Soils Developed on Serpentinite in Panyipatan District, South Kalimantan : Characteristics and Their Suitability for Maize

Tanah-Tanah yang Berkembang dari Serpentinit di Kecamatan Panyipatan, Kalimantan Selatan : Karakteristik dan Kesesuaiannya untuk Jagung

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ABSTRACT

Four representative soil pedons formed from ultrabasic or serpentinite parent materials were studied in the field and laboratory in order to determine their soil characteristics and suitability for maize. Maize is one of the most important agricultural food crops in Indonesia. Up to now, the need of this crop for any other usages tends to increase. However, maize production could not meet the demand. Therefore, extensification and intensification of the agricultural area for the crop cultivation need to be conducted. The results indicated that all the studied soils have deep solum, yellowish red to red colour, blocky structure, and friable to firm consistency. Particle-size distribution was dominated by clay fraction (73-88%). The soil bulk density and available water was relatively low (0.84-1.12 mg m^{-3} and 9-15%, respectively), while the total porosity was high (58-68%). Except pedon PN-35, some soils have acid reaction, medium C organic in the upper horizons, and low base saturation (<40%). The soil CEC and exchangeable Al were low (<12 and <1.3 $cmol_c\ kg^{-1}$, respectively). P retention of all the soils is high (60-87%). The soils were classified as Typic Hapludox, Anionic Acrudox, and Kandiudalfic Eutrudox. Most soils were moderately suitable (S2) for maize cultivation with nutrient retention (acid reaction, low CEC-clay and base saturation) and water availability (high wet months) as the main limiting factors. To increase soil productivity, application of agricultural lime, P fertilizers (rock phosphate) and organic matter were highly recommmended.

Keywords : Soil characteristics and suitability, Serpentinite, Maize

ABSTRAK

Empat pedon pewakil tanah yang terbentuk dari bahan induk ultrabasa atau serpentinit diteliti di lapangan dan laboratorium untuk mengetahui karakteristik tanah dan kesesuaiannya untuk jagung. Jagung merupakan salah satu tanaman pangan penting di Indonesia. Hingga kini, kebutuhan akan tanaman ini untuk berbagai keperluan cenderung meningkat. Akan tetapi, produksi tanaman ini belum dapat memenuhi permintaan tersebut. Oleh karena itu, ekstensifikasi dan intensifikasi areal pertanian untuk budidaya tanaman jagung perlu dilakukan. Hasil penelitian menunjukkan bahwa semua tanah yang diteliti memiliki solum dalam, warna merah kekuningan sampai merah, struktur gumpal, dan konsistensi gembur sampai teguh. Distribusi ukuran partikel didominasi oleh fraksi liat (73-88%). Bobot isi tanah dan air tersedia relatif rendah (masing-masing 0,84-1,12 mg m^{-3} dan 9-15%), sedangkan porositas total tinggi (58-68%). Kecuali pedon PN-35, beberapa tanah memiliki reaksi tanah masam, C organik sedang pada horison atas, dan kejenuhan basa rendah (<40%). KTK tanah dan Al dapat dipertukarkan rendah (masing-masing <12 dan <1,3 $cmol_c\ kg^{-1}$). Retensi P dari semua tanah adalah tinggi (60-87%). Tanah-tanah diklasifikasikan sebagai Typic Hapludox, Anionic Acrudox, dan Kandiudalfic Eutrudox. Sebagian besar tanah adalah cukup sesuai untuk budidaya tanaman jagung dengan faktor pembatas retensi hara (reaksi tanah masam, KTK liat dan kejenuhan basa rendah) dan ketersediaan air (bulan basah tinggi). Untuk meningkatkan produktivitas tanah ini, pemakaian kapur pertanian, pemupukan P (fosfat alam) dan bahan organik adalah sangat disarankan.

Kata kunci : Karakteristik tanah dan kesesuaiannya, Serpentinit, Jagung

INTRODUCTION

Serpentinite is part of ultrabasic igneous rocks that naturally composed of low quartz mineral but high in the dark-coloured ferromagnesian minerals (hornblende, micas, pyroxene) (White, 1987; Munir, 1996; Brady and Weil, 2000). Soils developed from this rock generally had low sand content and high base saturation. The soil colour was usually red due to high in free iron. The soil reaction was generally high, while the exchangeable Al was low. Clay minerals found in this rock-derived soils were kaolinite and halloysite in good drainage area and montmorilonite in poor drainage area (Hardjowigeno, 1993).

In Indonesia, studies on soils developed on ultrabasic or serpentinite rocks are still lacking so that the information of the soils related to their properties and management is limited. Some studies on the soil development, chemical properties, and mineralogical composition were carried out by Buurman and Soepraptohardjo (1980) and Anda *et al.* (2000). Buurman and Soepraptohardjo (1980)

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and Asmin *et al*. (1998) reported Oxisols developed on ultramafics rocks in South East Sulawesi and South Kalimantan. Oxisols in South East Sulawesi had high clay content, very low exchangeable bases, low CEC and Al content. Similar results were reported from Oxisols formed from serpentinite in South Kalimantan (Buurman and Soepraptohardjo, 1980 and Anda *et al*., 2000). The mineralogical composition of sand fraction in Oxisols from South East Sulawesi was dominated by opaque, while their clay fraction was mainly composed of kaolinite with minor gibbsite and quartz. Similar results were reported for Oxisols developed from serpentinite in South Kalimantan (Anda *et al*., 2000). Hidayat (2002) also reported that soil derived from ultrabasic rock in Pelaihari, South Kalimantan was dominated by iron oxide mineral such as goethite and hematite. While another research done by Prasetyo and Suharta (2004) of soil from ultrabasic rock from South Kalimantan reported that soil was dominated by kaolinite with few of goethite, hematite, and ilminite (Oxic Dystrudepts) and dominated by goethite, hematite, and ilminite without kaolinite (Anionic Acrudox).

Maize is one of important agricultural food crops in Indonesia. Badan Penelitian dan Pengembangan Pertanian (2005) reported that maize production at the period of 1993-2003 increases two times compared with the last period. However, it could not meet national need due to the high demand both for food and woof. To increase the maize production, extensification and intensification programmes of the agricultural food crops need to be conducted. To support the programmes, studies on the characteristics of soils and their suitability are necessary to obtain the economic areas for maize cultivation.

The objective of this study is to investigate the soil physical and chemical properties, to classify the soils according to Soil Taxonomy and Fertility Capability Classification (Sanchez and Buol, 1985), and to evaluate the soil suitability for maize cultivation. This information can be used to manage the soils.

MATERIALS AND METHODS

Description of the study area

The area of study was located in Sukaramah and Batumulia Villages, Panyipatan District, Tanah Laut Regency, South Kalimantan Province. Four representative soil pedons developed on ultrabasic or serpentinite rocks were used for this study. Location and environmental conditions of the pedons were presented in Table 1. Based on the

Table 1. Site characteristics of the studied soils

Tabel 1. Karakteristik lokasi dari tanah-tanah yang diteliti

No.	Pedon	Location	Elevation	Slope	Landuse
			m asl	%	
1.	PN-72	Sukaramah 114°46′15″ EL 3°56′39″ SL	30	1	Upland agriculture (maize)
2.	HI-68	Sukaramah 114°46′54″ EL 3°56′55″ SL	23	4	Upland agriculture (maize)
3.	PN-35	Sukaramah 114°46′43″ EL 3°57′03″ SL	23	6	Upland agriculture (maize)
4.	SO-21	Batumulia 114°44′43″ EL 3°57′46″ SL	20	1	Upland agriculture (maize)

Geological Map of Banjarmasin sheet, scale 1:250,000 (Sikumbang and Heryanto, 1994), the study area is located in the Pudak formation. This formation is igneous intrusive rocks of ultramafic composition of the Cretaceous period. The relief or topography of the studied area is nearly level (slope 0-2%) to gently sloping (slope 3-8%), with altitude between 20-30 m above sea level (asl). The present landuse is dominated by upland agriculture.

The site studied has a monsoon climate, with mean annual rainfall of 2,584 mm, and mean daily air temperature of 27.1 °C. Wet season occurs from November to April, and dry season from May to October. August and September are normally the driest months. The site belongs to B-rainfall type, and a C2-agroclimatic zone with 5-6 wet months and 2-3 dry months.

Field investigation

Field investigation was conducted to identify and characterize soil properties. Soil profiles were described using the standard guidelines for Soil Profile Description (FAO, 1990; Soil Survey Division Staff, 1993). The soil studied were classified at family level according to Keys to Soil Taxonomy (Soil Survey Staff, 2006), and Fertility Capability Classification (FCC) was carried out according to the method of Sanchez and Buol (1985). The FCC is a technical classification for grouping soils according to the kinds of constraints that impose from agronomic management.

Laboratory analyses

Soil was sampled from all horizons of each pedon. The procedure of analyses followed the standard methods used in the Soil Research Institute laboratories, as described in "Petunjuk Teknis Analisis Kimia Tanah, Tanaman, Air, dan Pupuk" (Sulaeman *et al.*, 2005), and some analyses also followed the procedures outlined in Soil Survey Laboratory Methods Manual (Soil Survey Laboratory Staff, 2004).

The type of analysis were selected as required to support classification of soils, elaboration of chemical properties and fertility, and of soil physical aspects. Different types of soil analyses were carried out, and consisted of : particle-size analysis, pH (H_2O and KCl), organic carbon, nitrogen, potential P_2O_5 and K_2O (25% HCl extraction), available P_2O_5 (Bray-1 extraction), phosphate retention, exchangeable cations and cation exchange capacity (1 N NH_4OAc, pH 7.0), and exchangeable Al (1 N KCl extraction). Physical soil analyses from undisturbed ring samples include : determination of water content, bulk density, total pore space, and water contents at 33 kPa and 1,500 kPa.

Soil analyses and field data were combined to carry out land evaluation and to determine suitability classes of soils for maize commodity. For this suitability evaluation computer software namely Automated Land Evaluation System (ALES) was used. Criteria for land evaluation were carried out according to Djaenudin *et al*. (2003).

RESULTS AND DISCUSSION

Morphological characteristics

All the soils show deep solum (Table 2). The soils colour is generally brown (7.5YR 4/4) to dark yellowish brown (10YR 4/4) in the upper horizons and strong brown (7.5YR 5/6), yellowish red (5YR 5/6) to red (2.5YR 4/8-5/8) in the lower horizons. The dark colour of the upper layers may indicate the presence of significant amounts of organic matter, while the reddish colour of the lower layers is due to the presence of iron oxide minerals.

Field investigation show that all the studied soils were dominated by clay fraction and classified as clay textural class. The domination of the clay content was caused by relatively high content of "weatherable minerals" and also high degree of weathering. On the other hand, the high clay content is related to the parent materials dominated by basic primary minerals which are easy to weathered.

Table 2. Morphological characteristics of the studied soils

Tabel 2. Karakteristik morfologi dari tanah-tanah yang diteliti

No.	Horizon	Depth	Colour	Texture	Structure	Consistency	Horizon boundary
		cm	moist				
1.	Pedon PN-72						
	Ap	0-18	7.5YR 4/4	C	2, m, sb	fm, s, p	c, sm
	AB	18-39	5YR 4/6	C	2, m, sb	fm, s, p	d, sm
	Bo1	39-66	5YR 5/6	C	2, m, sb	fm, vs, p	d, sm
	Bo2	66-89	2.5YR 4/8	C	2, m, sb	fm, vs, p	d, sm
	Bo3	89-116	2.5YR 5/6	C	2, m, sb	fm, vs, p	c, sm
	Bo4	116-155	2.5YR 5/8	C	2, m, sb	fm, vs, p	
2.	Pedon HI-68						
	Ap	0-16	7.5YR 4/4	C	1, f, ab	fm, ss, sp	c, sm
	Bo1	16-37	7.5YR 5/6	C	2, f, ab	fm, s, p	d, sm
	Bo2	37-70	7.5YR 5/8	C	2, f, ab	fm, s, p	d, sm
	Bo3	70-112	7.5YR 5/8	C	2, f, ab	fm, s, p	d, sm
	Bo4	112-142	7.5YR 5/8	C	2, f, ab	fm, s, p	d, sm
	Bo5	142-180	7.5YR 5/8	C	2, f, ab	fm, s, p	
3.	Pedon PN-35						
	Ap	0-23	10YR 4/4	C	2, m, sb	fr, s, p	c, sm
	Bo1	23-40	5YR 5/6	C	3, m, sb	fr, s, p	c, sm
	Bo2	40-59	5YR 5/6	C	3, m, sb	fm, vs, vp	c, sm
	Bo3	59-85	5YR 5/6	C	3, m, sb	fm, vs, vp	d, sm
	Bo4	85-117	5YR 5/6	C	2, m, sb	fr, vs, vp	d, sm
	Bo5	117-160	2.5YR 4/6	C	2, m, sb	fr, vs, vp	
4.	Pedon SO-21						
	Ap	0-16	7.5YR 4/4	C	2, m, sb	fm, s, sp	a, sm
	AB	16-36	5YR 4/6	C	2, m, sb	fr, s, p	g, sm
	Bo1	36-67	2.5YR 4/8	C	2, m, sb	fr, s, p	g, sm
	Bo2	67-99	2.5YR 4/8	C	3, m, sb	fr, s, p	g, sm
	Bo3	99-128	2.5YR 5/6	C	2, m, sb	fr, s, p	g, sm
	Bo4	128-160	2.5YR 5/8	C	2, m, sb	fr, s, p	g, sm

Remarks : C = clay; 1 = weak, 2 = moderate, 3 = strong; f = fine, m = medium; ab = angular blocky, sb = subangular blocky; fr = friable, fm = firm; ss = slightly sticky, s = sticky, vs = very sticky; sp = slightly plastic, p = plastic, vp = very plastic; a = abrupt, c = clear, g = gradual, d = diffuse; s = smooth

The soil structure is angular to subangular blocky with fine to medium size and moderate to strong development. The soil consistency is generally friable to firm in moist condition, sticky and plastic in wet condition. The soil structure and consistency may related the soil stucture.

The upper horizon boundary is clear to abrupt smooth related to the presence of significant amounts of organic matter, while the lower horizon boundary is gradual to diffuse smooth related to the homogenity of colour feature in soil solum.

In the studied area, despite relief or topography, parent material seems to play a significant role in soil formation. Other important factors that govern soil formation, is probably climate and time of soil formation. High annual rainfall, around 2,000-2,500 mm with isohyper-thermic soil temperature regime, had caused the formation of soils with advanced stage of weathering. Intensive chemical weathering has depleted primary minerals and bases as source of plant nutrient. Time of soil formation seems also had important effect. Deep to very deep soils, fine textured, low activity clay and rich in iron oxide are signs that soils had passes through a very long time in soil formation.

Physical properties

Results of the soil physical properties are presented in Table 3. Particle-size distribution of all the soils are dominated by clay fraction (more than 70%), while the sand and silt fractions are detected in less amounts. The high clay contents in all the soils may indicated that the soils have high degree of weathering. Furthermore, the high clay content is the results weathering of basic minerals from ultrabasic rocks. This high clay condition may cause the high soil plasticity so that they are slightly difficult to be tillaged.

Although the soils have high clay content, the bulk density of all the topsoils tend to be low (less than 1.12 mg m^{-3}). The low bulk density may cause the high total porosity (more than 58%). The low bulk density and the high total porosity are good condition for plant root development. The low bulk density and high total pore space may be affected by soil texture and the presence of moderate amount of organic matter in the topsoil. This is true because the solid particles of the fine-textured soils tend to be organized in porous granules. In theses aggregated soils, pores exist both between and within the granules. This condition assures high total pore space and a low bulk density (Brady and Weil, 2000).

Plant-available water is the amount of water held at potensials between those of field capacity (33 kPa) and wilting point (1,500 kPa). All of the studied soils have high moisture content both at

Table 3. Physical properties of the studied soils

Tabel 3. Sifat fisik dari tanah-tanah yang diteliti

No.	Horizon	Depth	Particle-size distribution			Bulk density	Total porosity	Moisture content		Available water
			sand	silt	clay			33 kPa	1,500 kPa	
		cm	.... %	....		mg m^{-3}	.... % volume	....		
1.	Pedon PN-72									
	Ap	0-18	3	13	84	1.12	57.7	44.6	30.0	14.6
	AB	18-39	4	12	84					
	Bo1	39-66	3	11	86					
	Bo2	66-89	3	13	84					
	Bo3	89-116	3	16	81					
	Bo4	116-155	2	24	74					
2.	Pedon HI-68									
	Ap	0-16	4	12	84	0.84	68.3	34.6	24.2	10.4
	Bo1	16-37	3	18	79					
	Bo2	37-70	3	10	87					
	Bo3	70-112	3	9	88					
	Bo4	112-142	2	23	75					
	Bo5	142-180	2	14	84					
3.	Pedon PN-35									
	Ap	0-23	7	24	69	1.01	61.9	39.3	29.5	9.8
	Bo1	23-40	6	15	79					
	Bo2	40-59	6	15	79					
	Bo3	59-85	7	17	76					
	Bo4	85-117	9	17	74					
	Bo5	117-160	7	40	53					
4.	Pedon SO-21									
	Ap	0-16	10	17	73	0.98	63.0	30.1	20.8	9.3
	AB	16-36	7	19	74					
	Bo1	36-67	6	16	78					
	Bo2	67-99	5	15	80					
	Bo3	99-128	3	18	79					
	Bo4	128-160	3	29	68					

field capacity and wilting point. However, the plant-available water of all the soils tend to be low. The lower value of the available water is due to the higher clay content. In this finer-texured soils, the moisture content at wilting point tend to increase, while the moisture content at field capacity tend to be highly constant. The high moisture content at wilting point in the studied soils is because the soils have very large specific surface area that give them a tremendous capacity to adsorb water (Brady and Weil, 2000).

Chemical properties

Chemical properties of the studied soils are presented in Table 4. All of the soils have medium organic carbon in A horizon and low to very low in B horizon. The medium content of topsoil's organic carbon is due to application of chicken manure each planting season, which release considerable amounts of organic carbon. This management practice is one the key successes for farmers to increase crop production, especially maize. Hence, the building up of soil organic carbon should be given much more attention in order to improve and maintain soil productivuty. Application of animal manure (e.g. chicken or cattle manure), and or incorporation of green manure into soil can be practiced.

Except pedon PN-35, most studied soils have acid to very acid soil reaction. Acid to very acid soil reaction of the studied soils may indicate that there is a limited amount of exchangeable cations (Ca, Mg, K, and Na) in the exchange complexes. The sum of exchangeable cations is mostly low (less than 5 $cmol_c$ kg^{-1}) indicating that only a few amounts of nutrients retained to support crop growth. Materials such as agricultural lime containing calcium carbonate ($CaCO_3$), dolomite, and basic slag can be used to increase the amounts of exchangeable cations in soils, and thus increasing soil reaction.

Exchangeable Al and Al saturation of all the soils is low (less than 1.5 $cmol_c$ kg^{-1} and 0 to 50%, respectively). The low value of exchangeable Al and Al saturation is due to the soils derived from ultramafic rocks. These types of rocks contain mainly ferromagnesian minerals that upon weathering only release a small amount of Al ion into the soil. On the contrary, Fe and Mg ions may be released in a higher amounts. Thus, in conclusion, Al toxicity seems to be not a major problem for food crops (maize) production in the studied area.

Cation exchange capacity (CEC) of soil could provide a figure of soil capability to retain and release cation nutrients from the exchange complex. All of the soils have low CEC, ranging from 5 to 12 $cmol_c$ kg^{-1}. This indicates that soils have a low capacity to retain cations. Organic matter in term of organic carbon content tend to influence the CEC of soil (Figure 1).

The simple regression also indicated that in the soil investigated, organic carbon contributed 78% to their CEC. The influence of organic carbon in this case was higher than Oxisols from low activity clay in South Kalimantan that contributed only 54% (Prasetyo and Suharta, 2004). Generally the contribution of organic carbon to the CEC of some Indonesian Oxisols is in the range between 84 to 89% (Prasetyo *et al.*, 1999). Therefore, management of CEC should received more attention in order to be able to reduce cation leaching that might occur during rainy season. Attemps to apply materials that increase soil CEC, such as farm manure (chicken or cattle), green manure, P fertilizer, silicate, basic slag and lime applications could be made to increase soil productivity.

Potential phosphate (P) content of the studied soils is expressed as mg P_2O_5 $100g^{-1}$ soil from 25% HCL extraction. Except pedon SO-21, most soils have medium (20-37 mg $100g^{-1}$ soil) to high (48-66 mg $100g^{-1}$ soil) content of potential P.

Table 4. Chemical properties of the studied soils

Tabel 4. Sifat kimia dari tanah-tanah yang diteliti

No.	Horizon	Depth	pH (1:5)		Org. C	N	C/N	Exchangeable bases				CEC-soil	ECEC	Exch. Al	CEC-clay	ECEC-clay	Base sat.	25% HCl		Bray-1 P_2O_5	P ret.	Al sat.
			H_2O	KCl				Ca	Mg	K	Na							P_2O_5	K_2O			
		cm			...... %			.... cmol$_c$ kg^{-1} soil						....	cmol$_c$ kg^{-1} clay		%	mg 100g^{-1} soil		ppm	... % ...	
1.	Pedon PN-72																					
	Ap	0-18	4.8	4.6	2.58	0.20	13	1.56	0.70	0.04	0.09	11.53	2.84	0.45	13.7	3.4	21	66	6	7.5		16
	AB	18-39	5.2	5.5	1.49	0.13	11	2.52	0.42	0.00	0.05	7.52	3.07	0.08	8.6	3.7	42	48	4	4.6		3
	Bo1	39-66	5.5	5.8	0.92	0.09	10	2.38	0.29	0.00	0.05	6.51	2.78	0.06	7.6	3.2	42	20	3	3.9		2
	Bo2	66-89	4.9	5.2	0.77	0.07	11	1.72	0.31	0.00	0.07	6.51	2.16	0.06	7.8	2.6	32	51	3			3
	Bo3	89-116	4.8	5.0	0.68	0.07	10	1.11	0.23	0.00	0.13	7.03	1.47	0.00	8.7	1.8	21	53	3			0
	Bo4	116-155	4.8	4.7	0.43	0.05	8	0.76	0.14	0.00	0.05	7.03	1.17	0.22	9.5	1.6	14	59	3			19
2.	Pedon HI-68																					
	Ap	0-16	4.1	4.4	2.80	0.24	12	0.92	0.25	0.07	0.09	10.21	2.65	1.32	12.2	3.1	13	37	8	1.1		50
	Bo1	16-37	4.4	4.5	1.64	0.12	14	0.70	0.26	0.02	0.07	8.01	1.63	0.58	10.1	2.1	13	22	5	0.8		36
	Bo2	37-70	4.4	4.7	0.92	0.08	12	0.74	0.30	0.02	0.03	6.56	1.17	0.08	7.5	1.4	17	24	5	0.8		7
	Bo3	70-112	4.4	4.9	0.70	0.07	10	0.59	0.25	0.02	0.08	6.00	0.94	0.00	6.8	1.1	16					0
	Bo4	112-142	4.5	4.8	0.49	0.04	12	0.43	0.14	0.00	0.08	5.80	0.65	0.00	7.7	0.9	11					0
	Bo5	142-180	4.6	4.7	0.40	0.04	10	0.52	0.10	0.02	0.06	6.16	0.76	0.06	7.3	0.9	11					8
3.	Pedon PN-35																					
	Ap	0-23	4.9	5.2	2.45	0.20	12	4.38	0.29	0.05	0.02	10.30	4.74	0.00	14.9	6.9	46	36	7	5.3	72	0
	Bo1	23-40	5.8	6.6	1.25	0.13	10	2.79	0.95	0.00	0.05	7.10	3.79	0.00	9.0	4.8	53	17	6	3.3	85	0
	Bo2	40-59	6.0	6.9	0.82	0.09	9	2.79	0.99	0.00	0.03	6.40	3.81	0.00	8.1	4.8	59	20	5	3.4	87	0
	Bo3	59-85	5.6	6.8	0.52	0.06	9	2.55	0.71	0.00	0.07	5.50	3.33	0.00	7.2	4.4	61	25	6	3.7	87	0
	Bo4	85-117	5.6	6.8	0.54	0.06	9	2.72	0.73	0.00	0.07	5.60	3.52	0.00	7.5	4.8	63				87	0
	Bo5	117-160	5.1	6.5	0.41	0.05	8	2.87	0.41	0.00	0.06	6.70	3.34	0.00	12.6	6.3	50				83	0
4.	Pedon SO-21																					
	Ap	0-16	4.3	4.2	2.36	0.17	14	0.50	0.11	0.07	0.05	8.80	1.51	0.78	12.1	2.1	8	12	9	4.6	59	52
	AB	16-36	4.6	4.5	1.75	0.14	13	0.43	0.11	0.02	0.08	6.80	0.94	0.30	9.2	1.3	9	6	6	0.8	65	32
	Bo1	36-67	4.5	4.7	1.18	0.09	13	0.46	0.13	0.02	0.14	5.60	0.82	0.07	7.2	1.1	14	7	6	0.8	66	8
	Bo2	67-99	4.6	5.0	0.55	0.06	9	0.62	0.14	0.00	0.05	4.60	0.81	0.00	5.8	1.0	18				76	0
	Bo3	99-128	4.7	5.0	0.55	0.05	11	0.62	0.24	0.00	0.07	5.00	0.93	0.00	6.3	1.2	19				78	0
	Bo4	128-160	4.8	5.0	0.41	0.04	10	0.87	0.32	0.00	0.07	5.30	1.26	0.00	7.8	1.9	24				74	0

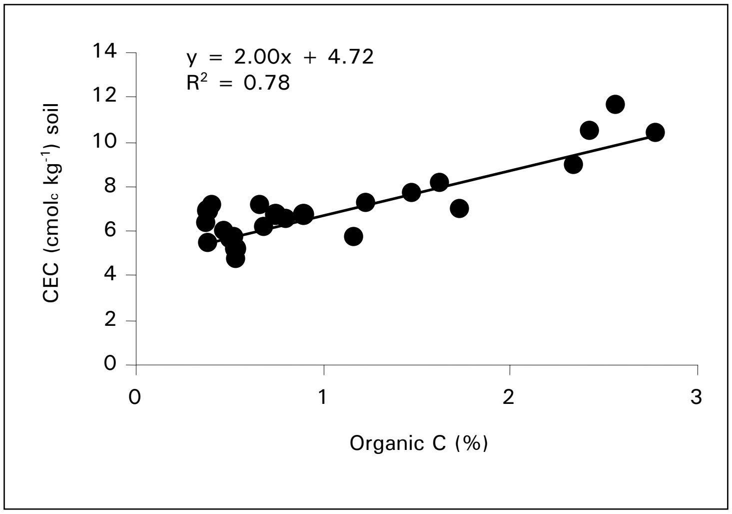

Figure 1. Relationship between soil CEC and organic-C of soils derived from serpentinite in South Kalimantan

Gambar 1. Hubungan antara KTK dan C-organik dari tanah-tanah yang berasal dari serpentinit di Kalimantan Selatan

Reasons for the occurrence of this medium to high potential P content, is probably due to annual application of chicken manure and P fertilizer commonly practiced by local farmer during the period of maize cultivation.

Available P content is expressed as ppm P_2O_5 extracted with Bray-1 solution. Although the status of potential P in the studied soils is mostly medium to high but the available P is very low (less than 7.5 ppm). This probably indicates that some P fixation has occurred. Limited data of phosphate retention show that the studied soils have high to very high P retention. In these soils with reddish color because of high Fe oxides and hydroxides, P fixation by Fe seems to play more important role, than that by Al. The very low available P suggests that P deficiency is the major problem for crop production. Therefore, application of P fertilizer is strongly required to support plant nutrient. Because soils have high P fixation, a high rate of P application is needed to alleviate P deficiency.

Potential potassium (K) content is expressed in mg K_2O $100g^{-1}$ soil extracted with 25% HCl solution. All the soils have very low potential K content (less than 10 mg $100g^{-1}$ soil). The low K status suggests that leaching of K ion has taken place intensively, and soil has no capacity to replenish it. This probably occurs because the soils have achieved advanced stage of weathering, therefore no more potassium bearing minerals present in the soil. Since K is one of the macronutrients needed by most crops to perform an optimal production, consequently potassium fertilizer must be applied as a part of fertilizer management to satisfy K need of food crops.

Soil classification

All soils were classified using Soil Taxonomy (Soil Survey Staff, 2006) up to soil family level (Table 5). Based on field observation and soil analysis data, all the studied soils are classified as Oxisols. This is because the soils have low cation exchange capacity (less than 16 $cmol_c$ kg^{-1} clay) and high clay content (more than 40%) without clay illuviation. At Great Group level, pedon PN-72 and HI-68 are classified as Hapludox, while pedon PN-35 and SO-21 are classified as Eutrudox (base saturation > 35%) and Acrudox (very low effective CEC), respectively. All of the pedons tend to have a mineralogical class of kaolinitic as they have low

CEC-clay (less than 15 $cmol_c$ kg^{-1} clay) (Uehara and Gillman, 1981; Tan, 1993). At family level pedon PN-72 and HI-68 are classified as very-fine, kaolinitic, isohyperthermic Typic Hapludox, while pedon PN-35 and SO-21 are classified as very-fine, kaolinitic, isohyperthermic Kandiudalfic Eutrudox and Anionic Acrudox, respectively.

The results of evaluation for the main fertility related to the soil constrain for agronomic management are presented in Table 6. The table shows that all mineral soils were classified as C-soils that is clay soil with low infiltration and high water holding capacity. The soils are generally easy to puddle but difficult to restructure after puddling. The symbol k is indicate that almost all rice soils have low exchangeable K (<0.20 $cmol_c$ kg^{-1}). The low value of exchangeable K, quantitatively defines soil with low inherent potentially comparable to those soil having less than 10% weatherable mineral in their sand and silt fractions within 50 cm of the soil surface (Kawaguchi and Kyuma, 1977).

Land evaluation

Land suitability evaluation is meant to know or to predict whether a land/soil is suitable or not suitable for growing and production of a particular crop. It is expected that land suitability could serve as a guideline to select and cultivate a certain crop or particular commodity that has a sustained yield, without damaging land/soil and or minimizing of soil degradation.

Maize is the most important food crop in the studied area. The result of land suitability for maize for soils developed on serpentinite or ultrabasic rock is presented in Table 7. In many field maize is planted in twice a year (November-January, and February-April), and cultivated in monoculture system in upland area. Maize is planted in the beginning of rainy season and soil ploughing is conducted at the end of dry season. Chicken manure, lime and phosphate fertilizer are common soil amendment. Maize grain yield is commonly not consumed as a staple food, but mostly is sold and forms the main income for farmer.

The result of land evaluation show that most soils (pedon PN-72, HI-68, and SO-21) developed on serpentinite are moderately suitable (S2) for production of maize. The soils exhibit nutrient retention (low clay-CEC, acid soil reaction, low base saturation and low organic carbon) and water availability (high wet months) as the main contraints. This land suitability class of moderately

Table 5. Classification of the studied soils at amily level

Tabel 5. Klasifikasi dari tanah-tanah yang diteliti pada tingkat famili

Pedon	Soil order	Great group	Subgroup	Family
PN-72	Oxisols	Hapludox	Typic Hapludox	Very-fine, kaolinitic, isohyper-thermic, Typic Hapludox
HI-68	Oxisols	Hapludox	Typic Hapludox	Very-fine, kaolinitic, isohyper-thermic, Typic Hapludox
PN-35	Oxisols	Eutrudox	Kandiudalfic Eutrudox	Very-fine, kaolinitic, isohyper-thermic, Kandiudalfic Eutrudox
SO-21	Oxisols	Acrudox	Anionic Acrudox	Very-fine, kaolinitic, isohyper-thermic, Anionic Acrudox

Sumber : Soil Survey Staff (2006)

Table 6. Fertility capability classification (Sanchez and Buol, 1985) of representative soil in South Kalimantan

Tabel 6. Klasifikasi kemampuan kesuburan (Sanchez dan Buol, 1985) dari tanah pewakil di Kalimantan Selatan

Soil	FCC class	Main constrain
Typic Hapludox	Ck	Low in infiltration rate, high water holding capacity, low exchangeable K, low inherent fertility
Kandiudalfic Eutrudox	Ck	Low in infiltration rate, high water holding capacity, low exchangeable K
Anionic Acrudox	Ck	Low in infiltration rate, high water holding capacity, low exchangeable K

Table 7. Land suitability for maize for studied soils

Tabel 7. Kesesuaian lahan untuk jagung dari tanah-tanah yang diteliti

No.	Pedon	Land suitability class	Limiting factor
1.	PN-72	S2 (moderately suitable)	Nutrient retention/water availability
2.	HI-68	S2 (moderately suitable)	Nutrient retention/water availability
3.	PN-35	S3 (marginally suitable)	Nutrient retention
4.	SO-21	S2 (moderately suitable)	Nutrient retention/water availability

suitable (S2) means that the land/soils have moderate limitation to use. Pedon PN-35 is considered marginally suitable (S3) with nutrient retention (low clay-CEC, acid soil reaction, high P retention and low organic carbon) as the common contraints. This land suitability class of marginally suitable (S3) means that the land/soil has severe limitation to use.

CONCLUSION

1. Soils developed on serpentinite in Panyipatan District, South Kalimantan, have deep solum, yellowish red to red colour, blocky structure, and friable to firm consistency. The soils were physically characterized by high content of clay fraction, low bulk density and available water, but high total porosity. Most soils chemically have acid reaction, medium C organic in the upper horizons, and low base saturation, low CEC and exchangeable Al, and high P retention.
2. All the studied soils were classified as Oxisols Order. At family level, the soils were classified as Typic Hapludox, Anionic Acrudox, and Kandiudalfic Eutrudox with particle size class of very-fine, mineralogical class of kaolinitic, and temperature regime of isohyperthermic.
3. Most studied soils were moderately suitable (S2) for maize cultivation with nutrient retention (acid reaction, very low clay CEC, and low base saturation) and water availability (high wet months) as the main limiting factors.

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