasa	33	3	0	11	37	0	0	13	0	0	3
Amnura	40	0	0	17	21*	0	0	19	0	0	3
Noadda–1	39	0	4	13	16*	0	0	19	0	1	9
Noadda–2	36	0	2	19	24*	0	0	19	0	0	0
Karail	30	0	0	16	33*	0	0	21	0	0	0
Kalma	45	0	10	12	15*	0	0	14	1	0	3

Mc: mica; St: smectite; Vt: vermiculite; Ch: chlorite; Kt: kaolinite; Vt/Ch: vermiculite–chlorite interstratified minerals; Mc/Ch: mica–chlorite interstratified minerals; Qr: quarts; Gt: goethite; Lp: lepidocrocite; Fd: feldspar

*Also contain interstratified Kt–St

kaolinite as well as small amount of smectite in addition to mica and chlorite.

On an overall, mica was found to be predominant mineral for all 28 studied soils ranging between 20 and 50% followed by chlorite ranging between 5 and 25% and kaolinite ranging between 2 and 37%. Vermiculite was identified in 20 soils. Only five soils (Sonatala–3, Sulla, Noakhali, Silmondi–4 and Kalma) have an approximate relative percentage of vermiculite $\geq$ 10%. Smectite was identified only in 5 soils (Gopalpur, Ishurdi, Noakhali, Ramgati and Pritimpasa soils) having an approximate relative percentage between 1 and 11%. In addition, vermiculite–chlorite intergrade (1–11%) and interstratified mica–chlorite (1–13%) were detected both in 11 soils.

Other than layer silicates, quartz (4–21%) was the predominant complex silicate mineral identified in all the studied soils. Next to quartz, feldspars was identified in 26 soils (except Karail, Sonatala–4 and Noadda–2) with an approximate relative percentage ranges between3 and 12%. Very small amount of goethite (1–2%) and lepidocrocite (1–3%) were identified only in 4 (Melandaha, Ishurdi, Noakhali and Ramgati) and 5 (Ghatail, Silmondi, Sonatala–2, Noadda–1 and Kalma) soils, respectively.

DISCUSSION

The texture of the studied soil set was mostly (24 out of 28) of medium–textured (mainly silt loam). As the majority of soil samples were collected from the rice growing floodplain areas, therefore, they showed the typical textural characteristics of floodplain soil with high silt content (FAO, 1971). Among the size fractions, fine silt fraction (2–20 μm) was appeared to be the dominant fraction in most of the studied soils (17 out of 28).

The variation in soil texture was found to be related with the position of soils or land type. Usually, soils collected from higher elevation (medium highland) were found coarse–textured while collected from lower elevation (medium lowland and lowland) were found fine–textured. This is mainly due to the deposition of finer soil particles in the lower position from the surrounding upper elevation through run–off water.

A wide variation was observed in clay mineralogical composition of the studied soils. This might be related to the differential nature of sediments deposited by the rivers in different times. Ranisankail and Gangachara soils those belongs to AEZ 1 (Old Himalayan Piedmont Plain) and 3 (Tista Meander Floodplain), respectively, were found to be dominated by mica and chlorite. Ranisankail soil contains 8% vermiculite while the Gangachara soil contains 10% mica–chlorite interstratified minerals. This is mostly in line with the previous findings by Moslehuddin and Egashira (1996) and Islam *et al*. (2003a) who found that mica and chlorite and sometimes interstratified mica–chlorite and vermiculite–chlorite intergrade were the major minerals in the clay fraction of the Baliadangi, Ranisankail and Gangachara soils of the Old Himalayan Piedmont Plain. They hypothesized that these minerals have been derived from the parent material originated from metamorphic rocks. It is assumed that mica–chlorite interstratified minerals, found in Gangachara soil, were possibly altered from chlorite as a weathering product and that in the course of weathering it had changed finally to vermiculite that was observed in Ranisankail soil. Presence of vermiculite instead of mica–chlorite interstratified minerals in Ranisankail soil strongly supports the above assumption.

Majority (15) of soil samples (Sonatala–1, 2, 3, 4, Silmondi–1, 2, 3, 4, Ghatail, Balina, Melandaha, Tarakanda, Gorargaon, Dhamrai, Sulla) were collected from AEZ 9 (Old Brahmaputra Floodplain) and found to be predominated by mica, chlorite, vermiculite/ vermiculite–chlorite intergrade and kaolinite. These results were pretty similar to those obtained by Egashira and Yasmin (1990), Alam *et al*. (1993a) and Islam *et al*. (2003b) who reported that soils of Old Brahmaputra Floodplain were dominated by mica and chlorite with some vermiculite and/or vermiculite–chlorite intergrade. The present study also broadly supports the tentative mineralogical suite (mica–chlorite–vermiculite*) (*mean partial chloritization) of AEZ 9 as proposed by Moslehuddin *et al*. (1999).

Soils developed from Ganges Floodplain (Gopalpur and Ishurdi) are generally calcareous in nature, thus, composed of substantial amount of smectite in addition to mica, chlorite, kaolinite and vermiculite. Rahman *et al*. (2005) also reported the similar findings that clay fraction of Ganges Floodplain soils were found to be enriched with mica and smectite. This smectite is composed of iron–rich high charge beidellite which has high inherent potentiality (Moslehuddin and Egashira, 1997).

Soils developed from Meghna sediment closer to the estuary are bit mineralogically heterogeneous because the sediments carried by the Meghna in this location are mostly admixture of several rivers such as Tista, Jamuna, Brahmaputra, Ganges and Meghna itself. Therefore, the mineralogical compositions of collected three soils (Faridganj, Noakhali and Ramgati) from AEZ 17 (Lower Meghna River Floodplain) were found variable. For an example, Noakhali and Ramgati soils have small amount of smectite while only Noakhali soil has a substantial amount of vermiculite. On the other hand, Faridganj soil has neither smectite nor vermiculite but substantial amount of vermiculite–chlorite intergrade. However, the amount of vermiculite (if exists) is lower than the chlorite. This is in line with Moslehuddin *et al*. (1998) who reported that soils developed from Meghna sediments contain higher amount of chlorite than vermiculite.

Soils originated from marine formation (Amnura, Karail, Noadda–1, 2 and Kalma) are aged soils thus highly weathered compared to recently developed floodplain soils. Therefore, these soils are enriched with 1:1 type clay (kaolinite) in addition to mica and chlorite. Soil collected from piedmont area (Pritimpasa) was also dominated by kaolinite for its old age and high weathering in nature.

CONCLUSIONS

Soil particle size distribution and mineralogy considered to be the major determining factor of soil fertility as well as productivity of Bangladeshi paddy soil. Most of the studied paddy soils of Bangladesh were found to be dominated by finer soil particles such as fine silt (2–20 μm) and clay (<2 μm) which are chemically very active in nature. Clay fractions of the studied soils were also found to be dominated by 2:1 type weatherable clay minerals such as mica and chlorite. A considerable amount of vermiculite and/or its intergrade were also noticed in most of the studied soils. All these clay minerals are chemically very active having high buffering and nutrient holding capacities. Therefore, based on the particle size distribution and clay mineralogical composition, it can be concluded that paddy soils of Bangladesh are still at the initial stage of weathering having high potentiality of holding and releasing nutrients for sustaining low input subsistence agriculture of Bangladesh.

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