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Mineralogical Approach to Parent Material Characterization of Soils from Agroecological Region 6, Lower Purnabhaba Floodplain, in Bangladesh

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The study was conducted to examine the mineralogical composition of deeper layers of soils from the agroecological region (AEZ) 6, Lower Purnabhaba Floodplain, in Bangladesh. Surface layers of soils of the same AEZ were analyzed for the mineralogical composition in a previous study. The parent material of the soils belonging to the AEZ 6 has been supposed to be the Tista Alluvium, however, the mineralogy of the surface layers was rather similar to that of terrace soils developed from the Madhupur Clay. In order to verify the mineralogical suite throughout the profile of soils of the AEZ 6, soil samples of three different depths of 30–45, 60–75 and 75–90cm selected from six profiles were subjected to particle–size and mineralogical analyses.

It was found that all soil samples contained the high amount of clay (31.0–54.0%) and that the texture of most soil samples were designated as silty clay. The <2 μm clay fraction was commonly dominated by mica (19–44%) followed by interstratified mica–vermiculite–smectite (26–40%) and kaolinite–smectite (19–39%) minerals, accompanied with small amounts of kaolinite, chlorite, interstratified mica–chlorite, vermiculite, quartz, feldspars and lepidocrocite. The results indicated that the Madhupur Clay as the parent material had a much greater impact on the mineralogical composition in the <2 μm clay fraction in all profiles with insignificant contribution of the Tista Alluvium, while one soil layer of the Jaonia–6 profile showed a relatively higher contribution of the Tista Alluvium. From the findings of the present study, soils of the Lower Purnabhaba Floodplain (AEZ 6) should be included in the mineralogical suite of mica–mixed layer minerals–kaolinite along with terrace soils in Bangladesh.

Key words: Bangladesh, clay mineralogy, Lower Purnabhaba Floodplain, parent material

INTRODUCTION

Bangladesh is one of the greatest deltaic plain of the world and has a wider range and greater complexity of the land. The country has been divided into 30 agroecological regions (AEZ), 88 sub–regions and 535 agroecological units, refer to the previous paper (Islam *et al.*, 2003) for the map of AEZs. Agricultural research and technology generation and transfer etc. are now going on the AEZ basis. To get an idea on genesis and classification, physico–chemical properties, nutrient behavior as well as inherent potentiality of soil on the national level, a plan has been undertaken to study mineralogy of soils from all AEZs of Bangladesh in the Department of Soil Science, Bangladesh Agricultural University, Mymensingh.

The present work was planned for getting the proper mineralogical information of six soil profiles from the AEZ 6, Lower Purnabhaba Floodplain. This AEZ is located in the western part of Naogaon district and includes the little area of Chapainawabgonj district. Total area of this AEZ is 129 km^2 only. Basins and *bils* (lakes) separated by low floodplain ridges occupy the whole area of the AEZ 6 (FAO–UNDP, 1988). The parent material of soils of this AEZ has been supposed to be the Tista Alluvium transported by the Purnabhaba River.

Although no report on the mineralogy of soils of the AEZ 6 was available, Moslehuddin *et al.* (1999), while preparing a tentative clay mineralogical map for the whole country, assumed that the parent materials of soils of the AEZ 6 are similar to those from which soils of the AEZs 1, 2 and 3 have been developed and put the AEZ 6 in the mica–chlorite suite along with the AEZs 1, 2 and 3. They described the mica–chlorite suite as that mica, chlorite and sometimes the interstratified mica–chlorite mineral are the dominant minerals and that the chlorite component is somewhat degraded.

Later, Moslehuddin *et al.* (2006) studied the mineralogical composition of six surface soil samples of the Jaonia series of the AEZ 6 and reported that the mineralogy of the clay fraction was rather similar to that of Barind Tract soils originating from the Madhupur Clay. The possible explanation was done as follows: since the AEZ 6 situated on a lower topographical position surrounded by the Barind Tract, the surface soil of the Lower Purnabhaba Floodplain has been mixed with Barind tract soils. It is likely to occur by the surface run–off from the Barind Tract over period of time. They suggested that the AEZ 6 should be placed in the mica–mixed layer minerals–kaolinite suite along with terrace soils.

The present study is a follow–up work of the previous one (Moslehuddin *et al.*, 2006). Deeper layers of the six soil profiles from the Jaonia series of the AEZ 6, instead of surface soils targeted in the previous study,

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were examined for clarifying the mineralogical composition of this AEZ and verifying the mineralogical suite assumed for it.

MATERIALS AND METHODS

Soil used

Six soil profiles, all belonging to the Jaonia series, were selected to represent the entire area of the AEZ 6 by considering differences in the location and land type. Three soil samples, representing the depths of 30–45, 60–75 and 75–90 cm, were taken from each soil profile. The 60–75 cm–deep sample of the Jaonia–3 was missing, and total sample number became 17 for this study. General features of the soils used in the present study are shown in Table 1.

Particle–size analysis

The soil samples were treated with hot 7% H_2O_2 to decompose organic matter, dispersed by mechanical stirring and adjusted to the pH 10 using 1 M NaOH. The <2 μm clay fraction was separated by repeated stirring–sedimentation–siphoning. The 2–20 μm silt fraction was separated by repeated sedimentation and siphoning, and the 20–53, 53–200 and 200–2000 μm fractions were separated by wet–sieving. Weights of each fraction were determined to calculate the particle–size distribution.

Mineralogical analysis

Specimens for X–ray diffraction (XRD) of the clay fraction were prepared by taking duplicate clay sols containing 50 mg of clay (<2 μm). Of the duplicate sets, one was saturated with K and the other with Mg by washing three times with 1 M KCl and 0.5 M $MgCl_2$, respectively. Excess salt was removed by washing one time with water. An aliquot of 0.4 ml of the clay sol was dropped onto a glass slide (28×48 mm) covering two–thirds of its area, air–dried and X–rayed (parallel powder mount). XRD patterns were obtained using a X–ray diffractometer (RINT 2100V, Rigaku) with Cu Kα radiation at 40 kV and 20 mA and at a scanning speed of 2° 2θ min^{-1} over a range of 3 to 30°, 2θ. In addition to the air–dried specimen, the Mg–saturated clay was X–rayed after solvation with glycerol, and the K–saturated clay was X–rayed after heating at 300 and 550°C for 2 hrs.

RESULTS AND DISCUSSION

Particle–size distribution

Particle–size distribution and the textural class determined by the USDA system of the soils under study are shown in Table 2. It was found that all soil samples contained the high amount of clay (31.0 to 54.0%) and that the clay content generally increased with depth of the horizon in each soil profile, with exception of Jaonia–1 and –2 profiles. The 2–20 μm silt fraction was identified as the second largest fraction (27.6 to 42.7%) while the 20–53 and 53–200 μm fractions ranged from 3.2 to 17.4% and 2.1 to 15.8%, respectively. The coarse sand fraction (200–2,000 μm) was absent in all soil samples. According to the USDA system for the textural class, most soil samples belonged to silty clay except Jaonia–2b, Jaonia–2c and Jaonia–6a samples which were silty clay loam, and Jaonia–5b and Jaonia–5c samples belonging to clay.

Mineralogical composition of the clay fraction

Peaks in the XRD patterns of the clay (<2 μm) fraction were sometimes sharp, indicating the good crystallinity and/or large crystallite size of the minerals. On the other hand, peaks of some samples were broad, indi-

Table 1. Description of the soils under study

Soil profile	Location	Parent material	Land type	General soil type	Topography	Drainage	Flood level	Vegetation
Jaonia–1	Radhanagor, Gomostapur, Chapainawa-bgonj	Tista Alluvium	Low land	Acid Basin Clays	Level	Poorly drained	Deeply flooded	Deep water aman, Boro (HYV), Khesari
Jaonia–2	Radhanagor, Gomostapur, Chapainawa-bgonj	Tista Alluvium	Medium low land	Acid Basin Clays	Level	Poorly drained	Moderately to deeply flooded	Deep water aman
Jaonia–3	Nitpur, Porsa, Naogaon	Tista Alluvium	Low land	Acid Basin Clays	Level	Poorly drained	Deeply flooded	Deep water aman
Jaonia–4	Nitpur, Porsa, Naogaon	Tista Alluvium	Medium low land	Acid Basin Clays	Level	Poorly drained	Moderately to deeply flooded	Deep water aman
Jaonia–5	Aihai, Sapahar, Naogaon	Tista Alluvium	Low land	Acid Basin Clays	Level	Poorly drained	Deeply flooded	Deep water aman
Jaonia–6	Aihai, Sapahar, Naogaon	Tista Alluvium	Medium low land	Acid Basin Clays	Level	Poorly drained	Moderately to deeply flooded	Deep water aman

Table 2. Particle–size distribution of the soils under study

Soil profile	Sample No.*	Particle–size distribution (%)					USDA** soil textural classes
		<2 μm	2–20 μm	20–53 μm	53–200 μm	200–2,000 μm	
Jaonia–1	1a	48.4	32.7	16.8	2.1	0.0	Silty clay
	1b	46.5	42.5	8.7	2.2	0.0	Silty clay
	1c	47.0	33.2	11.1	8.7	0.0	Silty clay
Jaonia–2	2a	43.6	42.7	10.9	2.8	0.0	Silty clay
	2b	36.2	41.1	17.2	5.4	0.0	Silty clay loam
	2c	39.1	36.1	16.6	8.1	0.0	Silty clay loam
Jaonia–3	3a	43.1	41.3	3.2	12.3	0.0	Silty clay
	3c	52.4	28.5	14.7	4.4	0.0	Silty clay
Jaonia–4	4a	42.6	40.3	13.3	3.8	0.0	Silty clay
	4b	46.5	34.3	14.2	5.1	0.0	Silty clay
	4c	54.0	28.9	12.6	4.4	0.0	Silty clay
Jaonia–5	5a	39.0	41.5	15.4	4.1	0.0	Silty clay
	5b	45.0	31.3	7.9	15.8	0.0	Clay
	5c	53.0	29.3	4.9	12.6	0.0	Clay
Jaonia–6	6a	31.0	41.1	17.4	10.0	0.0	Silty clay loam
	6b	45.1	36.2	14.6	4.1	0.0	Silty clay
	6c	53.7	27.6	14.6	4.0	0.0	Silty clay

* Sampling depth: a, 30–45 cm; b, 60–75 cm; and c, 75–90 cm
**USDA: United States Department of Agriculture.

cating low crystallinity and/or small crystallite size of the minerals or presence of mixed layer minerals. Mica was identified by the presence of the 1.0 nm peak in the Mg–saturated specimen which was used for the calculation of the mica peak intensity. Chlorite was identified by the remaining of the 1.42 nm peak in the K–saturated and 550°C–heated specimen, while the presence of kaolinite was ascertained by the decrease in the 0.714 nm peak intensity after heating of the K–saturated specimen at 550°C. To measure the intensities of chlorite and kaolinite, the 0.714 nm peak intensity of the Mg–saturated and glycerol–solvated specimen was allocated to chlorite and kaolinite according to the intensity ratio of the 0.354 nm (chlorite) and 0.357 nm (kaolinite) peaks.

Vermiculite was identified by the decrease in the peak intensity of the 1.42 nm peak with the corresponding increase in the intensity of the 1.0 nm peak by shifting from Mg–saturation to K–saturation followed by air–drying. The intensity of vermiculite–chlorite intergrade can be calculated from the 1.42 nm peak intensity of the K–saturated and air–dried specimen after subtracting the contribution due to chlorite. However, vermiculite–chlorite intergrade was not identified in any of the seventeen samples.

The interstartified kaolinite–smectite mineral was identified by the presence of a broad peak around 0.8 nm in the Mg–saturated and glycerol–solvated specimen. The 1.27 nm peak was used for identification of the interstratified mica–chlorite or mica–vermiculite mineral. The poorly defined diffraction effect between 1.0 and 2.0 nm in the Mg–saturated and glycerol–solvated specimen and the great increase in the intensity of the 1.0 nm peak after K–saturation is an indication of the interstratified mica–vermiculite–smectite mineral (Egashira, 1988). To identify and calculate the intensities of quartz, feldspars and lepidocrocite, the 0.425, 0.32 and 0.63 nm peaks, respectively, were used.

The approximate mineral composition of the clay fraction (<2 μm) was estimated based on the relative peak intensities of the respective minerals in the XRD charts according to the procedure described by Moslehuddin and Egashira (1996) and is shown in Table 3.

The results indicated that mica (19–44%) was the most predominant mineral in all soil samples. Next to mica, either the interstratified mica–vermiculite–smectite (26–40%) or kaolinite–smectite (19–39%) mineral was predominant in all soil samples except Jaonia–6a sample. Kaolinite was present in the entire soil sample with a range of 4–7%. Vermiculite (up to 6%) was identified in ten out of seventeen soil samples, while chlorite was detected in all soil samples with a range of 4–11%. The interstratified mica–chlorite mineral was present in all soil samples and ranged from 1 to 7%. Other than layer silicates, quartz (7–20%) was present in all soil samples while feldspers (1–12%) and lepidocrocite (1–10%) were noticed in fourteen and nine soil samples, respectively.

In Jaonia–1 profile, the interstratified mica–vermiculite–smectite mineral (26–40%) was predominant followed by the interstratified kaolinite–smectite mineral (19–22%) at all three depths. It indicates the major contribution of the Madhupur Clay from surrounding Barind Tract as a parent material to the soil formation until the

Table 3. Approximate mineral contents (%) in the clay fraction (<2 μm) of the soils under study

Soil profile	Sample No.*	Minerals[1)]									
		Mc	Vt	Ch	Kt	Kt–St	Mc–Vt–St	Mc–Ch	Qr	Lp	Fd
Jaonia–1	1a	26	_	5	5	22	26	4	10	–	2
	1b	22	2	5	4	19	30	4	10	–	4
	1c	19	–	5	4	20	40	2	11	–	–
Jaonia–2	2a	31	1	7	6	23	–	5	13	–	12
	2b	26	5	8	7	27	–	4	20	1	2
	2c	19	1	4	4	24	28	1	14	6	–
Jaonia–3	3a	20	–	5	4	23	32	3	11	–	2
	3c	25	–	5	5	23	28	4	11	–	1
Jaonia–4	4a	29	–	8	6	30	–	3	19	–	5
	4b	34	3	7	6	25	–	4	16	1	2
	4c	31	3	6	6	39	–	2	12	–	2
Jaonia–5	5a	36	2	8	7	29	–	5	8	2	3
	5b	29	–	5	5	25	26	1	7	2	1
	5c	33	–	5	4	–	33	2	15	5	3
Jaonia–6	6a	44	6	11	6	–	–	7	16	6	3
	6b	31	1	6	6	–	39	4	12	3	–
	6c	30	2	6	6	28	–	2	12	10	3

* Sampling depth: a, 30–45 cm; b, 60–75 cm; and c, 75–90 cm

[1)] Abbreviations: Mc, mica; Ch, chlorite; Kt, kaolinite; Vt, vermiculite; Qr, quartz; Fd, feldspars; Lp, lepidocrocite; Ch–Vt, Kt–St, Mc–Ch and Mc–Vt–St are the interstratified minerals of the respective minerals.

depth of 90 cm. A small amount of the interstratified mica–chlorite mineral (2–4%) implies the presence of sediments of the non–terrace–soil origin.

Jaonia–3 profile was almost similar to Jaonia–1 profile in respect of the mineralogical composition of the clay fraction, where both the interstratified mica–vermiculite–smectite (28–32%) and kaolinite–smectite (23%) minerals were major minerals in addition to some interstratified mica–chlorite mineral (3–4%).

The interstratified kaolinite–smectite mineral was a dominant mineral at all three depths in both Jaonia–2 (23–27%) and Jaonia–4 (25–39%) profiles. The interstratified mica–vermiculite–smectite mineral was identified only in Jaonia–2c sample (75–90 cm) with a value of 28%. On the other hand, the interstratified mica–chlorite mineral (1–5%) was present in all three layers in a decreasing trend with depth. Therefore, it can be mentioned that contribution of the Barind Tract sediments to the soil formation is dominant at all depths but that of the Tista sediments are in the low contribution.

In Jaonia–5 profile, like other profiles, the mineralogical composition of the clay fraction was developed by the predominant contribution of the Barind Tract sediments at all three depths with a small contribution of the Tista sediments.

In Jaonia–6 profile, chlorite (11%) and the interstratified mica–chlorite mineral (7%) were identified in the highest amount among seventeen soil samples at the 30–45 cm depth (Jaonia–6a). The interstratified kaolinite–smectite and mica–vermiculite–smectite minerals were absent at the same depth. This layer had much lower clay content (31%) than all other samples (Table 2). These findings indicate complete absence of the Barind Tract sediments at this depth. However, the Barind tract sediment was dominant over the Tista sediments in the contribution to the soil formation at the other lower depths.

The presence of the interstratified mica–vermiculite–smectite and kaolinite–smectite minerals as dominant minerals in the clay fraction has been reported to the terrace soils of Bangladesh (Egashira, 1988; Egashira and Yasmin, 1990; Moslehuddin and Egashira, 1996; Moslehuddin *et al.*, 2005; Rahman *et al.*, 2005; Moslehuddin *et al.*, 2008). While, the interstratified mica–chlorite mineral was detected as a dominant mineral in the soils of the Old Himalayan Piedmont Plain and the surrounding areas (Egashira and Yasmin, 1990; Moslehuddin and Egashira, 1996; Islam *et al.*, 2003; Samsuzzoha *et al.*, 2003), which have contribution to the Tista Alluvium.

In the present study, it was clarified that in all six soil profiles of the AEZ 6 examined, the interstratified mica–vermiculite–smectite and/or kaolinite–smectite minerals were present as dominant minerals with a small amount of the interstratified mica–chlorite mineral. These results, along with the results of the previous study (Moslehuddin *et al.*, 2006), indicate the major contribution of the Barind Tract sediments over the Tista Alluvium to the soil formation in the AEZ 6 throughout the profile until the depth of 90 cm. Exception was the Jaonia–6a sample in which neither the interstratified mica–vermiculite–smectite nor the kaolinite–smectite mineral was present. The proportion of the Barind Tract sediments and the Tista Alluvium in the contribution to the soil formation in the AEZ 6 could vary with locations in a smaller range with a small probability of the complete absence of the Barind Tract sediments.

Thus, it was clearly revealed that the present study does not support an idea of the mica–chlorite suite for the AEZ 6 assumed by Moslehuddin *et al*. (1999). The AEZ 6 should rather be placed in the mica–mixed layer minerals–kaolinite suite, similar to terrace soils in Bangladesh.

CONCLUSIONS

The soils of AEZ 6 (Lower Purnabhaba Floodplain) had the high amount of clay in all layers, and the clay fraction was dominated by mica followed by the interstratified mica–vermiculite–smectite and kaolinite–smectite minerals with a small amount of the interstratified mica–chlorite mineral. It indicates the dominant contribution of the Barind Tract sediments over the Tista Alluvium to the soil formation throughout the profile. Soils of the AEZ 6 should be placed in the mica–mixed layer minerals–kaolinite suite along with terrace soils in Bangladesh.

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