Understanding variability in texture and acidity among sandy soils in Cambodia

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Abstract
Sandy soils occupy a large proportion of the Cambodian landscape, and improved understanding of these soils is critically important to support agricultural development. This study aims to identify variability in soil particle size distributions and acidity among sandy soils from different parts of southern and eastern Cambodia. Soil samples were collected from different layers at 8 sites within 4 study provinces and analysed for particle size distribution, soil pH and exchangeable Al. Clay and silt were minor fractions and comprised similar amounts at most sites. Clay fractions generally increased at about 1 m depth. Soils at a site close to the beach and sites nearby coarse grained granite mountains contained very high percentages of coarse sand (up to 87 %). At other sites, fine sands were dominant fractions. Very low pH_{CaCl2} values (< 4) in whole profiles were found at 2 sites in the coastal area, close to the beach and sandstone mountain and at one site in eastern Cambodia. Highest whole profile exchangeable Al (0.44-1.13 cmol/kg) were seen at a site close to sandstone mountain and a site in eastern area.

Key Word
Particle size, soil pH, sandy soil, soil profile.

Introduction
Sandy soils occupy a large proportion of Cambodian land. Arenosols account for only 1.6 % of the land area; however, sandy surface soils cover a large proportion of the Cambodian landscape and are more widespread than Arenosols, *per se* (Seng *et al.* 2005). The Acrisol Soil Group, which commonly consists of sandy surface soils, occupies almost half of the land area of Cambodia.

Agriculture is expanding rapidly in Cambodia at the present, especially in the upland areas, where sandy soils account for a large proportion of land area. However, detailed information about upland sandy soils in Cambodia is very limited. Soil study by the Cambodia-IRRI-Australia Project during the 1990s focused on surface soils (0-0.50 m) in low land areas, where soils are mainly used for rice production (White *et al.* 1997). Recent sandy soil investigations in Tramkak, Ponhea Krek, and Kong Pisei District have been limited to describing soil-landscape relationships plus limited soil chemical analysis (Hin *et al.* 2007a; b; Hin *et al.* 2006). Sandy soil characteristics in these districts may not be common to other sandy terrains in Cambodia as more complete data is required. Preliminary analysis of a range of sandy soils in Cambodia indicates that large differences in Al saturation exist among profiles. Some profiles have > 80% Al saturation below 0.12 m depth, other profiles have less than 10 % Al saturation throughout (Seng and Bell unpublished data). The management of the highly acid forms of sandy soils will be quite different from those with non-acid profiles.

A more thorough understanding of the properties and constraints of sandy soils in the uplands of Cambodia will underpin an assessment of land suitability for non-rice crops and support the diversification of crop production in Cambodia in a sustainable manner. The present study aims to understand variability in texture and acidity among sandy soils from different parts of Cambodia. The underlying hypothesis is that parent materials have a strong influence on the key physical and chemical properties of sandy soils in Cambodia.

Materials and methods
Study areas, sites and soil sampling
The research was conducted in 4 study areas: Coastal zone in Kampot District of Kampot Province; Tramkak District of Takeo Province; Ponhea Krek District of Kampong Cham Province; and Kampong Chhnang Province (Figure 1). Soil samples were collected from 8 sites in the study areas. Two contrasting sites in each study area were selected with one at an upland location and another in a low lying part of the area. At each site, a pit was excavated to 1.50 m depth. From the bottom of the pit, the soil was augered until reaching approximately 2 m depth. Pits and cores were sectioned according to variation of texture, colour,

size and amount of stones. Approximately 1 kg soil was collected from each layer at each site. Soil samples were air-dried and ground to pass a 2-mm sieve.

Particle size analysis
Laboratory measurement of the particle size distribution of soil was made on 50 g air-dry samples using sieving and the sedimentation method (Bowman and Hutka 2002). The samples were pre-treated with hydrogen peroxide to remove organic matter. Particle-size data were classified according to the conventional size intervals of the International System (coarse sand 2000-200 μm, fine sand 200-20 μm, silt 20-2 μm, clay <2 μm).

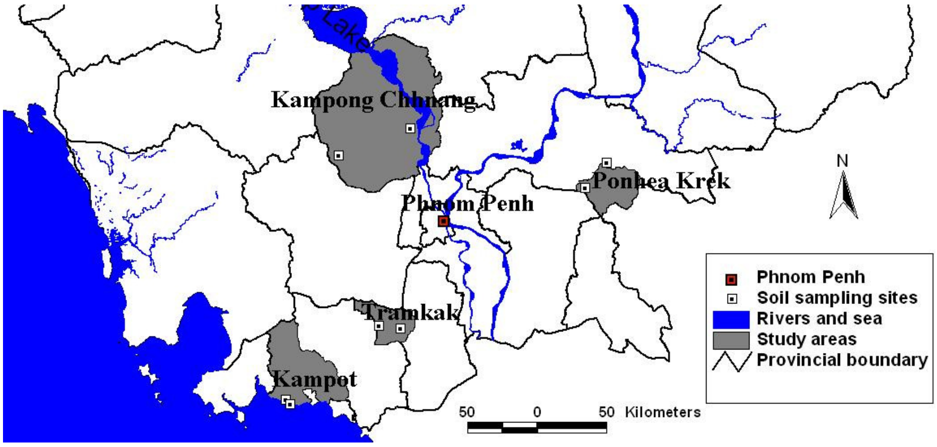

Figure 1. Study areas and sampling sites

Chemical analysis
Soil pH was measured in 1:5 ratio of soil to 0.01M $CaCl_2$ suspension. Determination of exchangeable Al was made using inductively coupled plasma atomic emission spectroscopy (ICP-AES). Soil extracts for Al determination were obtained by shaking end-over-end 1 g of air-dried soil with 50 ml of 0.01 M $(AgTU)^+$ at 25°C for 16 hours and then centrifuged to obtain a clear supernatant (Rayment and Higginson 1992).

Results

Particle size distribution
Fine and coarse sands were the prominent fraction at all study sites but their abundance within the profile decreased with depth, except at Kampot 1 and Kampot 2 (Table 1). High content (mostly >50%) of coarse sand fractions was found at Kampot 2 (56.6-79.8%), Kampong Chhnang 1 (28.4-54.35%) and Kampong Chhnang 2 (49.6-67.1%). At remaining sites, fine sand was the major size fraction (mostly >40%).

Silt content was only 0.4 to 9.2 % of < 2 mm fractions at most sites. Distinctive, high silt fractions were found at all layers of Tramkak 2, ranging between 19.8-34 %. At Ponhea Krek 2, the silt fractions considerably increased from 2.5 % in topsoil to 13.7 % at 2.10-2.50 m depth. Slight down-profile increase of the silt fraction was seen also at Tramkak 1, Ponhea Krek 1, and Kampong Chhnang 2. In other 4 profiles, there was no specific down-profile change in silt.

Low clay contents ranging between 0.8 and 5 %, were found in the top and middle layers of Kampot 2, Tramkak 1, Ponhea Krek 2, Kampong Chhnang 1, and Kampong Chhnang 2. Distinctive high contents of clay were found at the base of Kampong Chhnang 1(53.9%) and Ponhea Krek 2 (41.5%) profiles. In the whole profile of Ponhea Krek 1, clay content was relatively high and there was no down-profile change of clay contents below 0.15 m depth.

Chemical data
pH values of the whole profile of Kampot 1, 2 and Ponhea Krek 1 were 4 or less, the pH values of Tramkak 2 and Ponhea Krek 2 profiles were 4 or higher (Table 1). In the remaining profiles (Tramkak 1, Kampong Chhnang 1 and Kampong Chhnang 2), pH values of the upper 3-4 layers were generally higher and slightly decreased to the base of the profile. Exchangeable Al was variable among the sites and within each site. Kampot 1 and Ponhea Krek 1 have relatively high Al ranging between 0.44 and 1.13 cmol/kg. Most of remaining sites had exchangeable Al below 0.15 cmol/kg.

Table 1. Particle size and chemical data.

Site	Site location	Depth (m)	Particle size (%) Clay	Silt	Fine sand	Coarse sand	EC (dS/m)	pH (1:5 $CaCl_2$)	Exc. Al (cmol/kg)
Kampot1	N: 1168981,	0-0.18	5.1	5.7	56.0	33.2	0.03	3.4	0.53
	E: 393885,	0.18-0.50	8.4	4.8	51.1	35.7	0.02	3.5	0.78
	19 m asl	0.50-0.90	7.1	4.1	52.6	36.2	0.02	3.7	0.57
		0.90-1.30	5.6	3.9	52.5	37.9	0.01	3.7	
		1.30-1.58	9.8	3.6	49.9	36.6	0.01	3.6	
		1.58-2.20	14.4	3.0	43.4	39.1	0.02	3.4	
Kampot 2	N: 1166086,	0-0.20	4.1	1.6	14.6	79.8	0.02	3.6	0.34
	E: 396319,	0.20-0.57	2.3	0.9	9.4	87.4	0.01	3.8	0.13
	10 m asl	0.57-0.80	1.6	0.4	10.9	87.1	0.01	4.0	0.15
		0.80-1.05	1.9	0.4	11.9	85.8	0.01	4.0	
		1.05-1.45	10.7	1.6	16.0	71.7	0.01	3.7	
		1.45-1.75	18.6	2.8	22.0	56.6	0.01	3.9	
Tramkak 1	N: 1214584,	0-0.18	2.2	4.6	59.8	33.4	0.02	3.8	0.10
	E: 451562,	0.18-0.55	0.9	3.6	60.1	35.5	0.01	4.0	0.05
	55 m asl	0.55-0.91	0.8	7.1	56.8	35.3	0.01	4.1	0.04
		0.91-1.60	1.2	6.7	55.6	36.6	0.01	4.3	
		1.60-1.90	2.0	8.5	56.7	32.8	0.01	3.9	
		1.90-2.25	11.2	9.2	47.2	32.4	0.01	3.6	
		2.25-2.50	20.4	8.2	41.8	29.7	0.02	3.2	
Tramkak 2	N: 1213007,	0-0.12	6.0	19.8	52.2	22.0	0.04	4.7	0.02
	E: 464503,	0.12-0.25	7.9	22.7	42.4	27.0	0.02	4.2	0.01
	10 m asl	0.25-0.50	22.1	34.0	27.5	16.4	0.02	4.4	0.06
		0.50-0.95	36.0	22.8	24.2	17.0	0.02	4.1	0.90
		0.95-1.40	28.4	33.1	27.7	10.8	0.02	4.8	
		1.40-1.90	36.6	21.6	28.0	13.8	0.03	5.4	
Ponhea Krek 1	N: 1314599,	0-0.15	8.8	3.2	52.6	35.3	0.02	3.9	0.44
	E: 591781,	0.15-0.40	19.5	4.3	43.1	33.1	0.03	3.7	1.07
	36 asl	0.40-0.72	22.2	5.1	42.6	30.1	0.02	3.7	1.13
		0.72-1.15	22.6	5.6	40.0	31.9	0.02	3.7	
		1.15-1.70	24.9	6.3	39.1	29.7	0.03	3.6	
		1.70-2.20	24.9	6.2	36.9	31.9	0.03	3.7	
Ponhea Krek 2	N: 1299062,	0-0.19	1.3	2.5	91.9	4.2	0.01	4.3	0.08
	E: 578138,	0.19-0.44	1.5	3.0	91.0	4.4	0.01	4.4	0.10
	18 m asl	0.44-0.78	1.0	3.0	91.0	5.0	0.01	4.7	0.00
		0.78-1.03	0.8	5.7	88.2	5.3	0.01	4.7	
		1.03-1.30	5.0	8.4	82.2	4.5	0.01	4.0	
		1.30-1.48	6.3	8.9	80.3	4.6	0.01	4.0	
		1.48-1.80	18.0	11.4	66.4	4.2	0.02	4.3	
		1.80-2.10	29.4	11.9	55.0	3.6	0.03	4.5	
		2.10-2.50	41.5	13.7	43.3	1.6	0.03	4.6	
Kampong Chhnang 1	N: 1319465,	0-0.10	2.7	5.8	37.1	54.3	0.02	4.3	0.07
	E: 426532,	0.10-0.22	2.8	4.6	36.0	56.6	0.01	4.2	0.10
	117 m asl	0.22-0.40	4.6	3.9	35.1	56.4	0.01	4.0	0.26
		0.40-0.69	7.8	3.6	33.3	55.3	0.02	3.9	0.57
		0.69-0.86	11.0	5.1	31.1	52.7	0.01	3.9	
		0.86-1.20	26.2	4.2	24.1	45.5	0.01	3.7	
		1.20-1.75	34.6	3.4	17.6	44.4	0.01	3.7	
		1.75-2.20	53.9	3.6	14.1	28.4	0.01	3.6	
Kampong Chhnang 2	N: 1336103,	0-0.15	1.6	2.6	28.7	67.1	0.02	4.0	0.14
	E: 470581,	0.15-0.34	1.7	2.3	28.8	67.3	0.02	4.3	0.10
	10 m asl	0.34-0.62	1.0	2.0	34.3	62.7	0.01	4.5	0.04
		0.62-0.93	3.5	3.8	32.5	60.2	0.01	4.4	
		0.93-1.27	7.2	3.1	24.2	65.5	0.02	4.0	
		1.27-1.55	12.5	6.1	18.9	62.5	0.02	3.9	
		1.55-1.97	30.4	4.4	15.6	49.6	0.0	3.8	

Note: asl: above sea level, Particle size: Clay < 2 µm, silt 2-20 µm, fine sand 20-200 µm, coarse sand 200-2000 µm

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Discussion

Differences of soil particle distributions between two profiles in the coastal area of Kampot District indicate likely different in source parent materials. Based on its proximity at the base of mountain, Kampot 1 is most likely formed under colluvial sedimentation, derived from the weathering and erosional products of the Mesozoic sandstone of Bokor Mountain. Kampot 2, located close to the beach with lower elevation (10 m asl), may have been formed under marine deposition. The similar profile particle distributions and soil pH between Kampot 1 and Tramkak1 could be explained by their locations in the upland areas at the base of mountains. Rocks of Bokor Mountain are sandstone while the rocks of Damrei Romeal Mountain are predominantly quartzite (Workman 1972). Soil derived from weathering products of quartzite can contain a high coarse sand fraction but this is not a case in Tramkak 1. Further investigation may be needed to verify geology of Damrei Romeal Mountain.

Coarse grained granite rocks of Oral Mountain located in the west of Kampong Chhnang Province and some hilly outcrops in the province (Workman, 1972) may have strong influence on development of sandy soils in this area. High coarse sand fractions of two sites in this area (Kampong Chhnang 1 and Kampong Chhnang 2) suggest the granitic influence on soil parent materials. Particle size distributions of two profiles in Ponhea Krek District were quite different from profiles in other areas. Although the amount of fine and coarse sand of Ponhea Krek 1 was similar to those of Kampot 1 and Tramkak 1, the clay content was much higher. Ponhea Krek 2 also had highest fine sand content. The parent material of this area is reported to be old alluvium (Workman 1972). Based on pH results (Table 1), acidity is a major constraint for many field crops grown on these sandy soils. Among 8 profiles only Tramkak 2 had pH > 4.7 in topsoil (0-0.12 m), but low pH at deeper layers of this profile is likely to limit root depth. Low pH values and relatively high exchangeable Al of Kampot 1 and Ponhea Krek 2, indicate that Al toxicity is a likely limiting factor for crop production.

Conclusion

Variations in particle size distribution and acidity of sandy soils from different parts of Cambodia might be related to the influence of different parent materials of these soils. Proximity to granite and the coast was associated with mostly coarse sand fractions while sandstone and quartzite geologies were associated with an abundance of fine sand. Clay contents were similar at most sites as they were low in top layers and they generally increased at > 1 m depth. Soil pH values were generally low at all the sites between 3.4 and 4.7 but only Kampot1 and Ponhea Krek 1 had high exchangeable Al.

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