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Mineralogy of Soils from Different Agroecological Regions of Bangladesh: Region 17– Lower Meghna River Floodplain

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Bangladesh is consisting of 30 Agro–ecological Regions (AEZs) and different applied agricultural research has been conducted based on AEZ. An attempt has been taken to study the mineralogy of important soils from all AEZs of Bangladesh in order to provide basic information for applied research. As part of this attempt, the mineralogy of ten soils from five representative soil series (Silonia, Homna, Debidwar, Chandraganj and Chandina) of AEZ 17, Lower Meghna River Floodplain, was investigated. The soils of the AEZ were mostly medium textured, non–saline and very strongly acidic to slightly acidic in nature. The average content of <2 μm clay fraction was 14.2% and it varied from 8.7 to 19.1%. The 2–20 μm silt fraction lied between 27.5% and 57.6% with an average of 43.2%. The clay fraction was dominated by mica, chlorite and kaolinite in all the soils studied. Presence of two interstratified minerals namely, vermiculite–chlorite intergrade and mica–chlorite interstratified minerals were evident in some samples. The findings of the present study do not support the proposed mineralogical suite of mica–smectite for this AEZ.

Key words: clay mineralogy, Lower Meghna River Floodplain, Bangladesh

INTRODUCTION

Bangladesh with an area of 1,47,570 sq. km is a land of agriculture. Agriculture is the backbone of the economic development of Bangladesh (BBS, 2013). Soil is a major natural resource of Bangladesh. Judicial management of this resource is very much essential to maintain its potentiality for further cultivation. Due to high cropping intensity, soil resources of Bangladesh have been overexploited and soil fertility has declined (BARC, 2012).

Physiographically, the land of Bangladesh is classified into Holocene floodplains (80%), Tertiary hills (12%), and Pleistocene terraces (8%). Based on the mode of formation and morphological appearance, soils are grouped into 21 general soil types of the Bangladesh soil classification system that can be correlated with the USDA Taxonomy and FAO–UNESCO System of soil classification (Saheed, 1984). On the basis of land form and geology and agro–climatic condition, Bangladesh has been divided into 30 agro ecological regions (popularly known as AEZs), 88 sub–regions and 535 agro–ecological units (FAO–UNDP, 1988); refer to the previous paper (Islam *et al.*, 2003) for the map of AEZs.

The present study is focused on the AEZ 17 (Lower Meghna River Floodplain) covering an area of 90,934 ha which is situated in Chandpur (55,200 ha), Laxmipur (27,500 ha) and Noakhali (8,300 ha) districts of Bangladesh (BARC, 2012). This area occupies transitional area between the AEZs of Middle Meghna River Floodplain and the Young Meghna Estuarine Floodplain. The region has slightly irregular relief, but with little difference in elevation between the ridges and depressions.

Silt loam and silty clay loam texture in the relatively higher and depressed areas, respectively, was investigated with fairly uniform soil type of the area. Major classes of General Soil Types of this area described as Non–calcareous Dark Grey Floodplain and Calcareous Grey Floodplain Soils. Slightly acidic nature of surface soils in high land and slightly acidic to slightly alkaline in medium high land and medium low land is the major feature of soil reaction (BARC, 2012).

Minerals are the indicator of extent of weathering that has taken place, and the presence or absence of particular minerals give clues to how soils have been formed (Schulze, 1989). Few mineralogical studies of agriculturally important zones representing major soil series as well as physiographic units of Bangladesh had been conducted in the past. Such information was compiled together by Moslehuddin *et al.* (1999) and a tentative clay mineralogical map of the country was proposed. In context of lack of enough information a plan has been undertaken to study mineralogy of soils from all AEZs of Bangladesh in the Department of Soil Science, BAU, Mymensingh. The present piece of work deals with the mineralogy of soils of AEZ 17. According to Moslehuddin *et al.* (1999), this AEZ was assumed to be placed under mica–smectite suite indicating that mica and smectite were major minerals. Further study is essential to clarify the comprehensiveness of this. In such point of view, the present study was undertaken to determine the mineralogical composition of soils collected from AEZ 17 and also to verify the proposed mineralogical suite of this AEZ.

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MAERIALS AND METHODS

Soil Used

Ten soil samples of AEZ 17, Lower Meghna River Floodplain were collected from 0–15 cm soil depth. The soils belonged to five soil series viz. Silonia (3 samples), Homna (2 samples), Debidwar (2 samples), Chandraganj (1 sample), and Chandina (2 samples). 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 following standard procedures and preserved in plastic containers for subsequent laboratory analyses.

Particle–size analysis

The soil samples were treated with hot 7% H_2O_2 to decompose organic matter present in those samples, dispersed by mechanical stirring and adjusted to the pH 10 using 1 M NaOH. The <2 μm fraction was separated by repeated stirring–sedimentation–siphoning. The 2–20 μm fraction was separated with repeated sedimentation–siphoning, and the 20–53, 53–212, 212–2000 μm fractions were separated by wet sieving. The weight of each fraction was determined to calculate the particle–size distribution.

Determination of pH and EC

The pH was determined electrochemically with the help of a glass–electrode pH meter in the soil suspension having a soil:water ratio of 1:2.5 after 30 minutes shaking. The electrical conductivity (EC) was measured by an EC meter in the soil suspension having a soil:water ratio of 1:5, after 30 minutes shaking.

Determination of exchangeable cations (Na, K and Ca)

Exchangeable K, Ca, and Na were determined by adding 8 ml of $CH_3CHOONH_4$ in a 15 mL centrifugal tube having 2.5 g soil sample in it. After 10 minutes shaking of the tube, the suspension was centrifuged for 5 minutes at 1500 ppm and the supernatant was decanted and filtered into a 25 mL volumetric flask. The process was repeated two more times. Extracted K, Na, and Ca were determined directly by flame photometer.

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). The sols were placed in 10 mL centrifugal tubes. Washing by centrifugation and decantation were carried out twice with 8 mL of an equal mixture of 1 M NaCl and 1 M CH_3COONa (pH 5) in order to decrease the pH of preserved clay sols. Of the duplicate sets, one was saturated with K and the other with Mg by washing three times with 8 mL of 1 M KCl and 0.5 M $MgCl_2$, respectively. Excess salt was removed by washing once with 8 mL of water.

Clay in the tube was thoroughly suspended with 1 mL of water. An aliquot of 0.4 mL of the sol was dropped on to a glass slide (7.6 cm × 2.6 cm), covering two–thirds of its area, air–dried and X–rayed (Parallel powder mount). The XRD patterns were obtained using a Rigaku X–ray diffractometer (RINT 2100V) 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°C and 550°C for 2 hrs.

RESULTS

Particle–size distribution

Particle–size distribution and textural classes of the soils as determined by the USDA system are presented in Table 2. Each soil sample was fractioned into five groups, viz. <2, 2–20, 20–53, 53–200 and 200–2000 μm. The average clay content of soils of the AEZ 17 was 14.2%. The highest clay content was found in Debidwar–1 soil (19.1%) whereas the lowest content (8.7%) was found in Homna–1 soil. Clay content varied in Silonia

Table 1. General information of the sampled soils

Sample name	Land Type[1]	USDA Soil Taxonomy	Location	Cropping pattern[3]
Silonia–1	MLL	Non–acid Aeric Haplaquepts	Sadar Upazila[2], Noakhali	B– F– F
Silonia–2	MHL	Non–acid Aeric Haplaquepts	Sadar Upazila, Noakhali	R– F/D.A.R– T.A
Silonia–3	MLL	Non–acid Aeric Haplaquepts	Sadar Upazila, Noakhali	B– F– F
Homna–1	MLL	Non–acid Aeric Haplaquepts	Sadar Upazila, Noakhali	R– F/D.A.R– T.A
Homna–2	MHL	Non–acid Aeric Haplaquepts	Sadar Upazila, Noakhali	R– F/D.A.R– T.A
Debidwar–1	MLL	Non–acid Aeric Haplaquepts	Sadar Upazila, Noakhali	B– F– F
Debidwar–2	MLL	Non–acid Aeric Haplaquepts	Sadar Upazila, Noakhali	B– F– F
Chandraganj	MHL	Non–acid Aeric Haplaquepts	Sadar Upazila, Noakhali	R– F/D.A.R– T.A
Chandina–1	MLL	Non–acid Aeric Haplaquepts	Sadar Upazila, Noakhali	B– F– F
Chandina–2	MLL	Non–acid Aeric Haplaquepts	Sadar Upazila, Noakhali	B– F– F

[1] MHL=Medium high land, MLL=Medium Low Land, which is normally flooded up to a depth of 90 cm and 90–180 cm, respectively, during the monsoon season.
[2] Upazila = Subdistrict; [3] B: Boro; D.A.R: Dibbling aus rice; F: Fallow; R: Rabi; T.A: Transplant Aman

soil series from 9.0% (Silonia–2) to 16.8% (Silonia–3), in Homna soil series from 8.7% (Homna–1) to 15.9% (Homna–2), in Debidwar soil series from 17.6% (Debidwar–2) to 19.1% (Debidwar–1), in Chandraganj soil series 16.7% and in Chandina soil series from 12.5 (Chandina–2) to 13.3% (Chandina–1).

The average 2–20 μm silt fraction was 43.2% and it varied from 27.5% in Homna–1 soil to 57.6% in Silonia–1 soil. This fraction dominated in 70% of the investigated samples. The 20–53 μm fraction varied from 8.9% in Homna–1 soil to 54.3% in Silonia–2 soil. The average 53–212 μm sand fraction was 9.7% and it ranged from 0.6% in Chandina–1 soil to 54.1% in Homna–1 soil. Except Homna–1 and Debidwar–2, this fraction was below 10% in all other soils. The amount of coarse sand (212–2,000 μm) was found in a low range (less than 1.0%). Out of ten soil samples five belonged to silt, four to silt loam and one to sandy loam textural class according to the USDA system for textural classes.

Soil pH and EC

The soils of Lower Meghna River Floodplain were found to be very strongly acidic to slightly acidic in nature with the pH values ranging between 4.33 (Debidwar–1 and Debidwar–2) and 5.72 (Homna–1). The EC value varied from 0.31 (Silonia–1) to 1.68 (Chandraganj) dS m^{-1} (Table 3).

Exchangeable sodium, potassium and calcium

The average exchangeable sodium was 0.51 $cmol_c$ kg^{-1} in soils with a range of 0.27 $cmol_c$ kg^{-1} (in Silonia–3 series and Chandina–2 series) to 1.30 $cmol_c$ kg^{-1} (in Chandraganj series). Exchangeable potassium content varied from 0.16 $cmol_c$ kg^{-1} (in Homna–2 series) to 0.40 $cmol_c$ kg^{-1} (in Silonia–2 series) and the average content was 0.27 $cmol_c$ kg^{-1}. Again, the average content of exchangeable calcium was 3.55 $cmol_c$ kg^{-1} and it ranged from 2.05 $cmol_c$ kg^{-1} (in Homna–2 series) to 5.34 $cmol_c$ kg^{-1} (in Homna–1) (Table 3).

Table 2. Particle–size distribution and textural classes of sampled soil

Sample name	Particle–size distribution (%)					USDA soil textural class
	<2 μm	2–20 μm	20–53 μm	53–212 μm	212–2000 μm	
Silonia–1	12.0	57.6	28.4	1.5	0.5	Silt
Silonia–2	9.0	27.9	54.3	7.9	0.9	Silt
Silonia–3	16.8	46.2	34.7	2.1	0.2	Silt loam
Homna–1	8.7	27.5	8.9	54.9	0.1	Sandy loam
Homna–2	15.9	45.0	36.5	2.1	0.5	Silt
Debidwar–1	19.1	49.2	22.7	8.9	0.1	Silt loam
Debidwar–2	17.6	46.8	19.6	16.1	0.0	Silt loam
Chandraganj	16.7	49.0	32.9	1.3	0.1	Silt loam
Chandina–1	13.3	43.4	42.4	0.6	0.2	Silt
Chandina–2	12.5	39.7	46.3	1.2	0.3	Silt
Average	14.2	43.2	32.7	9.7	0.3	

USDA: United States Department of Agriculture

Table 3. pH, EC, exchangeable Na, K and Ca of the sampled soils

Sample name	pH	EC (dS m^{-1})	Exchangeable Na ($cmol_c$ kg^{-1})	Exchangeable K ($cmol_c$ kg^{-1})	Exchangeable Ca ($cmol_c$ kg^{-1})
Silonia–1	4.91	0.31	0.38	0.30	4.11
Silonia–2	5.60	0.74	0.67	0.40	4.12
Silonia–3	4.60	0.36	0.27	0.28	2.87
Homna–1	5.72	0.33	0.61	0.21	5.34
Homna–2	5.45	1.45	0.61	0.16	2.05
Debidwar–1	4.33	0.44	0.29	0.26	3.08
Debidwar–2	4.33	0.53	0.42	0.32	3.08
Chandraganj	5.16	1.68	1.30	0.33	4.31
Chandina–1	5.70	0.53	0.31	0.21	3.50
Chandina–2	4.64	0.39	0.27	0.21	3.08
Average	5.04	0.68	0.51	0.27	3.55

Mineralogical composition of clay fraction

The XRD patterns of the clay (<2 μm) fraction of samples are shown in Figures 1. The peaks of the most samples sharp, indicating the good crystallinity and/or large crystallite size of the minerals. The process of identification of different mineral components i.e. mica, chlorite, kaolinite, smectite, vermiculite, quartz, goethite and feldspars from the peaks in XRD charts were done following Akter *et al*. (2015).

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 following Moslehuddin and Egashira (1996) is presented in Table 4. Eight different minerals were identified in the soils under study. These were mica, smectite, vermiculite, chlorite, kaolinite, feldspar, quartz and goethite. Except these minerals, vermiculite–chlorite intergrade and interstratified mica–chlorite were also identified (Table 4).

Mica was found as the most dominant among the min-

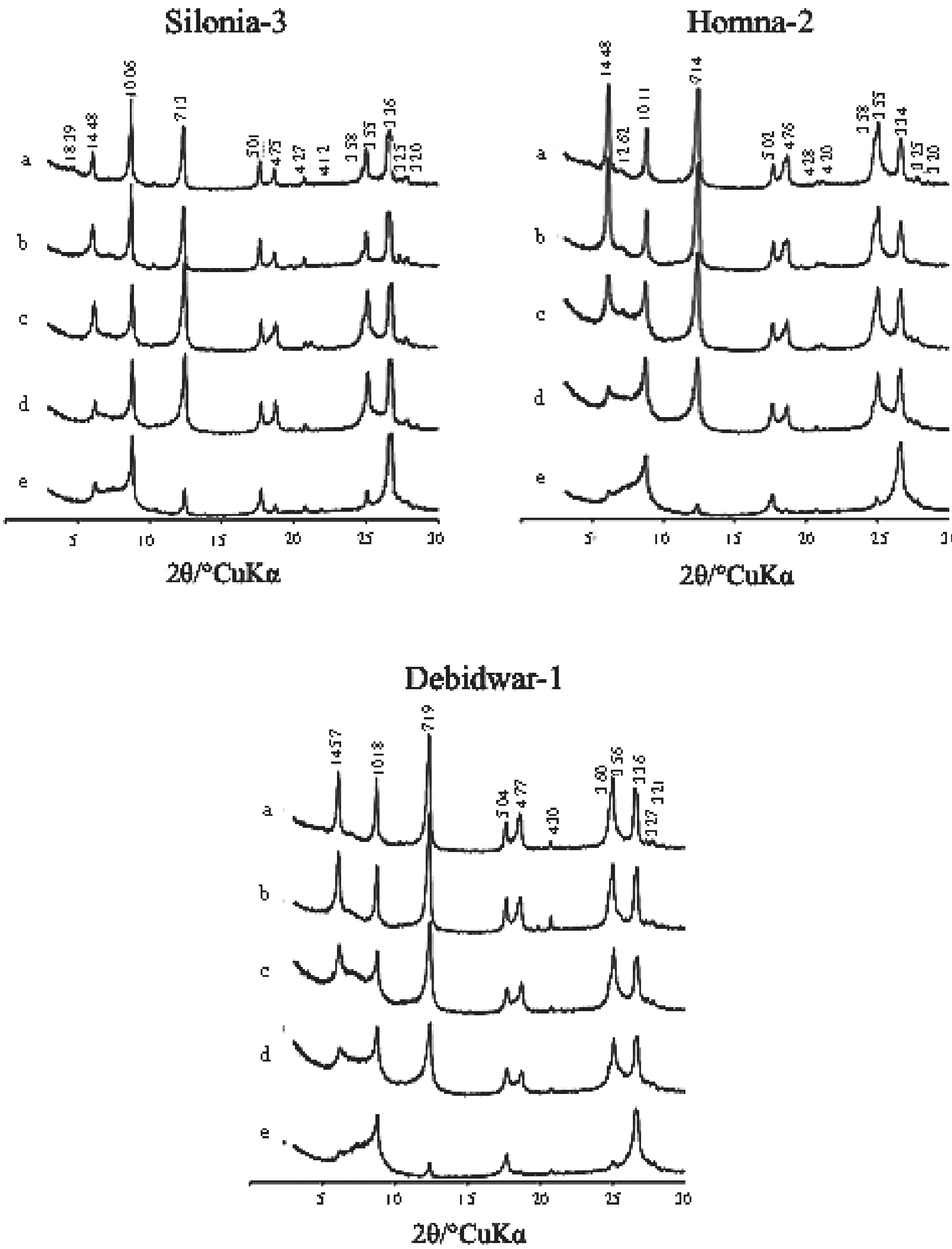

Fig. 1. X–ray diffraction patterns of the <2 μm clay fraction of Silonia–3, Homna–2 and Debidwar–1 soil. Spacing is in Å. Treatments: a) Mg–saturation and glycerol–solvation; b) Mg–saturation and air–drying; c) K–saturation and air–drying; d) K–saturation and heating at 300°C; e) K–saturation and heating at 550°C.

Table 4. Approximate mineral contents (%) in the clay fraction (<2 μm) of sampled soils

Sample name	AEZ	Minerals									
		Mc	St	Vt	Ch	Kt	Vt–Ch	Mc/Ch	Qr	Gt	Fd
Silonia–1	17	36	2	5	26	18	–	2	9	–	2
Silonia–2	17	38	2	–	20	9	1	–	21	–	9
Silonia–3	17	31	3	–	26	20	7	1	7	–	5
Homna–1	17	33	–	–	24	14	–	1	18	3	7
Homna–2	17	29	–	12	26	17	–	3	8	2	3
Debidwar–1	17	34	–	–	29	17	–	–	13	–	7
Debidwar–2	17	41	–	–	27	18	–	3	9	–	2
Chandraganj	17	29	1	10	28	18	–	1	11	–	2
Chandina–1	17	27	3	6	24	16	6	3	10	2	3
Chandina–2	17	32	–	–	28	18	4	3	12	1	2

Abbreviations: Mc: mica; St: smectite; Vt: vermiculite; Ch: chlorite; Kt: kaolinite; Vt–Ch: vermiculite–chlorite intergrade; Mc–Ch: interstratified mica–chlorite Qr: quartz; Gt: goethite; Fd: feldspar.

erals identified. It varied from 27 to 41% with the highest value in Debidwar–2 soil and the lowest in Chandina–1 soil. Next to mica, chlorite was present in good amounts which ranged from 20 to 29%. The highest value was observed in Debidwar–1 soil while the lowest was in Silonia–2. Kaolinite was also found in all the soil samples in a range from 9 to 20%, with the highest value in Silonia–3 soil and the lowest value in Silonia–2 soil. Smectite was found in only five soil samples in a negligible amount viz. Silonia–1 (2%), Silonia–2 (2%), Silonia–3 (3%), Chandraganj (1%) and Chandina–1 (3%). Good amount of vermiculite was present in two samples namely Chandraganj (10%) and Homna–2 (12%) while Silonia–1 and Chandina–1 soils had 5 and 6% vermiculite respectively. Quartz was present in all soil samples ranging from 7% (Silonia–3) to 21% (Silonia–2). A little amount of feldspar was identified in all soils ranging from 2% (Silonia–1, Debidwar–2 Chandraganj, and Chandina–2) to 9% (Silonia–2). In four soil samples (Silonia–1, Silonia–2, Chandina–1 and Chandina–2), goethite was present in a negligible amount varying from 1 to 3%. Vermiculite–chlorite intergrade mineral was found in four samples viz. Silonia–2 (1%), Silonia–3 (7%), Chandina–1 (6%) and Chandina–2 (4%). Mica–chlorite interstratified mineral was found in a small amount (1 to 3%) in almost all the samples except Siolonia–2 and Debiwar–1.

DISCUSSION

Particle–size distribution showed that most of the soils of AEZ 17 were medium textured with silt loam to silt textural classes with the exception of Homna–1 soil which belonged to sandy loam. Moslehuddin *et al*. (1998) also reported that Faridgonj (1) and Faridgonj (2) soils of Lower Meghna River Floodplain were medium textured. The present finding is also supported by SRDI (1999).

The soils under present study were very strongly acidic to slightly acidic in nature which is in agreement with BARC (2012). The results are accorded to the report of SRDI (1999) regarding the soil reaction of relevant soil series. The soils of Silonia, Homna and Debidwar were non–saline to slightly saline in nature and Chandraganj and Chandina were non–saline in nature. The reason behind such slight salinity is possibly flooding with tidal water.

The exchangeable K content was high in three soils, medium in four soils while optimum in three soils, whereas the exchangeable Ca content was low in two soils, medium in seven soils, optimum in one soil. SRDI (2000) also support the present data in relation to exchangeable K and Ca content of the soils under study.

The results in this study indicated that mica, chlorite and kaolinite were the predominant minerals in all the soils. Moslehuddin *et al*. (1998) reported the mineralogy of two series (Faridgonj–1 and Faridgonj–2) of AEZ 17 as mica, vermiculite and chlorite were the major minerals and kaolinite was present in good proportion with some amounts of smectite and interstratified mica–chlorite minerals. Kader *et al*. (2015) also reported similar mineralogy in case of Faridganj series of this AEZ.

Moslehuddin *et al*. (1999) while preparing a tentative clay mineralogical map of Bangladesh put the soils of AEZ 17 in the mica–smectite suite, although scarce data was available on mineralogy of this AEZ. They assumed that the soils of Lower Meghna River Floodplain were originated from the Ganges sediments mainly, with admixture of the Brahmaputra (Jamuna) and Meghna sediments, and apprehended that this region has mica–smectite suite. They further opined that due to decalcification of the Ganges sediments and/or admixture of the Brahmaputra and Meghna sediments, smectite may not always be dominant. From the present study, it is evident that smectite is not a dominant mineral in AEZ 17 soils. The reason could be the dominance of the Brahmaputra (Jamuna) and Meghna sediments over the Ganges sediments. A small amount of smectite in 50% of the samples is an indication of negligible proportion of Ganges sediments as parent material of the soils under study. Thus the present study does not support the mica–smectite suite for this AEZ. However, the study area was limited to a part of this AEZ. Further study is recommended with soils from other areas of this AEZ for final comment on it.

CONCLUSION

The soils of Lower Meghna River Floodplain are mostly non–saline, medium textured with very strongly acidic to slightly acidic in nature. The clay fraction is dominated mostly by mica, chlorite and kaolinite. Therefore, the result of the present study does not support the mineralogical suite of mica–smectite for this AEZ by Moslehuddin *et al*. (1999). Further study is needed to confirm this issue. The findings of the research are useful for solving soil related problems and for consideration of land use and management, especially in terms of nutrient and water management and selection of crops and so on.

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