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SOIL PROPERTIES OF THE ALLUVIAL PLAIN AND ITS POTENTIAL USE FOR AGRICULTURE IN DONGGALA REGION, CENTRAL SULAWESI

Hikmatullah[a] and M. Al-Jabri[b]

[a]*Indonesian Center for Agricultural Land Resources Research and Development, Jalan Ir. H. Juanda No. 98, Bogor 16123, Indonesia*
[b]*Indonesian Soil Research Institute, Jalan Ir. H. Juanda No. 98, Bogor 16123, Indonesia*

ABSTRACT

Agricultural lands of Donggala region are extensively distributed in alluvial plain. However, information on soil properties and fertility constraints has not been known in detail. An investigation of soil resources was conducted in September 2003 and December 2004 to characterize surface soil properties of alluvial plain and to evaluate soil fertility constraints. For this study, 55 representative soil profiles consisting of 187 soil samples were selected for physical, chemical, and mineralogical analyses. The soil profiles were classified as soil groups of Ustifluvents, Haplustepts, Eutrudepts, and Endoaquepts. All the soil physical and chemical data were calculated as weighted average based on top 30 cm soil layer analyses. The results showed that soil texture ranged from sandy loam to loam. In ustic moisture regime, the average pH was neutral (7.0-7.2), but in udic moisture regime it was slightly acid (5.5-6.2). In all soil groups, the organic carbon content was very low to low (0.58-1.44%), P retention was very low (3-18%), and soil cation exchange capacity (CEC) was very low to low (9-14 cmol(+) kg^{-1}). In contrast, all the soil groups showed very high content of potential phosphate (81-118 mg P_2O_5 100 g^{-1}) and potassium (338-475 mg K_2O 100 g^{-1}), but the available phosphate and potassium were 16-47 mg kg^{-1} P and 0.18-0.35 cmol(+) kg^{-1}, respectively, which were considered to be low to medium range. The very high P_2O_5 and K_2O were probably derived from weathered mica-schist and granite rocks, but low exchangeable K was probably due to K fixation. The sand mineral fraction was composed of relatively high (> 20%) weatherable minerals of acid parent materials, such as orthoclase and sanidine, while the clay mineral was composed of smectite and illite. The low soil-CEC, low organic matter, and exchangeable K contents were the main soil fertility constraints. Therefore, soil management should be directed to organic matter application to increase soil carbon content, CEC, and nutrient availability. Fertilizer recommendation for wetland rice and several upland crops is suggested based on the soil properties.

[*Keywords*: Alluvial soils, soil chemico-physical properties, cation exchange capacity, organic matter, soil fertility]

INTRODUCTION

Soils of alluvial plain are formed from various materials deposited at flat to nearly flat slope by fluvial and/or colluvial processes, through water flow and gravity force. The processes lead to variation in physical, chemical, and mineralogical properties, as well as nutrient accumulation (Brubaker 1993). Therefore, the productivity of alluvial soils is often higher than the soils of uplands. Variability of soil properties could be studied spatially and evaluated using statistical analysis for better management purposes (Ameyan 1986; Tchienkoua and Zech 2004).

The Donggala region in Central Sulawesi is one of the priority areas planned to improve poor farmer income by increasing agricultural land productivity. However, the availability of soil resource data of the region is still limited. Therefore, soil resource survey should be conducted to provide reliable and updated soil property data. Previous soil investigation surrounding Palu valley in Central Sulawesi was conducted by Suhardjo (1988) and more recently by Hikmatullah *et al*. (2004; 2005) at scale of 1:50,000 covering 400,000 ha of 1.047 million ha of Donggala regency. About 57,000 ha of the surveyed area are known as alluvial plain which are being used mainly for agriculture, consisting of wetland rice, upland food crops (maize, groundnut, onion, and sweet potatoes) and perennial crops, mainly cocoa and coconut.

Distribution of alluvial plain in this region covers a portion of Palu valley, the western and northern parts of the area. The Palu valley is known as graben, a valley block along fault area, bordered both sides by active fault lines, as indicated by the presence of some spring water (Sukamto 1975). The alluvial plain along the west and north coastal areas consists of alluvial fans, alluvial and colluvial landforms, developed from weathered metamorphic rocks (schist, gneiss) and intrusive rocks (granite, granodiorite) from the hilly and mountain regions (Sukamto 1973).

The Palu valley belongs to relatively dry climate with annual rainfall ranging from 720 to 1,428 mm and classified as E rainfall type, suggesting ustic soil moisture regime. However, the area has some spring water making part of subsoils become moist. The western and northern coast areas have relatively humid climate with annual rainfall ranging from 1,400 to 2,095 mm, and classified as B rainfall type (Schmidt and Fergusson 1951) and udic soil moisture regime.

The objectives of the study were to characterize physical and chemical soil properties of alluvial plain and evaluate soil fertility and management constraints for agricultural development in part of Donggala region, Central Sulawesi.

MATERIALS AND METHODS

The soil investigation was conducted twice, firstly in September 2003 and secondly in December 2004, each for 20 days. The alluvial plain distribution was delineated based on satellite image analyses and followed by soil survey. As many as 187 alluvial soils from 55 soil profiles collected during the soil survey of Donggala region were selected for physical, chemical, and mineralogical analyses. All the soil physical and chemical data were calculated as weighted average based on top 30 cm soil layer. The profiles represented the dominant soil groups, consisting of Ustifluvents, Haplustepts, Eutrudepts, and Endoaque pts according to Soil Taxonomy (Soil Survey Staff 2003). The distribution of the alluvial plain and soil sampling is shown in Figure 1.

Laboratory analyses of soil texture of sand, silt, and clay contents were determined by the Pipette method. The pH values of the soil suspensions were determined in H_2O and 1 M KCl (soil solution ratio 1:2.5) using a glass electrode. The total organic carbon content was determined by wet oxidation of Walkley and Black, and total nitrogen by the Kjeldahl method. The potential P_2O_5 and K_2O contents were extracted by HCl 25%, and available P was by Olsen method. Phosphate retention was determined according to Blakemore *et al*. (1981). The exchangeable bases (Ca, Mg, K, and Na) and cation exchange capacity (CEC) were determined by 1.0 M NH4-OAc at pH 7.0 extractions, and individual cation concentration was by using the atomic absorption spectrophotometer. The procedure and interpretation of soil analyses were described in Soil Survey Laboratory Staff (1992) and Sulaeman *et al*. (2005).

Soil fertility evaluation was based on the soil analysis data by grouping into weighted average the upper 30 cm layer of each soil group. The average of soil parameter values, standard deviation, and coefficient of variation were calculated for evaluating soil variation. A regression equation was calculated to evaluate the correlation between soil-CEC against clay and organic carbon content.

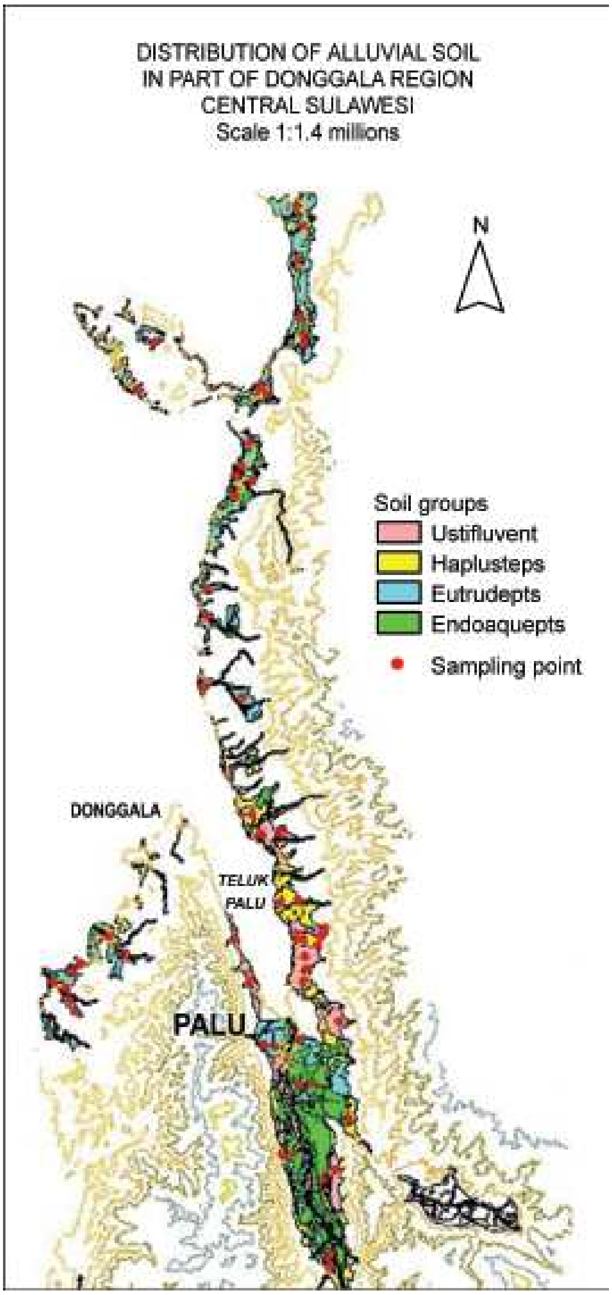

Fig. 1. Distribution of alluvial soils and soil sampling in the study area of Donggala region, Central Sulawesi.

For mineralogical studies, the total sand mineral fractions of some profiles were determined by line counting method, using polarization microscope, whereas clay mineral fraction was by using X-ray diffraction, with standard saturation of Mg^{2+} and K saturation plus heating to 550°C.

Land suitability evaluation was applied for wetland rice and other crops (maize, groundnut, soybean, sweet potatoes, cocoa, and coffee) using criteria outlined by Djaenudin *et al*. (2003).

RESULTS AND DISCUSSION

Physical and Chemical Properties

The summary of statistical analysis, namely the mean, range, standard deviation (SD), and coefficient of variation (CV) of the upper 30 cm properties of the four soil groups are presented in Table 1. The texture of Ustifluvents ranged from loamy sand to sandy loam with average of sandy loam (71% sand, 18% silt, and 11% clay). The texture of Haplustepts was similar to Ustifluvents, ranging from loam, sandy loam, to sandy clay loam (53% sand, 29% silt, and 17% clay). Eutrudepts had texture ranging from loam, sandy loam, sandy clay loam, to clay loam (39% sand, 38% silt, and 23% clay). Endoaquepts with aquic moisture regime and existing land use of wetland rice, had a similar texture class as Eutrudepts. Both Eutrudepts and Endoaquepts had a little higher clay content than the first two soils. The average texture of top soils of the four dominant soil groups varied from sandy loam to loam, and classified as medium texture which was favorable for crop growth.

The average pH-H_2O of Ustifluvents and Halustepts was neutral (pH 7.0-7.2), but it varied from slightly acid to alkaline (pH 5.7-8.6) for Ustifluvents, and pH 4.9-8.5 for Haplustepts. For Eutrudepts and Endoaquepts, the average pH was slightly acid (5.5-6.2),

Table 1. Simple statistics of soil properties of 0-30 cm layer in the study area of Donggala region, Central Sulawesi.

Soil properties	Ustifluvents				Haplustepts			
	Mean	Range	SD	CV	Mean	Range	SD	CV
Sand (%)	71	60-89	9	12	53	24-72	15	28
Silt (%)	18	6-31	7	38	29	16-51	11	37
Clay (%)	11	10-18	3	30	17	9-29	6	33
pH-H_2O	7.2	5.7-8.6	1.2	16	7.0	4.9-8.5	1.3	19
pH-KCl	6.5	4.7-7.9	1.3	20	6.1	3.9-7.8	1.5	24
Organic C (%)	0.58	0.28-1.39	0.36	61	0.77	0.39-1.98	0.45	59
Total N (%)	0.06	0.03-0.11	0.03	47	0.08	0.05-0.14	0.03	36
P_2O_5 (mg 100 g^{-1})	118	54-183	34	29	81	8-167	62	76
K_2O (mg 100 g^{-1})	338	227-506	102	30	356	12-635	190	54
Available P (mg kg^{-1})	16	4.5-34	10	64	19	7-61	16	82
P retention (%)	3	1-4	1	36	5	1-12	4	71
Ca^{++} (cmol(+) kg^{-1})	12.89	7.06-24.59	6.32	49	16.58	1.78-48.32	12.93	78
Mg^{++} (cmol(+) kg^{-1})	2.08	0.86-3.43	0.85	41	2.79	0.56- 6.04	1.52	54
K^+ (cmol(+) kg^{-1})	0.28	0.06-0.69	0.19	67	0.35	0.05-0.89	0.22	63
Na^+ (cmol(+) kg^{-1})	0.18	0.04-0.63	0.18	97	0.32	0.08-0.88	0.24	74
CEC (cmol(+) kg^{-1})	9	6-15	3	30	14	4-22	6	42
Base saturation (%)	100	100	0	0	98	87-100	4	4
	Eutrudepts				Endoaquepts			
Sand (%)	39	15-71	15	37	41	5-66	22	54
Silt (%)	38	25-55	9	23	41	20-67	17	42
Clay (%)	23	4-30	7	31	18	11-31	6	33
pH-H_2O	5.5	4.9-7.0	0.6	10	6.2	5.2-8.5	1.3	21
pH-KCl	4.5	3.8-6.0	0.6	14	5.4	4.1-8.0	1.6	29
Organic C (%)	1.08	0.42-1.88	0.40	37	1.44	0.69-2.17	0.60	42
Total N (%)	0.09	0.05-0.16	0.03	35	0.14	0.08-0.28	0.06	44
P_2O_5 (mg 100 g^{-1})	86	29-210	58	68	108	65-181	42	39
K_2O (mg 100 g^{-1})	475	50-897	231	49	385	13-752	246	64
Available P (mg kg^{-1})	47	8-152	38	81	38	12-77	25	66
P retention (%)	11	6-14	4	39	18	2-37	12	69
Ca^{++} (cmol(+) kg^{-1})	11.20	5.18-22.61	4.27	38	13.83	5.78-36.27	9.81	71
Mg^{++} (cmol(+) kg^{-1})	2.99	1.46-4.77	0.90	30	2.71	1.03-4.92	1.32	49
K^+ (cmol(+) kg^{-1})	0.24	0.12-0.50	0.15	62	0.18	0.05-0.51	0.15	84
Na^+ (cmol(+) kg^{-1})	0.34	0.10-1.38	0.42	124	0.27	0.14-0.39	0.10	38
CEC (cmol(+) kg^{-1})	13	6-19	4	28	10	8-12	2	17
Base saturation (%)	98	84-100	5	5	99	94-100	2	2

SD = standard deviation; CV = coefficient of variation.

with variation of acid to alkaline (pH 4.9-7.0 for Eutrudepts, and 5.2-8.5 for Endoaquepts). Soil pH in udic moisture regime was more acid than in ustic moisture regime. This is probably due to a relatively higher rainfall that affects the leaching of bases. In ustic moisture regime with low rainfall, the higher pH was related to accumulation of bases. The higher bases, such as Ca and Mg may also be affected by the presence of 2:1 clay mineral, such as smectite mineral group (Prasetyo *et al*. 2000). The negative delta pH (KCl) - pH (H_2O) indicated negative charges of clay particles, and that the soils can exchange cations, such as Ca and Mg.

Organic carbon content of all the top soils was very low (< 1%) for Ustifluvents and Haplustepts, and low (1-2%) for Eutrudepts and Endoaquepts. The low organic matter content is one of the main problems of soils in the humid tropic where organic matter decomposition is intensive because of high temperature (Lal 2000; Sanchez 1976) and intensive land use without organic matter recycling.

Potential P_2O_5 and K_2O contents extracted by HCl 25% for all the soil groups were very high. These may be derived from weathered metamorphic and intrusive rocks. However, the average content of available P for Ustifluvents and Haplustepts was medium (16-19 mg kg^{-1}), and for Eutrudepts and Endoaquepts was high (38-47 mg kg^{-1}). The low availability of P seemed resulted by fixation by calcite (Afzal *et al*. 1999). Furthermore, the exchangeable K as assumed as available K was low to medium (0.18-0.35 cmol(+) kg^{-1}) for all the soil groups. For soils with exchangeable K of < 0.30 cmol(+) kg^{-1} is suggested to apply K fertilizer (Adiningsih and Sudjadi 1983; Yost *et al.* 2006).

The average content of exchangeable Ca^{2+} was high with values of 12.89, 16.58, 11.20, and 13.83 cmol(+) kg^{-1} for Ustifluvents, Haplustepts, Eutrudepts, and Endoaquepts respectively, while exchangeable Mg^{2+} was 2.08, 2.79, 2.99, and 2.71 cmol(+) kg^{-1}, respectively. Base saturation was also very high (98-100%) for all the soil groups. The high exchangeable cations in a part of Palu valley with soil ustic moisture regime, were dominated by Ca^{2+} and Mg^{2+} resulted from accumulation of bases in dry conditions (Suhardjo 1988). However, the high exchangeable cations can also be derived from the source of parent materials, such as weathered Ca-feldspars from schist and granite rocks.

Soil-CEC was low to very low for all the soil groups. It may be affected by low to very low organic carbon and clay contents. The average soil-CEC for Ustifluvents, Haplustepts, Eutrudepts, and Endoaquepts was 9, 14, 13, and 10 cmol (+) kg^{-1} respectively. The low soil-CEC and low organic matter are the main constraints of fertility of these soils. Therefore, organic matter application is recommended to improve CEC, carbon content, and nutrient availability.

The soil-CEC had a positive correlation with clay and organic carbon contents (Fig. 2). Similar results were also reported by Prasetyo *et al.* (1999) for East Kalimantan soils. The coefficient of determination, R^2 ranged from 0.39 to 0.64 for clay content against soil-CEC relationship, while organic carbon content against soil-CEC ranged from 0.21 to 0.41. The R^2 values show that the contribution of clay content to soil-CEC values is higher than that of the organic carbon, except for Ustifluvents, that have very low clay content.

The ratios of Ca/K, Ca/Mg, and Mg/K, or percentage of the cations to soil-CEC can be used as an indicator of availability of exchangeable cations for various crops. The K saturation percentage ranged from 2 to 3% (Table 2) which was lower than the ideal ratio of 5% (Haby *et al.* 1990) prompting that K should be added.

Composition of Sand and Clay Minerals

The mineral composition of sand fraction was dominated by quartz and rock fragments (Table 3). However, the presence of weatherable minerals, such as orthoclase, sanidine, biotite, and hornblende, with few albite, andesine, and muscovite, with a total percentage of > 20%, suggests the moderately high weatherable mineral reserve. The mineral composition indicated acid parent materials. Very little amounts of epidote, turmaline, enstatite, monasite, and garnet, indicated that the source of materials is from metamorphic rocks. The composition of mineral association agreed with that as reported by Sukamto (1973) and Suhardjo (1988).

The composition of clay minerals of top soils of the three soil groups (Table 4) showed a mixture of smectite in fair to dominant proportion, followed by illite in fair and minor proportions. The vermiculite, kaolinite, and quartz were present in trace proportion.

Agricultural Suitability of the Soils

All the soil groups were evaluated their suitability for agricultural development purpose. Land suitability for several crops, e.g. wetland rice, maize, soybean, groundnut, sweet potatoes, onion, cocoa, and coffee was evaluated according criteria outlined by Djaenudin *et al*. (2003) and the results are indicated in Table 5.

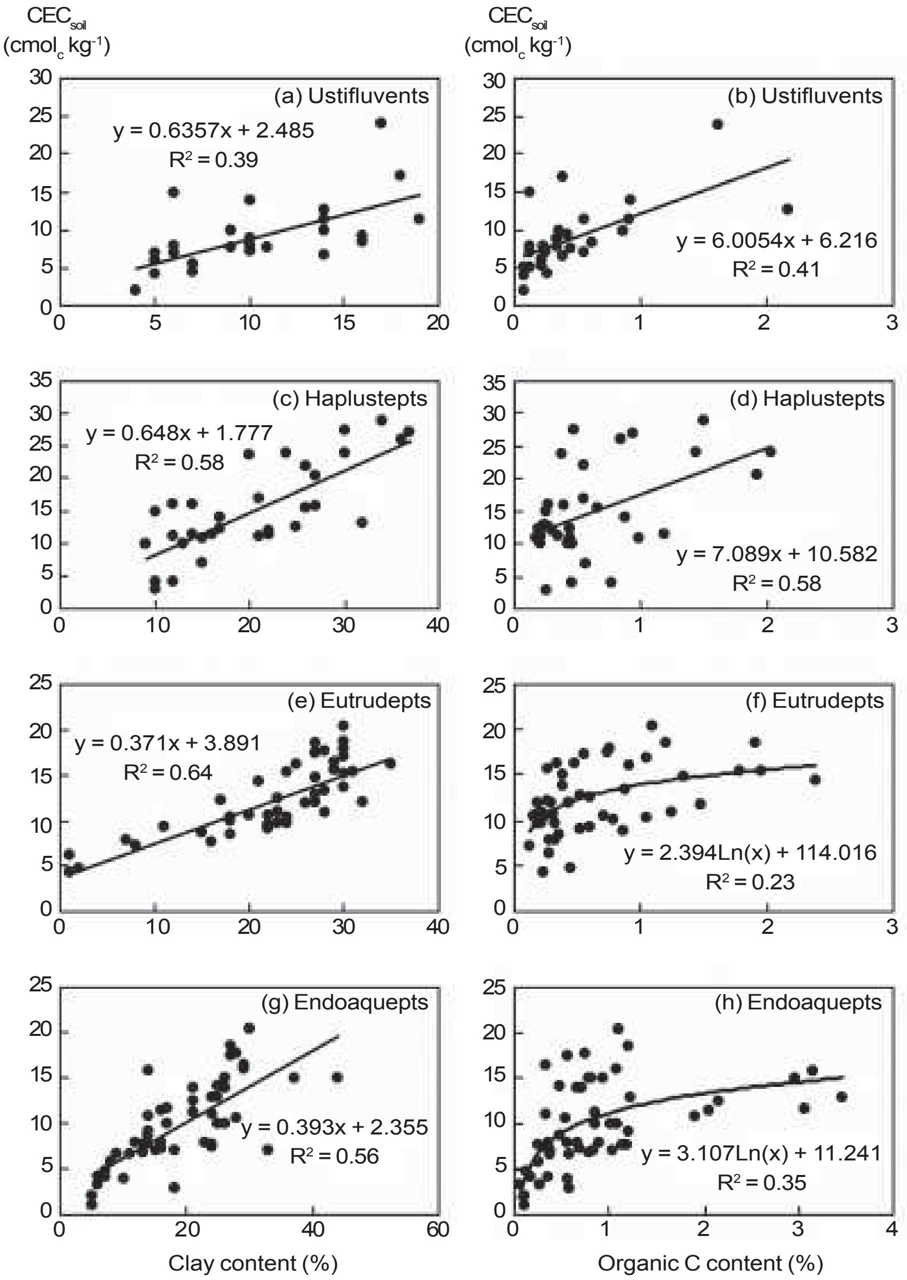

Fig. 2. Relationship between soil-CEC against clay and organic carbon content of the soil groups in Donggala region, Central Sulawesi.

Table 2. Ratios of Ca/K, Ca/Mg, Mg/K, and percentage of saturation of the soil groups in Donggala region, Central Sulawesi.

Ratio, % saturation	Ustifluvents	Haplustepts	Eutrudepts	Endoaquepts	Ideal ratio[2]
Ca/K	46/1	47/1	47/1	77/1	13/1
Ca/Mg	6/1	6/1	4/1	5/1	6.5/1
Mg/K	7/1	8/1	12/1	15/1	2/1
% Ca[1]	143	118	86	138	65
% Mg	23	20	23	27	10
% K	3	2.5	2	2	5

[1]% Ca saturation = (Ca^{2+}/soil-CEC) x 100%.
[2]Haby *et al.* (1990).

Table 3. Mineral composition (%) of sand fraction of the soil groups in Donggala region, Central Sulawesi.

Minerals	Soil groups									
	Ustifluvents		Happlusteps		Eutrudepts				Endoaquepts	
	PL1		PL2		PL3		PL4		PL5	
	A	Bw1	A	Bw2	A	Bw1	A	Bw1	A	Bw1
Opaque	2	4	9	9	2	2	-	-	1	2
Zircon	-	-	2	-	1	1	-	2	-	-
Turbid quartz	35	36	27	32	38	27	21	26	32	32
Transparent quartz	16	9	9	11	12	14	8	11	16	25
Weathered minerals	1	3	-	1	-	-	30	6	3	-
Rock fragments	19	19	9	15	20	18	16	9	16	17
Albite	1	4	5	2	-	-	1	2	-	1
Oligoclase	1	1	1	1	-	-	-	1	-	-
Andesine	-	1	2	-	-	1	2	1	1	-
Labradorite	-	-	-	-	-	2	-	1	1	1
Orthoclase	1	1	24	18	14	12	11	17	1	-
Sanidine	2	1	2	3	2	1	3	3	1	1
Muscovite			-	-	-	1		1	2	2
Biotite	12	6	-	-	3	7	4	11	22	13
Green hornblende	7	10	6	5	5	8	4	9	1	5
Augite	-	-	-	-	-	1	-	-	-	-
Hypersthene	-	-	-	-	-	1	-	-	-	-
Total[1]	**24**	**24**	**40**	**29**	**24**	**34**	**25**	**46**	**29**	**23**
Epidote	3	4	1	1	1	1	-	-	2	-
Turmaline	-	-	1	-	-	-	-	-	-	1
Enstatite	-	1	1	-	2	2	-	-	-	-
Monazite	-	-	1	1	-	-	-	-	-	-
Garnet	-	-	-	1	-	1	-	-	1	-

PL1, PL2, PL3, PL4, and PL5 = pedon; A, Bw1, and Bw2 = horizon.
[1]Total of weatherable minerals (from Albite to Hypersthene).

Table 4. Composition of clay minerals in top soils of the soil groups in Donggala region, Central Sulawesi.

Soil groups	Smectite	Illite	Vermiculite	Kaolinite	Quartz
Ustifluvents	+++	+	-	(+)	(+)
Haplustepts	++	++	(+)	+	(+)
Eutrudepts	++	+	(+)	(+)	(+)

+++ = dominant; ++ = fair; + = minor; (+) = trace.

The soil group of Ustifluvents with ustic moisture regime (the soils are dry within 90 or more cumulative days in normal years), were classified as marginally suitable (class S3) for all the crops evaluated, except for wetland rice which was grouped as not suitable (class N) due to moderately coarse texture (high sand content). Similar to Ustifluvents, the soil group of Haplustepts that also had ustic moisture regime, were classified as moderately suitable (class S2), except for wetland rice, cocoa and coffee which were marginally suitable. The main constraints were nutrient retention (low organic carbon and low soil CEC) and water availability (low rainfall).

The soil groups of Eutrudepts with udic moisture regime (the soils are always or usually moist, have never dry more than 90 days in normal years) were classified as moderately suitable for all the crops evaluated. The main constraints of these soils were nutrient retention (slightly acid soil pH, low CEC) and moderately excessively drained.

The soil groups of Endoaquepts with aquic moisture regime (the soils are always wet) were moderately suitable for wetland rice, but marginally suitable for other crops evaluated. The main constraints were imperfect or poor soil drainage. This soil group was better for wetland rice rather than for other dry land crops.

Based on this study, about 42,000 ha of 57,000 ha of the alluvial soils in part of Donggala region, consisting of Eutrudepts, Endoaquepts and Haplustepts, are potential for agricultural development, in most of which fall in the S2 and S3 land suitability classes. Alternative choices for crop development are wetland rice, maize, groundnut, red onion, and cocoa. For optimal crop production it is necessary to fertilize,

Table 5. Land suitability class of soil groups for several crops in Donggala region, Central Sulawesi.

Soil groups	Relief	Wetland rice	Land suitability[1]						
			Maize	Soybean	Groundnut	Onion	Sweet potatos	Cocoa	Coffee
Ustifluvents	Almost flat	N-r,w	S3-n,w	S3-n,w	S3-n,w	S3-n,w	S3-n,w	S3-n,w	S3-n,w
Haplustepts	Gently sloping	S3-n,o	S2-n,w	S2-n,w	S2-n,w	S2-n,w	S2-n,w	S3-n,w	S3-n,w
Eutrudepts	Almost flat	S2-n	S2-n,o	S2-n,o	S2-n,o	S3-n,o	S2-n,o	S2-n,o	S2-n,o
Endoaquepts	Flat	S2-n	S3-o	S3-o	S3-o	S3-o	S3-o	N-o	N-o

[1]Suitability class: S2 = moderately suitable; S3 = marginally suitable; N = not suitable.
Constraints: n = nutrient retention (soil CEC, soil pH, organic carbon) and nutrient availability (total P_2O_5, K_2O, available P); o = soil drainage; r = rooting condition (texture, soil depth; coarse materials); w = water availability.

especially based on organic matter, P_2O_5 and K_2O content.

Soil Management

Based on soil properties, climate, and relief, the alluvial plains of Donggala region have good potentials for agricultural development, both for food crops (wetland rice, maize, soybeans, groundnuts, sweet potatoes, and onion) and estate crops (cocoa and coffee). From the previous discussion it is clear that the dominant limiting factors of soil fertility include low organic matter content, low soil CEC, and low exchangeable K.

Soil management should be directed to increase organic matter for better soil CEC organic matter and water holding capacity. This may include addition of farmyard manure, green manures, and/or crop residues (Lal 2000; Wade and Sanchez 1983). The use of supplementary inorganic fertilizers, such as urea, SP-36, and KCl at a balance rate, could warrant sustainable production of food crops. Since the soils of wetland rice (group of Endoaquepts) show low N status, but high potential P_2O_5 and K_2O, the recommended fertilizers is about urea 200 kg, SP-36 50 kg and KCl 50 kg plus rice straw of 5 t ha^{-1} (Badan Penelitian dan Pengembangan Pertanian 2006). For the dry land soils (group of Eutrudepts, Haplustepts, and Ustifluvents) with high potential of P_2O_5 and K_2O, but low organic matters, the recommended fertilizers for maize, soybean, and onion are about SP-36 100 kg, KCl 50 kg, 2 t ha^{-1} of green manure, such as *Crotalaria grahamiana, Mucuna munaneae*, and *Flemingia macrophylla*, and urea 200 kg ha^{-1}, except for groundnut which require about urea 50 kg ha^{-1} if the soil has been inoculated with N fixing bacteria. All the dosage of SP-36 and organic matters should be given in one time before planting, while Urea should be given twice, a half dosage at planting time and the remaining one month afterward (Indonesian Soil Research Institute 2007).

CONCLUSION AND RECOMMENDATION

The surface soils of alluvial plain in the study area of Donggala region showed variation in their physical and chemical properties. All soil groups indicated high to very high contents of P_2O_5 and K_2O extracted by HCl 25%, but low in organic matters, soil CEC, and exchangeable K. Soil pH was slightly acid to alkaline with medium to high contents of Ca and Mg, and high base saturation.

Sand mineral fraction was composed of moderately high weatherable minerals, reflecting high source of nutrient reserve. Clay minerals showed dominance of smectite and illite, which were inherited from weathered parent materials.

Land suitability for several crops showed moderately to marginally suitable with constraints of nutrient retention, soil drainage, soil texture, and water availability. The soils had a good potential for agricultural development, with the main fertility constraints of low organic matter, low soil CEC, and low exchangeable K.

Recommended fertilizers for wetland rice in soil groups of Endoaquepts are urea 200 kg, SP-36 50 kg, KCl 50 kg and rice straw of 5 t ha^{-1}. While for soil groups of Eutrudepts, Haplustepts and Ustifluvents the recommended fertilizers for maize are about urea 200 kg, SP-36 100 kg, KCl 50 kg, and green manure of 2 t ha^{-1}.

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