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Soil and Landscapes of Banan District, Battambang Province, Kingdom of Cambodia

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Abstract

Rapid expansion of cropping is occurring in Cambodia outside of the areas traditionally used for lowland rice. Soils and landscapes in these areas are poorly described at present, hampering efforts to develop sustainable soils management and crop production systems. In the present project, soils and landscapes in Banan district Battambag province were investigated by a semi-detailed soil survey. A soil-landscape map was developed for the district in which 14 units were recognised. The main soil-landscape units in order of their capability for non-rice cropping were: Kein Svay an alluvial loam along the Sangke River, the brown phase of Toul Samroung Soil group on gently undulating plains and a calcareous phase of the Kompong Siem Soil group that develops on sloping land surrounding limestone hills. All soils are prone to waterlogging during periods of heavy rain. Otherwise the Kein Svay has few chemical or physical limitations for non-rice crops. Toul Samroung soil may be strongly acid, and contains high extractable manganese levels. The Kompong Siem calcareous phase is a shallow to moderately deep clay soil that forms deep cracks when dry. It is prone to stickiness when wet and hardness when dry. Severe iron chlorosis on this alkaline soil is a serious limitation for many crops. Crop performance on Kompong Siem calcareous phase was poor compared to elsewhere in Cambodia on Kompong Siem soil on basalt, and compared to Kein Svay and Toul Samroung soils in the same district. Properties of additional soils in the south of Banan district were not determined due to access limitations.

1 Introduction

Upland agriculture is beginning to expand rapidly in Battambang province in the northwest of Cambodia where maize, soybean, mung bean and sesame are the most prevalent crops. Proximity to markets in Thailand appears to be a driving force behind the expansion. Rising population in the more densely settled lowland rice producing areas may be another trigger. Expansion of upland cropping in these areas, and elsewhere is occurring on soils whose properties are poorly known. The concentration of research in Cambodia over the last 15 years has been on rice producing soils, and substantial progress has been made both in the development of a Cambodian Agronomic Soil Classification (CASC), and in the development of appropriate soil management technologies for rice soil groups (Dobermann and White, 1999: White et al., 1997, 2000). However, knowledge of the upland soils has stagnated with little new information being reported since the study of Crocker (1962).

The aims of the present study were to determine the range of soils on terrain of Banan district, Battambang and the key properties of the soils that would act as constraints to agricultural development. This report documents the main soils and landscapes in Banan district, and the method used to delineate them. This information will assist agronomists and land resources planners in the identification of different soils and landscapes in the district, and assist research into determining the best agronomic practices in the district. The soil-landscape units will form the basis for land capability assessment for the soils of the soils of Battambang province, Cambodia. The general soil-landscape relationships identified in Banan district are expected to have relevance to other districts in Battambang where the terrain is based on limestone and marl geology and the influence of alluvial, colluvial and lacustrine depositional processes: however, the relative prevalence of the soil-landscape mapping units may vary from place to place.

2 District overview

Location

The district of Banan in the province of Battambang is located in the north west of Cambodia, about 310 km from Phnom Penh. The province of Battambang is bordered by Thailand to the west and on the east partially lies on the Tonle Sap lake (Figure 1). The Sangke River runs through the southeast of the district of Banan. Figure 2 shows the Banan district with roads, rivers, commune offices and boundaries.

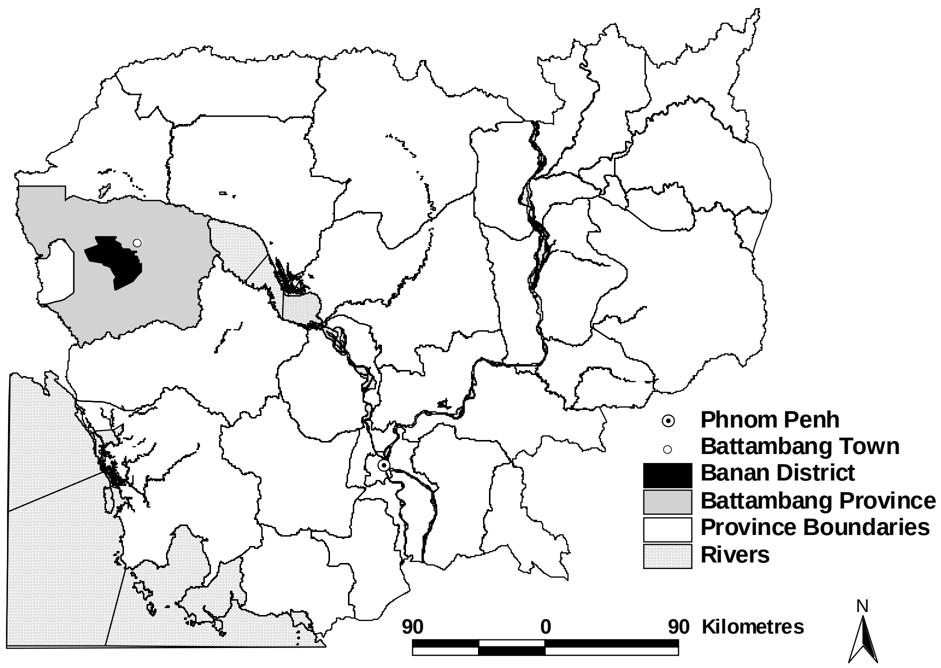

Fig. 1. Map of Banan district in the province of Battambang.

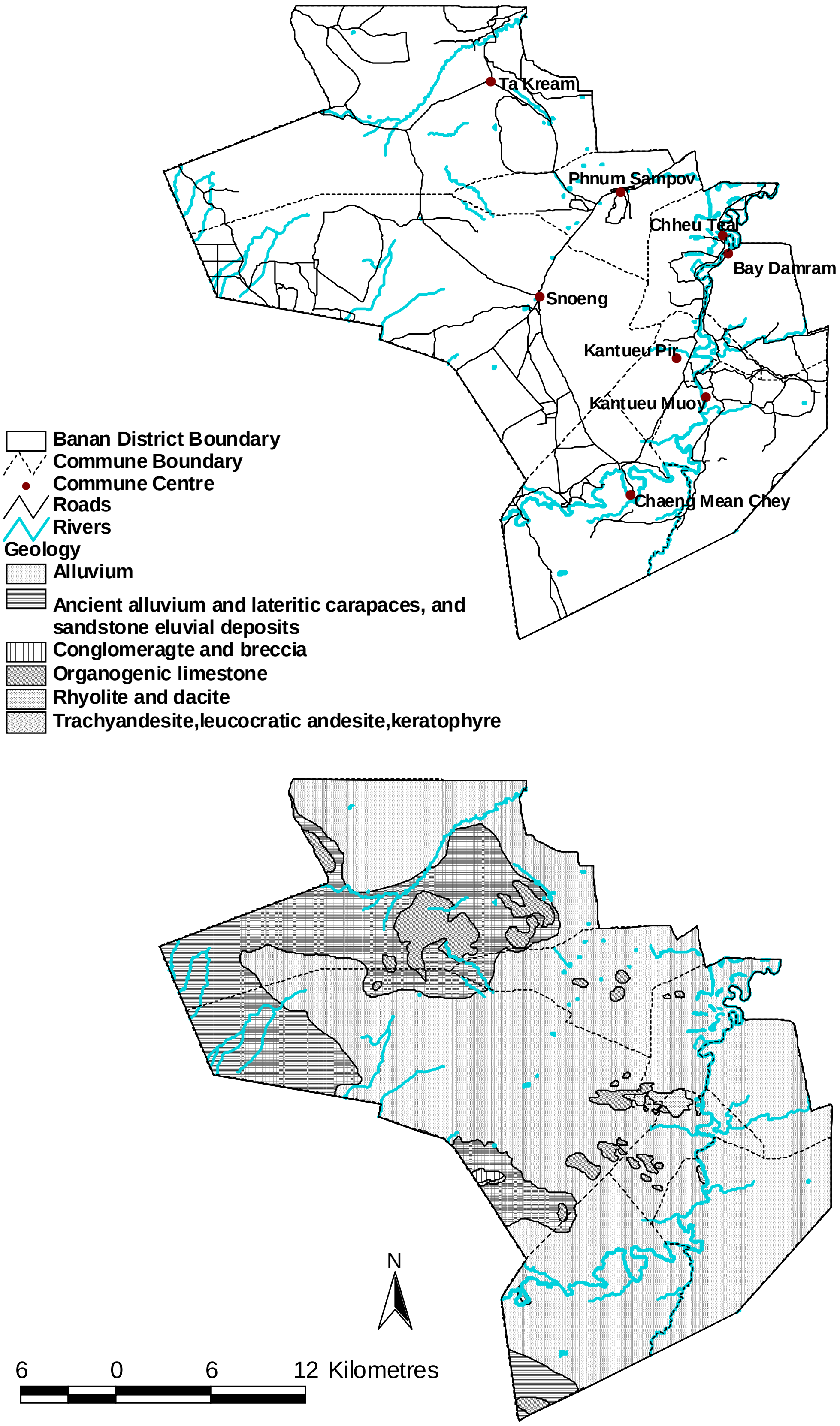

Fig. 2. Map of Banan district showing communes, roads and rivers and the geology.

Climate

Cambodia has a monsoonal climate, which is characterised by distinct wet and dry seasons. The dry season starts in November, with the early wet season beginning in April and the main wet season beginning in July. In Banan district, the average annual rainfall is between 1500 and 1750 mm (Nesbitt 1997). Rainfall begins in March but total falls are low until April and May, and peak in September. In 2001 and 2002, annual rainfall for Banan was 943 and 855 mm, respectively, suggesting considerable year-to-year deviation from the mean. Average monthly rainfall for 53 years in Battambang town is in Figure 3. Daily temperatures range from 21 to 35 ^{o}C. Maximum temperatures are reached in April to May with the coolest time of the year being from October to January.

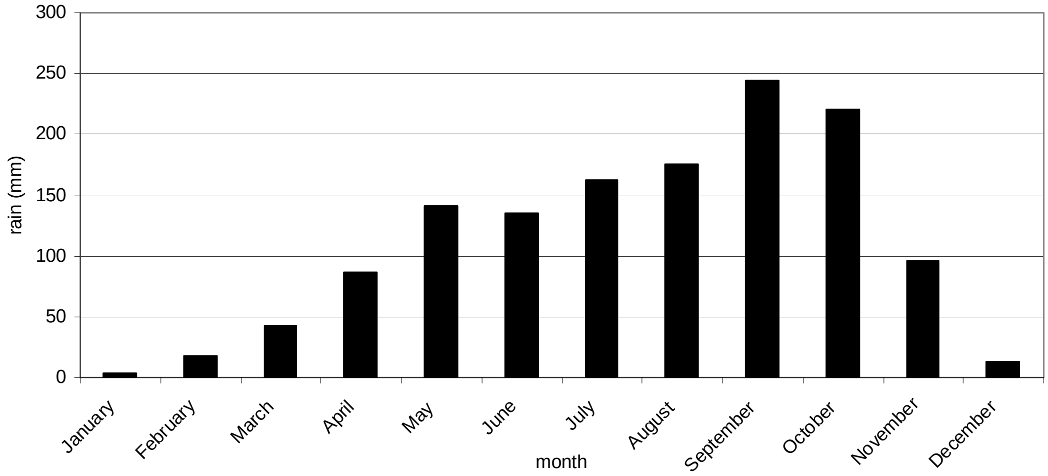

Fig. 3. Average monthly rainfall for Battambang town in Battambamg province (53 years of data) (Vance *et al.* 2004). Average annual rainfall in Battambang town is 1295 mm.

Geology

The geology of Banan province is dominated by sedimentary deposition in the Cenozoic and Mesozoic geological era (Workman 1972). Mesozoic limestone hills surrounded by Cenozoic pediments are scattered through the district. Small hills of other geologies (mainly rhyolite) also occur throughout the district. These hills are surrounded by Cenozoic lakebeds deposits, alluvial plains and deltaic deposits (Figure 2).

Land use

The main land use across Banan district is flooded rice in the wet season, and in the dry season irrigated rice is grown near Kampingpuoy Reservoir in the north.

Along the Sangke River, fruit trees (oranges), vegetables (especially chillies) and field crops are grown. The main field crops grown in Banan district in the uplands and surrounding the river are maize, soybean, mungbean, peanut and chilli.

3 Methods of soil-landscape survey

Soil survey

Detailed soil profile descriptions were completed on 8 soil pits, in areas of the landscape which were deemed to represent the different soil-landscape units. An additional 16 less detailed soil observations were also made in the district. In Banan district, the following resources were used to guide soil sampling location: rice soils map for the district (Oberthur *et al.* 2000); a geology map (Mekong River Commission- MRC); digital elevation models (MRC); US Army Corp topography maps (1:50,000 1967) and digital ortho-rectified aerial photographs (Department of Geography 1:50,000 1992). However, locations of soil pits were constrained being predominantly at locations used for crop trials. In southern Banan district, many areas not accessible by vehicle so the mapping units for those areas could not be ground truthed.

Soil classification was completed for detailed profile descriptions using FAO descriptors (FAO-ISRIC 1990). Data from all soil profile observations have been recorded in the CARDI Soil Profile Database of Cambodia.

Soil chemical analyses

At each soil pit, samples of soil were taken from each horizon. These samples have been analysed for electrical conductivity (1:1 soil:water), pH (1:1 soil:water) in the CARDI laboratory. Analyses of soil chemical characteristics were also completed at CSBP laboratory in Western Australia. These analyses included: nitrogen concentrations as ammonium, nitrate, and total nitrogen; extractable phosphorus and potassium, sulphur, copper, zinc, manganese, iron and boron; exchangeable calcium, magnesium, sodium, potassium and aluminium; organic carbon and the electrical conductivity, $pH_{(CaCl2)}$ and $pH_{(water)}$ of the soil (Rayment and Higginson 1992). Data from all soil chemical analyses has been recorded in the CARDI Soil Profile Database of Cambodia.

Soil-landscape map production

A soil-landscape map of Banan district was completed by combining the soil survey information (detailed pits and observations) with digital air photos, a digital elevation model, Landsat TM satellite images (1989) and expert knowledge to create land unit maps. Arcview software was used to combine these data layers. Polygons of the new soil-landscape map units were digitised. The soil-landscape map was ground truthed where possible by further observation of the soil-landscapes in the district to determine if the observed soil types were predicted in the soil-landscape map. The soil-landscape map was modified as required.

4 Soil-landscape overview

The geology in the Banan District is varied, leading to a corresponding range of soils and landscapes.

On the eastern side of the district, the Sangker River flows from south to north towards the city of Battambang. The recent brown alluvial soils (Kein Svay Soil group according to White et al. 1997) associated with this river are popular for horticultural purposes (Ba11).

On the alluvial plains further away from the river, brown cracking clay soils (Toul Samroung) dominate mapping unit Ba4 and Ba6. The alluvium of these plains stretches north-west and south east from Banan on the western side of Boeng Tonle Sap, and there is likely to be a lacustrine influence in their evolution.

Numerous small hills of limestone and other geologies (mainly rhyolite) occur throughout the district. The limestone hills are usually fairly rugged and dominated by rock outcrop (Ba1). The colluvial slopes within about 500 m of the limestone hills have structured grey clays over nodular carbonates at less than 1 metre (Ba2). Further from the hills, the dark clays are deeper, and carbonate nodules start much deeper, usually below 1 metre (Ba3). These soils have been classified as Kompong Siem Soil group in CASC, but they vary significantly from those that occur on colluvium and alluvium from basalt in eastern Cambodia, and will classified as a new calcareous phase of the Kompong Siem Soil group. The soils on colluvium surrounding rhyolite have not been well enough investigated to describe the dominant soils on that landform (Ba7, Ba8).

There is an area of sandy surfaced soils (Prey Khmer and Prateah Lang) on west side of the road to Pailin in the south-west of the district (Ba13, Ba14). These appear to be derived from sandstone bedrock further to the south and hence may have more in common with upland soils further east in Pursat.

Gently sloping areas in the west and south-west have variable soils, and have not been well investigated as access is difficult. Brown loamy surfaced soils with paler clay subsoils are most common (Ba5, Ba9).

Table 1 describes each of the map units outlined above. Figure 4 is a map which shows the distribution of each map unit in the landscape of Banan district.

5 Soil Profiles

The Kompong Siem, Toul Samroung, Kein Svay, Pateah Lang and Prey Khmer Soil groups have been previously described in detail by White et al. (1997). A map covering the lowland rice soils of the district shows predominantly Toul Samroung, with Kompong Siem and Prateah Lang as minor soil groups (Oberthur et al. 2000). The Kompong Siem calcareous phase is a newly proposed phase for the Cambodian Agronomic Soil Classification (Bell et al. 2005) and hence is described in more detail here.

The Kompong Siem Soil group, calcareous phase is a very dark grey coloured soil with a high proportion of carbonate nodules. Carbonate nodules are < 2 to 6 mm diameter, white to pale grey and effervescent (produce gas bubbles) when treated with dilute HCl (White et al. 1997). Kompong Siem Soil group, calcareous phase is derived from weathering of limestone and is commonly found on mid to lower slopes of the rugged limestone hills (Fig. 5), and also extends out onto the alluvial plains. The latter form of Kompong Siem has previously been described by White et al. (1997) because it is suited to padi rice production. Using the CASC (White et al. 1997), the hill slope occurrences of dark grey calcareous clay soils presently do not key to Kompong Siem Soil group: they are assigned to an undefined group of soils.

Kompong Siem Soil group can occur on limestone or calcimorphic parent rocks when it occurs on lower colluvial/ alluvial plains (White et al. 1997). Hence to resolve this anomaly it is proposed to create the calcareous phase of Kompong Siem to cover both the plain and the hillslope forms of this Soil group. This also creates a more formal recognition of the differences between Kompong Siem on basalt and Kompong Siem on limestone, which are especially important for non-rice crop production.

Table 1. Map unit descriptions - Soil-landscape map of Banan district, Battambang province

Map Unit	Area (%)	Summary description of soil-landscape unit
Ba1	4.2	Steep hills and mountains on limestone and minor sandstone/claystone. Shallow soils and much rock outcrop. Variable stony soils including shallow grey to black clays on footslopes below limestone. Regrowth forest
Ba2	13.7	Gentle footslopes and gently sloping terrain surrounding limestone and minor sandstone/claystone. Dark clays over limestone or marl, variable depth, often shallow (Kompong Siem calcareous phase). Also minor inclusions of brown gradational soils in this mapping unit including Toul Samroung.
Ba3	1.1	Very gently sloping plains associated with limestone hills. Kompong Siem calcareous soils. Marl usually occurs below 50 cm. Some Toul Samroung soils
Ba4	6.7	Alluvial plain, complex of Toul Samroung and Komping Siem soils
Ba5	12.9	Alluvial plains in south. Soils not yet ground truthed due to lack of road access
Ba6	27.2	Alluvial plain, Toul Samroung soils dominant.
Ba7	0.5	Hills and mountains on acid volcanics (Rhyolites and rhyodacites).
Ba8	0.2	Slopes surrounding acid volcanics (Rhyolites and rhyodacites). Soils yet not ground truthed
Ba9	18.5	Pediments/colluvial slopes in south. Soils yet not ground truthed
Ba10	3.7	Swampy areas of creeks/lakes. Seasonally flooded.
Ba11	5.1	Alluvium adjacent to active rivers. Kein Svay soils dominant. Toul Samroung and intergrades between Kein Svay and Toul Samroung common.
Ba12	2.1	Permanent water, Komping Puoy. Map unit boundary approximate only as extent of permanent water varies with season.
Ba13	4.2	Very gentle slopes and plain with sandy-surfaced soils. Prateah Lang and Prey Khmer common.
Ba14	-	Very gentle lower slopes and plain with Prey Khmer and Prateah Lang soils

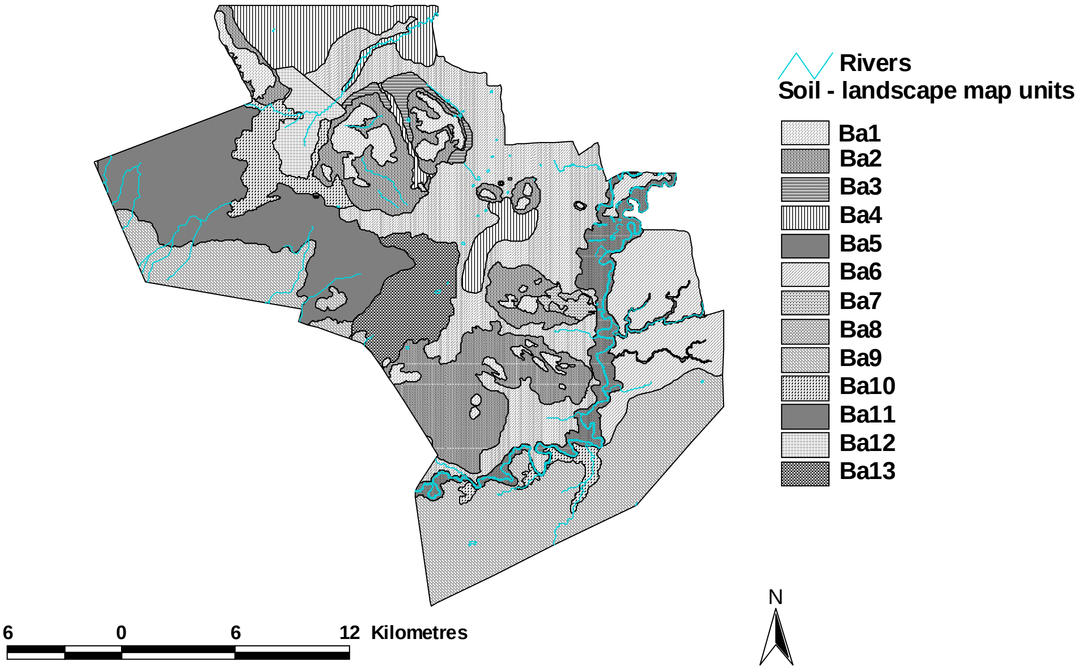

Fig. 4. Map of Banan district indicating the location of each soil- landscape unit. Map Unit 14 is too small to represent on this map. See Table 1 for detailed descriptions of each soil mapping unit.

Figure 5. Typical landscape of limestone hills (background) with Kompong Siem Soil group calcareous phase on the mid to lower slopes (foreground) in Banan district.

The Kompong Siem calcareous phase profile is shallow (45 cm) to moderately deep (> 1 metre). The surface horizon is 24 to 30 cm deep, very dark grey, clayey texture, with few fine carbonate nodules. The surface is hard to very hard when dry. The sub-surface layers are very dark grey to dark grey, extend to 45 cm depth or more, have clay texture, and are characterised by many fine carbonate nodules (Fig. 6). At 45 to 110 cm depth or greater, the solum lies on weathered light grey limestone. A more detailed description of the Kompong Siem calcareous phase is reported elsewhere (Bell et al. 2005).

Typical soil profiles for the upland soil-landscape units are shown below. A more complete list is available from the soil database maintained at CARDI. Lowland soil groups are not described below as a detailed description of their profiles is reported in White et al. (1997).

Kompong Siem, calcareous phase

Project & Site Code: ACIAR 0031
Described by: Noel Schoknecht **Date:** 4/2/04
Location: Datum: IND60 Zone: 48 288761 mE 1445515 mN GPS measurement
Disturbance: ploughing
Landform
Landform pattern: pediment *Relief/modal slope:* low-gradient footslope
Slope class (US): gently sloping *Landform element:* slope
Morphological type: lower slope *Slope curvature:* straight
Surface and Hydrological Properties
Physical properties: surface crust
Geology/parent material
Soil parent material: limestone, other carbonate rock
Limestone colluvium
Geology: limestone, other carbonate rock
Land use
Site: rainfed arable cultivation *Surrounds:* rainfed arable cultivation
Current Classification
World Reference Base (FAO-ISRIC-ISSS 1998): Hypercalcic Chernozem

Horizon	Depth (cm)	Description
A1t	0-8	very dark grey (2.5YR 3/0 moist); hard dry consistence; pedal, moderate, sub-angular blocky structure; rough-ped fabric; no segregations; many roots, very fine, non-cemented and non-compacted; common, fine and medium, medium porosity, vughs void; clear, smooth boundary.
A2t	8-30	Dark grey (2.5YR 4/8 moist) clay; firm moist consistence; pedal, moderate, medium, sub-angular blocky structure; rough-ped fabric; very few segregations, very fine carbonates (calcareous) nodule rounded white hard; few roots, very fine, non-cemented and non-compacted; gradual, wavy boundary.
k	30-45	dark grey (5YR 4/1 moist) clay; firm moist consistence; pedal, weak, medium, sub-angular blocky structure; rough-ped fabric; many

		segregations, very fine carbonates (calcareous) nodule rounded white both hard and soft; no roots, non-cemented and non-compacted; abrupt, wavy boundary.
Ck	45-100	pinkish grey (5YR 7/2 moist) clay; medium faint reddish brown (5YR 4/3 moist) biological mottles; friable moist consistence; weak, medium, sub-angular blocky structure; dominant segregations, fine carbonates (calcareous) nodule rounded white both hard and soft; no roots, non-cemented and non-compacted.

Toul Samroung, brown phase

Project & Site Code: ACIAR 0034
Described by: Noel Schoknecht **Date:** 4/2/04
Location: Datum: IND60 Zone: 48 284860 mE 1450240 mN GPS measurement
Location notes: Gently undulating alluvial plain next to small creek
Landform
Landform pattern: alluvial plain
Relief/modal slope: plain *Slope class (US):* nearly level
Surface and Hydrological Properties
Surface coarse fragments: no gravel
Physical properties: cracking surface
Geology/parent material
Soil parent material: fluvial
Land use
Site: rainfed arable cultivation *Surrounds:* rainfed arable cultivation

Horizon	Depth (cm)	Description
A1	0-10	brown (7.5YR 4/2 moist); fine distinct mottles; hard dry consistence; weak, fine, sub-angular blocky structure; many roots, very fine; no coarse fragments; moderate permeability; medium porosity void; sharp, smooth boundary.
A2	10-40	brown (7.5YR 5/2 moist), pinkish grey (7.5YR 6/2 dry); fine distinct brown (7.5YR 4/4 moist) redox mottles; slightly hard dry consistence; moderate, fine, sub-angular blocky structure; very few segregations, fine manganese (manganiferous) concretion rounded soft; common roots, fine; no coarse fragments; rapid permeability; medium porosity void; clear, wavy boundary.
B1t	40-80	pinkish grey (7.5YR 6/2 moist) clay loam; reddish brown (2.5YR 4/4 moist) redox mottles; firm moist consistence, sticky; moderate, medium, angular and sub-angular blocky structure; few segregations, fine manganese (manganiferous) concretion rounded soft; few roots, fine; no coarse fragments; slow permeability; very low porosity void; gradual, wavy boundary.
B2t	80-100+	pinkish grey (7.5YR 6/2 moist) clay; fine distinct red (2.5YR 4/6 moist) redox mottles; firm moist consistence, sticky; moderate, medium, angular and sub-angular blocky structure; few segregations,

fine manganese (manganiferous) concretion rounded soft; few roots; no coarse fragments; slow permeability; very low porosity void.

6 Soil Chemical Properties of Profiles

A limited number of soil profiles were sampled to depth and analysed in full. The description below is a first approximation for the soil chemical properties, but further analyses are needed to confirm these characteristics. Interpretations were based on Peverill et al. (1999).

Kompong Siem, calcareous phase

Two profiles were sampled for complete analysis but additional information on the chemical properties of this soil profile type was reported by White et al. (1997).

The surface horizon contains moderate to low organic carbon and low total N and mineral N. (Table 2). The profiles are slightly alkaline in the surface horizons, rising to moderately alkaline at depth. Electrical conductivity (1:5 extract) values were > 0.5 mS/cm below 30 depth in Site 33 indicating significant levels of soluble salts. This same soil profile also contained high exchangeable Na levels (Table 3), and moderate alkalinity.

Exchangeable Ca was very high, and exchangeable Mg variable from high to very low in some layers of Site 33. Exchangeable K was moderate in the surface soil layer, but dropped to low in sub-soils.

Kompong Siem soil profiles contained low bicarbonate extractable P (Table 4). Extractable S levels were variable with Site 31 having low and Site 33 high KCl-40 extractable S. DTPA Cu levels were moderate, and DTPA Zn varied from moderate to low, with the lower values in sub-soils. DTPA Fe levels were also low especially at Site 31, and DPTA Mn was lower than other profiles in Banan and elsewhere in Cambodia. Very low sub-soil B levels were obtained in Site 33, otherwise moderate to low levels of B were extracted from the Kompong Siem profiles.

Toul Samroung, brown phase

Only one profile was analysed in full, but additional information on the chemical properties of this soil profile type was reported by White et al. (1997).

The surface horizon contains low to moderate organic carbon and low extractable and total N. (Table 2). The profiles were strongly acid in the 0-80 cm layer. However, exchangeable Al levels comprised < 20 % of effective CEC so Al toxicity may not be a concern on this soil (Table 3). However, analysis of further profiles is needed to confirm this. Also the acidity may give rise to Mn toxicity and possibly low molybdenum.

Toul Samroung soil contains moderate levels of exchangeable Ca and Mg and low exchangeable K (Table 3). Sub-soil exchangeable Na was high.

Toul Samroung soil contained low extractable P and S (Table 4). Moderate levels of Cu and Zn were obtained in Toul Samroung soil. Very high DTPA Mn was extracted especially in surface and moderate to low B.

Kein Svay

Only one profile was analysed in full, but additional information on the chemical properties of this soil profile type was reported by White et al. (1997).

The surface horizon contains low to moderate organic carbon (Table 2). Kein Svay soil profile contained high nitrate- and ammonium-N but only moderate total N (Table 3). The profile was only moderately acid and did not contain significant exchangeable Al.

Exchangeable Ca, Mg and K were moderate to high throughout the Kein Svay soil profile (Table 3).

Bicarbonate extractable P was moderate throughout the profile (Table 4). Extractable S was moderate in the surface 10 cm layer, but low below that. Moderate levels of DTPA Cu, Zn and Mn and moderate hot $CaCl_2$ extractable B levels were obtaiend from the Kein Svay soil profile.

Table 2: . Organic carbon, electrical conductivity (EC) and pH of soils of Banan district.

Site	Cambodian Soil Group		Depth	Organic	EC	pH	pH
	Group	Phase		carbon	(1:5)	$CaCl_2$	H_2O
			(cm)	(%)	(dS/m)		
31	Kompong Siem	calcareous	0-8	1.3	0.11	7.2	8.2
			8-30	0.9	0.06	7.3	8.3
			30-45	0.6	0.09	7.6	8.6
			45+	0.19	0.06	7.7	9
33	Kompong Siem	calcareous	0-3	1.81	0.30	7.6	8.5
			3-30	0.89	0.27	7.9	9.1
			30-60	0.34	0.52	8.3	9.6
			60-100	0.33	0.49	8.4	10.1
			100-110	0.2	0.76	8.6	9.9
34	Toul Samroung	brown	0-10	1.17	0.03	4.5	5.5
			10-40	0.34	0.01	4.2	6.3
			40-80	0.3	0.01	4.3	6.6
			80-100+	0.24	0.05	5.2	6.8
42	Kein Svay		0-18	1.1	0.18	5.6	6
			18-60	0.52	0.02	5.3	6.5
			60-100	0.41	0.02	6.3	7.4

Table 3. Exchangeable cations, effective cation exchange capacity (ECEC) and Al saturation in soils of Banan district.

Site	Cambodian Soil Group		Depth	Ca	Mg	Na	K	Al	ECEC	Al saturation
	Group	Phase	(cm)	(cmol/kg)						(%)
31	Kompong Siem	calcareous	0-8	41.1	4.13	0.03	0.35	0	45.7	0
			8-30	44.2	0.96	0.04	0.14	0	45.3	0
			30-45	39.0	0.39	0.03	0.13	0	39.5	0
			45+	16.1	0.08	0.02	0.05	0	16.3	0
33	Kompong Siem	calcareous	0-3	45.2	6.86	2.43	0.63	0	55.1	0
			3-30	40.9	7.94	5.95	0.4	0	55.2	0
			30-60	24.2	10.2	11.6	0.13	0	46.1	0
			60-100	17.3	14.9	18.3	0.15	0	50.5	0
			100-110	12.4	12.8	15.1	0.2	0	40.5	0
34	Toul Samroung	brown	0-10	8.8	3.23	0.24	0.34	0	12.7	0
			10-40	5.1	1.48	0.64	0.08	2.02	9.3	22
			40-80	10.2	6.87	2.77	0.14	2.09	22.1	9
			80-100+	13.7	9.01	3.34	0.19	0.19	26.4	1
42	Kein Svay		0-18	12.1	5.71	0.26	0.4	0	18.5	0
			18-60	16.4	8.14	0.18	0.3	0.02	25.0	0
			60-100	19.9	7.79	0.17	0.3	0	28.1	0

Table 4. Extractable nutrient levels in soils of Banan district.

Site	Cambodian Soil Group		Depth	Nitrogen			Bicarb. P	KCl-S	DTPA	DTPA	DTPA	DTPA	Hot $CaCl_2$
	Group	Phase		NO_3	NH_4^+	Total N			Cu	Zn	Mn	Fe	B
			(cm)	(mg/kg)	(mg/kg)	(%)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
31	Kompong Siem	calcareous	0-8	12.0	7.0	0.12	18	4.1	1.29	0.4	7.97	5.11	0.4
			8-30	4.0	4.0	0.09	6	1.7	1.6	0.3	5.24	4.54	0.4
			30-45	7.0	2.0	0.06	3	1.4	1.76	0.21	3.12	5.81	0.3
			45+	1.0	1.0	0.02	3	1	0.44	0.19	1.28	1.05	0.2
33	Kompong Siem	calcareous	0-3	11.0	8.0	0.15	18	17.8	3.15	0.7	11.2	9.48	0.3
			3-30	5.0	7.0	0.08	9	12.4	2.73	1.78	11.3	15.3	0.2
			30-60	1.0	3.0	0.03	2	32.3	1.11	0.11	4.22	2.74	0.1
			60-100	1.0	3.0	0.02	1	42.1	1.35	0.21	3.18	2.24	0.1
			100-110	1.0	2.0	0.02	2	23.8	0.81	0.31	2.91	2.84	0.1
34	Toul Samroung	brown	0-10	6.0	8.0	0.1	7	3.9	2.31	0.72	208	60.9	0.3
			10-40	1.0	2.0	0.03	3	1.1	1.25	0.34	43.4	18.9	0.4
			40-80	1.0	4.0	0.03	2	1	1.25	0.45	35.0	12	0.3
			80-100+	1.0	3.0	0.02	1	1.1	1.41	0.48	28.5	11.9	0.2
42	Kein Svay		0-18	75.0	32.0	0.1	22	11.4	2.4	1.32	35.4	38.4	0.4
			18-60	1.0	1.0	0.04	20	2.4	3.46	0.75	22.1	38.2	0.4
			60-100	1.0	1.0	0.04	10	1.6	1.89	0.83	16.5	3.44	0.4

7 Soil Management

The Kein Svay soil is a fertile alluvial loam with no significant limiting factors apart from temporary waterlogging during periods of high flood and after heavy rainfall. Crop productivity on this soil was higher than most other soils assessed. Clayey phases of this soil occur on the backslopes of the major rivers and these have a markedly different capability for non-rice crops due to seasonal inundation. Similarly, sandy phases of Kein Svay on the levee bank will have poorer water storage and greater risk of leaching of nutrients.

The Toul Samroung is mostly used for rice and is regarded as a productive soil for this purpose in Cambodia (White et al. 1997). The undulating plains of Toul Samroung soil include areas that are sufficiently elevated for non-rice cropping and it is these landforms that are the subject of the present report. This corresponds to the brown phase of Toul Samroung Soil group (White et al. 1997). Toul Samroung Soil group is hard setting when dry. It is difficult to till to produce a seedbed, which may hinder crop establishment. Water ponding on the surface after heavy rain is a risk. The surface soil tends to crack when dry but nevertheless does not form a plough pan at 20-25 cm. Waterlogging risk is a major limiting factor for non-rice crops.

The Toul Samroung profile was strongly acid in the 0-80 cm layer. However, exchangeable Al levels comprised < 20 % of effective CEC so Al toxicity may not be a concern on this soil except for very sensitive crops Sanchez et al. 2003). However, analysis of further profiles is needed to confirm the Al toxicity risk. Acidity may also give rise to Mn toxicity and Mo deficiency. Very high DTPA Mn levels were extracted from the surface horizon.

Toul Samroung soil contains low exchangeable K. Sub-soil exchangeable Na was high suggesting that dispersion of clays in this layer may contribute to low permeability when the clays wet up. Toul Samroung soil contained low extractable P and S. Rice responds well to P fertiliser (White et al. 1997) even though the soil has high P sorption (Pheav et al. 2002). Moderate to low B levels were found in the Toul Samroung soil.

Kompong Siem calcareous phase is a shallow to moderately deep alkaline clay soil. When dry it forms large cracks. The first rains may not evenly wet up the profile, and leaching may occur at this time also. The surface is prone to be hard when dry but sticky when wet. Hence it is difficult to till to produce a suitable seedbed for non-rice crops. It is prone to waterlogging during heavy rain. Crops on the shallow forms of this soil (45 cm to weathered limestone) may be prone to drought. Otherwise on the deeper profiles (110 cm), soil water storage will be high. The high clay content may limit plant availability of stored water especially if only light showers of rain occur, and soaking rains may be necessary for reliable early wet season crop establishment. Water erosion risk is low except on steeper slopes.

Due to high pH, severe chlorosis indicating Fe deficiency is commonly observed on peanut growing on this soil. DTPA extractable Fe levels were low on this soil. Efficient varieties of crops like maize do not suffer Fe deficiency. Electrical conductivity values were > 0.5 mS/cm at 30 depth and deeper in one profile sampled indicating significant levels of soluble salts. This same soil profile also contained high exchangeable Na levels and moderate alkalinity.

Kompong Siem soil profiles contained low bicarbonate extractable P. Availability of added P may be restricted by high pH. Extractable S levels were variable from low to high. Exchangeable K was moderate in the surface soil layer, but drops to low in sub-soils. Micronutrient availability appeared to be low probably due to the alkaline pH. DTPA Zn varied from moderate to low, with the lower values in sub-soils. Very low sub-soil B levels were obtained in one profile, otherwise moderate to low levels of B were extracted from the Kompong Siem profiles.

Crop performance on Kompong Siem calcareous phase was poor compared to Kompong Siem soil on basalt, and compared to Kein Svay and Toul Samroung soils in the same district.

8 General Discussion

Kein Svay Soil group is a highly productive soil in Banan district that is derived from alluvial depositions along the Sangke River. Already these soils are intensively used for crop production. Non-rice field crops, while productive, will face competition from high value crops such as chilli, vegetable and fruit trees on account of proximity to the markets in Battambang town, Phnom Penh, and Thailand.

Toul Samroung soils appear to be quite extensive, but the low lying plains that make up most this mapping unit are already largely used for wet season rice. Only the higher elevation, better drained brown phase of Toul Samroung has prospects for non-rice crops. Its productivity potential is limited by soil acidity and waterlogging risk. Hence Toul Samroung is somewhat less productive as a soil for non-rice crops than for rice.

Kompong Siem Soil group occurs on alluvial plains where it is predominantly used for wet season rice. In elevated sites and hill slope occurrences of this soil type, non-rice crops can be grown. The yield potential of these soils is only fair, possibly due to shallowness of the soil which makes crops prone to drought, low nutrient availability, and waterlogging. Heavy soaking rains are probably needed for reliable crop establishment on these soils as soil water from light rains is not readily available for crop uptake.

Extensive areas of pediments/colluvial slopes and alluvial plains were mapped in south of the district from air photographs and satellite images, but due to limited access and safety concerns, the characteristics of the soil profiles could not be checked. The potential of soils in this area for cropping once road access improves is unclear at this stage.

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Figure 6. Profile of Kompong Siem calcareous phase