កំពង់សៀម ការល់គែ: ជាអនុក្រុមថ្មីនៃក្រុមដីកំពង់សៀម សម្រាប់ចំណាត់ថ្នាក់ដីកសិកម្មកម្ពុជា

KOMPONG SIEM CALCAREOUS: A NEW PHASE FOR THE KOMPONG SIEM SOIL GROUP OF THE CAMBODIAN AGRONOMIC SOIL CLASSIFICATION

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នៅប្រទេសកម្ពុជានាពេលបច្ចុប្បន្ន វិស័យកសិកម្មតំបន់ខ្ពង់រាប មានការរីកដុះដាលយ៉ាងឆាប់រហ័ស ប៉ុន្តែការសិក្សាស្វែងយល់អំពីដីតំបន់ខ្ពង់រាបនៅមានកម្រិត ដោយសារភាគច្រើនត្រូវបានធ្វើឡើងនៅតំបន់ទំនាបដាំដុះស្រូវ។ នៅក្នុងខេត្តបាត់ដំបង ការសិក្សាបានរកឃើញដីកើតចេញពីថ្មកំបោរដែលមានលក្ខណៈសម្បត្តិផ្សេងសម្រាប់ដំណាំចំការ។ ដីបែបនេះត្រូវបានរកឃើញនៅក្នុងស្រុកបាណន់ តាមរយៈការសិក្សាអង្កេតដី ការវិភាគគីមី និងការពិសោធន៍លើដំណាំផ្សេងៗ។ ដីអាល់កាឡាំងនៅតាមជម្រាល និងវាលរាប ជុំវិញជើងភ្នំដែលមានថ្មកំបោរ បង្កើតផលិតផលដំណាំបានទាប ដោយសារមានបញ្ហាកង្វះជាតិដែក និងកត្តារារាំងនានាពាក់ព័ន្ធនិងជាតិអាល់កាឡាំង។ ដីដែលជាដីឥដ្ឋពិណក្រមៅ កកើតឡើងដោយសារថ្មកំបោរ និងសិលាមេនានា ត្រូវបានចាត់ថ្នាក់បញ្ចូលទៅក្នុងក្រុមដីកំពង់សៀមអនុក្រុមកាល់គែ ដើម្បីញែកវាចេញពីក្រុមដីកំពង់សៀមដែលកើតចេញពីថ្មបាសាល់។ អនុក្រុមកាល់គែ នៃក្រុមដីកំពង់សៀមនេះ មានពណ៌ប្រផេះក្រម៉ៅខ្លាំង ដែលមានអត្រាដុំកាបូណាតច្រើន ប៉ុន្តែពណ៌ និងវាយនភាពរបស់វាអាចឱ្យយើងចាត់ថ្នាក់ជាក្រុមដីកំពង់សៀមបាន ដោយប្រើប្រព័ន្ធធ្វើចំណាត់ថ្នាក់ដីតាមបែបក្បែត្រវិទ្យារបស់កម្ពុជា។ ទោះជាយ៉ាងនេះក្តី នៅតាមជម្រាលជើងភ្នំ អនុក្រុមកាល់គែនេះ មិនអាចចាត់ថ្នាក់ទៅជាក្រុមដីកំពង់សៀមបានឡើយ ព្រោះវាមិនសមស្របសម្រាប់ដំណាំស្រូវ។

ពាក្យគន្លឹះ: អាល់កាឡាំង ថ្មបាសាល់ ទិន្នផលដំណាំ ថ្មកំបោរ វាលរាបជើងភ្នំ លក្ខណៈគីមីដី។

Abstract

Upland agriculture is expanding rapidly in Cambodia, but in-depth studies of the soils have been confined to rice soils. In Battambang province, soils associated with limestone have been identified with distinctive properties for non-rice crops. These soils were characterised in Banan district through soil surveying, soil chemical analysis and crop production trials. Alkaline soils on the pediments and gently sloping plains surrounding limestone hills have low crop productivity on account of iron deficiency and alkalinity-related constraints. It is proposed that these dark clay soils developed on limestone and related parent rocks be assigned to a calcareous phase of the Kompong Siem Soil group to distinguish them from related soils developed on basalt. The Kompong Siem calcareous phase is a very dark grey coloured soil with a high proportion of carbonate nodules. When it occurs on sites suitable for wetland rice, its color and texture should lead to identification as the Kompong Siem Soil group in the Cambodia Agronomic Soil Classification. However, on hill slopes, Kompong Siem calcareous phase is not suited to rice and hence such soils cannot presently be keyed to Kompong Siem Soil group.

Keywords: alkalinity, basalt, crop yield, limestone, pediment, soil chemistry.

Introduction

Upland agriculture is beginning to expand rapidly in the northwest of Cambodia where maize, soybean, cassava, 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 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 naming and identification of the Rice Soil groups has become familiar to agronomists, extension officers and farmers in Cambodia due to their common usage and many training programmes conducted on their identification and properties (Heer et al. 1999). However, the Rice Soil Manual does not describe all the soils of Cambodia, neither was it intended to do so (White et al. 1997). The key for identification of rice soils allows for undefined and unclassified soils and for the creation of new phases of existing Soil groups. Most of the upland soils of Cambodia are likely to fall into these categories. Increased interest in crop diversification and upland farming has created a need for more detailed information on the soils in the upland areas. It is important to note that for upland soils, profile descriptions will need to be deeper than the upper 50 cm that is mostly used for rice soils, because of the greater root depth of field crops on upland soils, and their greater reliance on sub-soil stored water and nutrients.

The Soil Group concept for Kompong Siem has already been defined by White et al. (1997). It already allows for Kompong Siem soils formed on calcareous parent materials.

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The group concept of Kompong Siem is as follows:
"Soils on which stones or boulders of basalt or calcimorphic limestone are clearly visible in the profile or on the soil surface and which have a black or dark grey, clayey textured topsoil, which forms deep cracks over a clayey textured subsoil".

It is proposed to recognise the Kompong Siem soils formed on calcareous parent material as a new phase largely because their alkalinity requires different management for crops apart from paddy rice. The calcareous phase also extends the group concept to include soils on slopes that are unsuited to rice (Bell et al. 2006).

The purpose of this paper is to assist agronomists, extension officers and farmers to recognise a new calcareous phase of the Kompong Siem Soil group, to outline its main limiting factors, soil management requirements, and potential for land use. We describe the appearance and properties of the calcareous phase of the Kompong Siem Soil group, and contrast it with Kompong Siem soils developed on basalt, to help in its recognition in the field and to guide management for improved productivity. A more detailed explanation of the taxonomy, pedogenesis and soil chemical properties can be found in Hin et al. (2005).

Material and methods

Location

The study was conducted in Banan district, Battambang province located in the north west of Cambodia, about 310 km from Phnom Penh. The Sangke River runs through the southeast of the district of Banan. Contrasting Kompong Siem soils developed on basalt were studied in, Kampong Cham province (Hin et al. 2007). Additional field investigation was conducted in the district of Ou Reang Ou in the province of Kompong Cham, about 165 km from Phnom Penh.

Climate

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 1. 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.

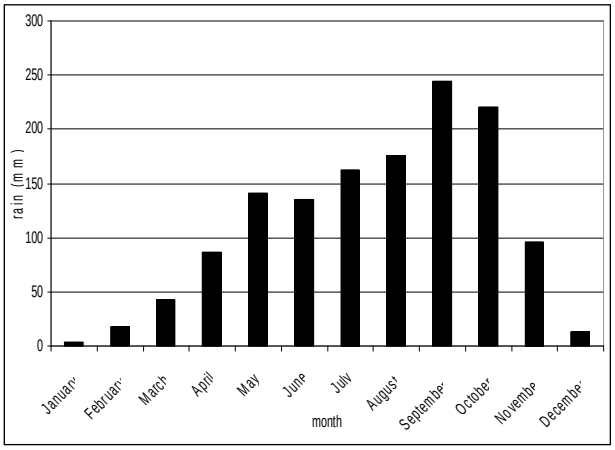

Figure 1. Average monthly rainfall for Battambang town in Battambamg province (53 years of data) (Vance *et al.* 2004). Average annual rainfall in Battambang town is 1295 mm.

Geology

The geology of Banan district 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. The focus of the present paper is on the limestone hills and soils associated with its pediment and surrounding colluvial/ alluvial plains.

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. The main field crops grown in Banan district in the uplands and surrounding the river are maize, soybean, mungbean, peanut and chilli.

Methods of soil-landscape survey

Detailed soil profile descriptions were completed on 4 soil pits, in areas of the landscape deemed to represent the Ba2, Ba3, and Ba4 soil-landscape units mapped by Hin et al. (2005) (Figure 2). In Banan district, the following resources were used to guide soil sampling location: rice soil 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). Detailed soil profiles for this soil were made at the following locations and the full profile description plus soil analysis results are available from the Cambodia Soil Profile database located at CARDI.

Site code	Eastings	Northings
ACIAR0031	288761	1445515
ACIAR0032	287213	1446779
ACIAR0033	285603	1450277
ACIAR0064	297051	1427549

Note: Datum IND60 Zone 48.

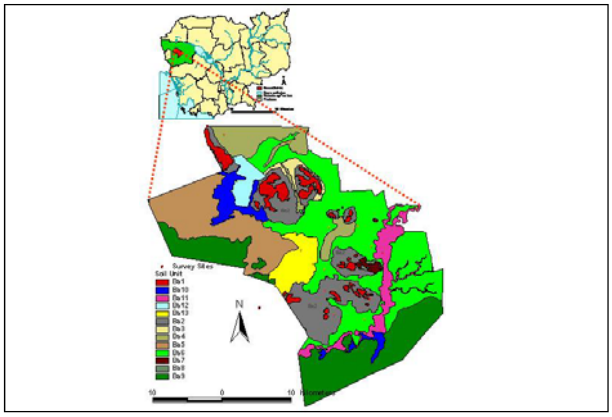

Figure 2. Map of Banan district in Battambang province showing the distribution of Kompong Siem calcareous soil which occurs predominantly in soil unit, Ba2 (Grey shading).

Soil chemical analyses

At each soil pit, samples of soil were taken from each horizon. These samples were analysed for electrical conductivity and 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 were recorded in the CARDI Soil Profile Database of Cambodia.

Crop productivity trials

On-farm trials were conducted in 2004 and 2005, with early wet season (EWS) and main wet season (MWS) sowings of maize, mung bean, peanut, sesame and soybean on Kompong Siem calcareous soil, as well as other soils in Banan district. Similar trials were conducted in Ou Reang Ov district, Kampong Cham and Tram Kak district, Takeo province. Yields for all these trials were ranked to assess overall productivity on the different soils, in particular to rank Kompong Siem calcareous phase relative to Kompong Siem on basalt and other soils of Banan district.

Results and discussion

Soil-landscape overview

Hin et al. (2005) reports the properties and distribution of soil-landscape units in Banan district. 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. The colluvial slopes (pediment) within about 500 m of the limestone hills have structured grey clays over nodular carbonates at less than 1 metre. Further from the hills, the dark clays are deeper, and carbonate nodules start much deeper, usually below 1 metre. These soils associated with limestone 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, suggesting that they should be classified as a new calcareous phase of the Kompong Siem Soil group. Collectively they occupy about 19-22 % of the area of Banan district (Hin et al. 2005). Similar calcareous soils occur elsewhere in Battambang province, for example on pediments surrounding limestone hills in Rotonak Mondol district.

The limestone hills and associated pediments occur in landscapes with prevalent alluvial and lacustrine sediments (Hin et al. 2005). On the eastern side of the district, the Sangke 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. On the alluvial plains further away from the river, brown cracking clay soils (Toul Samroung Soil group) dominate. The alluvium of these plains stretches north-west and south east from Banan on the western side of Boeng Tonle Sap (Great Lake), and there is likely to be a lacustrine influence in their evolution. Collectively these soils occupy about 35 % of Banan district.

Gently sloping areas in the west and south-west of Banan district have variable soils, and have not been well investigated as access is difficult. These are tentatively described as brown loamy surfaced soils with paler clay subsoils covering about 31 % of Banan district.

Soil Profiles

The calcareous phase of Kompong Siem Soil group is a very dark grey colored soil with a high proportion of carbonate nodules (Figure 3). 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). Nodules are derived from weathering of limestone and are commonly found on mid to lower slopes of the rugged limestone hills, and also extend out onto the colluvial/alluvial plains. Kompong Siem Soil group can occur on limestone or calcimorphic parent rocks when it occurs on lower colluvial/alluvial plains (White et al. 1997). This form of Kompong Siem has previously been described by White et al. (1997) because it is suited to paddy rice production. However, 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. 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. In the World Reference Base (ISSS-ISRIC-FAO 1998), the calcareous phase is classified as a Hypercalcic Chernozem whereas on basalt the Kompong Siem soil is classified as a Gleyic Phaeozem. Hence on the basis of pedological characteristic there is a clear distinction between

Figure 2. Profile of Kompong Siem calcareous phase in Banan district of Battambang province (ACIAR 0031 in the CARDI Soil Profile database of Cambodia).

[1] Calcareous nodules are hard or soft, white to pale grey colored rounded segregations (White et al. 1997, p. 69). They can vary in size from sand to gravel and stones (< 2- 6 mm). They are predominantly comprised of calcium carbonate, which can be confirmed by the effervescence (fizzing or bubbling reaction) developed when a drop of dilute hydrochloric acid (1 N) is placed on it.

the calcareous phase of Kompong Siem and the gravely and non-gravelly phases developed on basalt.

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. 3). 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 (Hin et al. 2005; Bell et al. 2006).

A typical soil profile for the Kompong Siem calcareous phase, based on Site 0031 from the Soil database, is shown below. A complete set of profiles is available from the CARDI Soil profile database of Cambodia held at CARDI.

Landform
Landform pattern: pediment
Slope class (US): gently sloping
Morphological type: lower slope
Relief/modal slope: low-gradient footslope
Landform element: 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

Horizon	Depth (cm)	Description
A1t	0-8	very dark grey (2.5YR 3/0 moist) clay; 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 carbonate (calcareous) nodules 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 carbonate (calcareous) nodules rounded white both hard and soft; no roots, non-cemented and non-compacted.

Soil chemical properties of profiles

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

Table 1: Organic carbon, electrical conductivity (EC) and pH of Kompong Siem soils. Sites 0031 and 0033 are in Banan district, while Sites 0010 and 0013 are in Ou Reang Ov district on basalt

Site	Cambodian Soil Group		Depth	Organic C	EC (1:5)	pH	pH
	Group	Phase	(cm)	(g/kg)	(dS/m)	$CaCl_2$	H_2O
0031	Kompong Siem	calcareous	0-8	13.0	0.11	7.2	8.2
			8-30	9.0	0.06	7.3	8.3
			30-45	6.0	0.09	7.6	8.6
			45+	1.9	0.06	7.7	9.0
0033	Kompong Siem	calcareous	0-3	18.1	0.30	7.6	8.5
			3-30	8.9	0.27	7.9	9.1
			30-60	3.4	0.52	8.3	9.6
			60-100	3.3	0.49	8.4	10.1
			100-110	2.0	0.76	8.6	9.9
0010	Kompong Siem	non gravelly	0-10	13.9	0.02	5.1	6.1
			10-25	9.1	0.02	5.4	6.5
			25-43	4.7	0.01	5.2	6.3
			43-78	2.1	0.02	5.4	6.4
			78-115	2.3	0.12	6.9	7.9
0013	Kompong Siem	non gravelly	0-10	10.3	0.02	5.6	6.5
			10-40	6.3	0.02	6.1	6.9
			40-75	4.3	0.02	5.9	7.1
			75-115	0.9	0.03	6.3	7.4

The surface horizon contains moderate to low organic carbon and low total N and mineral N. (Table 1). 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 0033 indicating significant levels of soluble salts. This same soil profile also contained high exchangeable Na levels (Table 2), and moderate alkalinity.

Exchangeable Ca was very high, and exchangeable Mg variable from high to very low in some layers of Site 0033. Exchangeable K was moderate in the surface soil layer, but dropped to low in sub-soils.

Table 2. Exchangeable cations, and effective cation exchange capacity (ECEC) in Kompong Siem soils. Sites 0031 and 0033 are in Banan district, while Sites 0010 and 0013 are in Ou Reang Ov district on basalt

Site	Cambodian Soil Group		Depth	Ca	Mg	Na	K	ECEC
	Group	Phase	(cm)	(cmol(+)/kg)				
0031	Kompong Siem	calcareous	0-8	41.1	4.13	0.03	0.35	45.7
			8-30	44.2	0.96	0.04	0.14	45.3
			30-45	39.0	0.39	0.03	0.13	39.5
			45+	16.1	0.08	0.02	0.05	16.3
0033	Kompong Siem	calcareous	0-3	45.2	6.86	2.43	0.63	55.1
			3-30	40.9	7.94	5.95	0.40	55.2
			30-60	24.2	10.2	11.6	0.13	46.1
			60-100	17.3	14.9	18.3	0.15	50.5
			100-110	12.4	12.8	15.1	0.20	40.5
0010	Kampong Siem	non gravelly	0-10	5.94	5.8	0.15	0.05	12.0
			10-25	6.44	6.07	0.12	0.03	12.7
			25-43	3.22	6.51	0.27	0.03	10.1
			43-78	2.23	6.51	0.55	0.04	9.4
			78-115	3.49	16.90	2.23	0.09	22.7
0013	Kampong Siem	non gravelly	0-10	7.04	6.0	0.10	0.19	13.3
			10-40	4.76	3.92	0.09	0.05	8.8
			40-75	4.92	6.87	0.30	0.04	12.1
			75-115	5.61	16.1	1.36	0.07	23.2

Kompong Siem soil profiles contained low bicarbonate extractable P (Table 3). Extractable S levels were variable with Site 0031 having low and Site 0033 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 0031, and DPTA Mn was lower than other profiles in Banan and elsewhere in Cambodia. Very low sub-soil B levels were obtained in Site 0033, otherwise moderate to low levels of B were extracted from the Kompong Siem profiles.

Kompong Siem non-gravelly phase, formed on basalt in Ou Reang Ov district, Kampong Cham province had distinctly different soil chemical properties, the most significant of which is the moderately acid pH compared to the alkaline to strongly alkaline pH of the calcareous phase (Tables 1-3).

Table 3. Extractable nutrient levels in soils of the Kompong Siem group. Sites 0031 and 0033 are in Banan district, while Sites 0010 and 0013 are in Ou Reang Ov district on basalt.

Site	Cambodian Soil Group		Depth	Nitrogen			Bicarb.	KCl-S	DTPA	DTPA	DTPA	DTPA	Hot $CaCl_2$
	Group	Phase		NO_3^-	NH_4^+	Total N	P		Cu	Zn	Mn	Fe	B
			(cm)	(mg/kg)		(g/kg)				(mg/kg)			
0031	K. Siem	calcareous	0-8	12.0	7.0	1.2	18.0	4.1	1.29	0.40	7.97	5.11	0.4
			8-30	4.0	4.0	0.9	6.0	1.7	1.60	0.30	5.24	4.54	0.4
			30-45	7.0	2.0	0.6	3.0	1.4	1.76	0.21	3.12	5.81	0.3
			45+	1.0	1.0	0.2	3.0	1.0	0.44	0.19	1.28	1.05	0.2
0033	K. Siem	calcareous	0-3	11.0	8.0	1.5	18.0	17.8	3.15	0.7	11.2	9.48	0.3
			3-30	5.0	7.0	0.8	9.0	12.4	2.73	1.78	11.3	15.3	0.2
			30-60	1.0	3.0	0.3	2.0	32.3	1.11	0.11	4.22	2.74	0.1
			60-100	1.0	3.0	0.2	1.0	42.1	1.35	0.21	3.18	2.24	0.1
			100-110	1.0	2.0	0.2	2.0	23.8	0.81	0.31	2.91	2.84	0.1
0010	K. Siem	non gravelly	0-10	6.0	7.0	0.2	14.0	1.7	3.6	1.02	52.3	58.3	0.3
			10-25	3.0	5.0	0.7	11.0	<1	2.79	0.72	37.7	40.3	0.3
			25-43	3.0	4.0	0.6	16.0	<1	1.58	0.48	8.08	31.4	0.3
			43-78	4.0	7.0	0.2	29.0	2.1	0.78	0.68	66.6	29.3	0.3
			78-115	2.0	5.0	0.2	4.0	1.2	0.72	0.79	6.74	10.9	0.2
0013	K. Siem	non gravelly	0-10	2.0	9.0	0.9	16.0	2.4	3.1	0.86	40.0	36.0	0.3
			10-40	<1.0	4.0	0.4	11.0	1.0	1.72	0.37	8.82	16.8	0.3
			40-75	1.0	4.0	0.4	8.0	1.0	0.97	0.29	6.64	15.8	0.3
			75-115	2.0	4.0	0.2	6.0	1.5	1.03	0.33	4.79	15.6	0.2

Crop productivity

Crop performance in on-farm trials conducted during the early wet and main wet seasons of 2004 and 2005 in Banan district 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 (Table 4). Mung bean and soybean exhibited acute Fe deficiency that caused severe leaf chlorosis (yellowing) often leading to plant death. Peanut also displayed severe chlorosis, especially of young leaves, but survived to produce moderate yields.

Table 4. Ranking of yield of crops in on-farm trials of 2004 and 2005 on various soils of Banan district plus the Kompong Siem soil on basalt in Ou Reang Ov district. Ranking was determined as follows: firstly yield for each crop on each soil was calculated; secondly, yields across soils were ranked from 1 (highest) to 10 (lowest) for each crop; finally, ranks were averaged across crop species to determine mean soil ranking

Soil group, phase	**Soil rank**	Maize	Mungbean	Soybean	Peanut
Kompong Siem	**2.5**	3.5	2.5	2.5	1.5
Kein Svay	**2.7**	2.0	3.5	2.5	2.5
Toul Samroung	**3.5**	4.0	4.0	3.5	2.5
Kompong Siem, calcareous	**4.7**	4.0	5.5	6.0	3.5

Soil Management

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, mung bean, soybean and sesame growing on this soil (Bell et al. 2006). DTPA extractable Fe levels were low on this soil. Some varieties of maize, such as cv. Composit, do not suffer Fe deficiency symptoms but their yield was still relatively low on this soil. 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.

Fertility Capability Class

The Fertility Capability Classification (Sanchez et al. 2003) of the soil is $CCr^{+}dhns^{-}v$, indicating a uniformly clayey soil to 50 cm depth with limestone gravels and seasonal dryness of the profile for > 60 days per year, free calcium carbonate, abundance of cracking clays, and incipient salinity and sodicity in the sub-soil.

Land capability

The Kompong Siem calcareous phase on hillslopes is not suited for paddy rice unless the fields are terraced and bunded to retain rainfall. Overall capability for other field crops is low. Crop yields on this soil are generally inferior to those on the basaltic phases of Kompong Siem, and on Kein Svay and Toul Samroung Soil groups in Banan district. Alkaline tolerant crops like maize are favoured over peanut, mung beans and sesame. However, for each of these species, efficient cultivars could be selected to achieve higher yield on this soil by overcoming Fe deficiency.

Kompong Siem Soil group occurs primarily on alluvial plains where it is predominantly used for wet season rice. However, in elevated sites and hill slope occurrences of this soil group, 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. Soils can be either too hard for tillage when dry or too sticky when wet, limiting the range of conditions under which good seedbed preparation can be achieved.

General discussion

The calcareous phase of the Kompong Siem Soil group is associated with limestone hills of western Cambodia. It is well developed in Battambang province. The most detailed observations of this soil have been in Banan district, Battambang, but its prevalence elsewhere has not been adequately described.

In Battambang, soils resembling the Kompong Siem Soil group occur on slopes of hills and therefore do not key out as Kompong Siem in the Cambodia Agronomic Soil Classification (White et al. 1997). They vary significantly in a number of properties for non-rice crops from those that occur on colluvium and alluvium from basalt in Kampong Cham Province, and hence have been made into a new phase of the Kompong Siem Soil group. This is the first new phase of a Soil group in the CASC since the original publication of White et al. (1997). A formal description of the phase in the style of White et al. (1997) is reported in Bell et al. (2006).

Modification of the Key in White et al. (1997) would be necessary to allow for the identification of the new calcareous phase when it occurs on flat and undulating land. For identification of the Kompong Siem calcareous phase on sloping land and on the sides of hills and mountains, either the Key developed by White et al. (1997) needs modification or an entirely new Key needs to be developed for upland soils. The latter may be preferable to avoid compromising the integrity and utility of the Key for Rice soils which is already well recognised and in common usage.

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