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SOIL OF PAMETIKARATA, EAST SUMBA: ITS SUITABILITY AND CONSTRAINTS FOR FOOD CROP DEVELOPMENT

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ABSTRACT

Pametikarata, Lewa subdistrict, is the priority area for food crop development in East Sumba. To evaluate its suitability and constraints, chemical properties, suitability and fertility capability classification for rice and secondary crops of some potential soils have been studied both in the field and in the laboratory. Seven soil profiles consisted of forty one soil samples were subjected to chemical and mineralogical analyses in the laboratory. The analyses consisted of clay fraction and organic-carbon contents, pH, potential P and K (25% HCl extraction), available P, phosphate retention, exchangeable cations and cation exchange capacity (NH_4OAc 1N, pH 7), and mineralogical composition of the clay fraction. The results indicate that soil acidity varies from acid to neutral. Exchangeable cations are dominated by Ca cation and soil CEC ranges from low to very high. Clay mineral composition also varies, some are dominated by montmorillonite, others show mixed mineralogy between montmorillonite and kaolinite, and the rests are dominated by kaolinite. With the exception of wet Vertisols, all soils are grouped as marginally suitable (S3) for rice and secondary crops. Nutrient availability and retention are the common limiting factors. Using fertility capability classification (FCC), all soils are grouped as clayey soils with low infiltration and high water holding capacity. The serious constraint for food crop development in this area is uncontrolled grazing that makes a conflict of interests between farming and cattle herding systems. Optimum success of food crop development in the area could be reached by controlling the herding system and improving the existing agricultural system.

[*Keywords:* land suitability; food crop development; cattle]

INTRODUCTION

East Nusa Tenggara is one of the priority area for development in the Second Long-Term National Development, with special emphasis on food crop development. Utilization of the area with a long dry season faced many limiting factors, therefore the use of soil, water, and topography should be adjusted to the climatic condition. Two main limiting factors for food crop and tree crop development are physical and climatic conditions. The physical factors are shallow soil and topography of the area which mostly has steep slope (>45%), while the climatic condition is a pronounced dry season with a short period of growing season and limited water availability for crop growth (Adiningsih *et al.*, 1996). Erosion hazard is another problem due to high rainfall intensity striking within the short time upon the soil of steep sloped topography (Momuat and Malian, 1988).

Pametikarata, Lewa subdistrict, is one of the priority area for food crop development in East Sumba regency (Fig. 1). The area is selected by the local government based on several reasons, i.e., the topography is relatively flat, water for irrigation is available from natural springs, and the climate is the wettest compared to the other area in this regency. Soils in the area are mainly developed from alluvium, colluvium, limestone, and a portion derived from tufaceous marl and old lava basalt. According to geological map of Effendi and Apandi (1981), originally the area was a sea floor, which was uplifted and latter experienced erosion and denudation processes.

The climate of the area is quite different to others in the regency. The annual rainfall is 204-2,882 mm with an average of 2,043 mm $year^{-1}$ (Table 1). Based on Schmidt and Ferguson (1951), the rainfall type of Lewa is D, and Oldeman *et al.* (1980) classified it as C3 type. Calculated water balance shows water deficit during six-month period from middle of April to October (Fig. 2). Planting season normally takes place for six months, from November to April.

Based on the semidetail soil map of the area, five soil orders were found in Pametikarata, i.e., Entisols, Inceptisols, Vertisols, Mollisols, and Ultisols (Pusat Penelitian Tanah dan Agroklimat, 1997). General soil distribution, simplified from the semidetail soil map of Pametikarata, is shown in Fig. 3. Shallow Entisols and Mollisols are predominant soils in the hilly area. In the undulating area, deep soils of Ultisols and Mollisols are found. Mollisols with black color commonly occupy the upper part of the landscape, having a larger slope than those of Ultisols, while Ultisols with reddish color and smaller slope are generally found in the lower part. In the flat to slightly flat areas, Vertisols and Inceptisols are dominant. Of the whole 33,000 ha surveyed area, about 11,506 ha (34,9%) are suitable for rice and secondary crops.

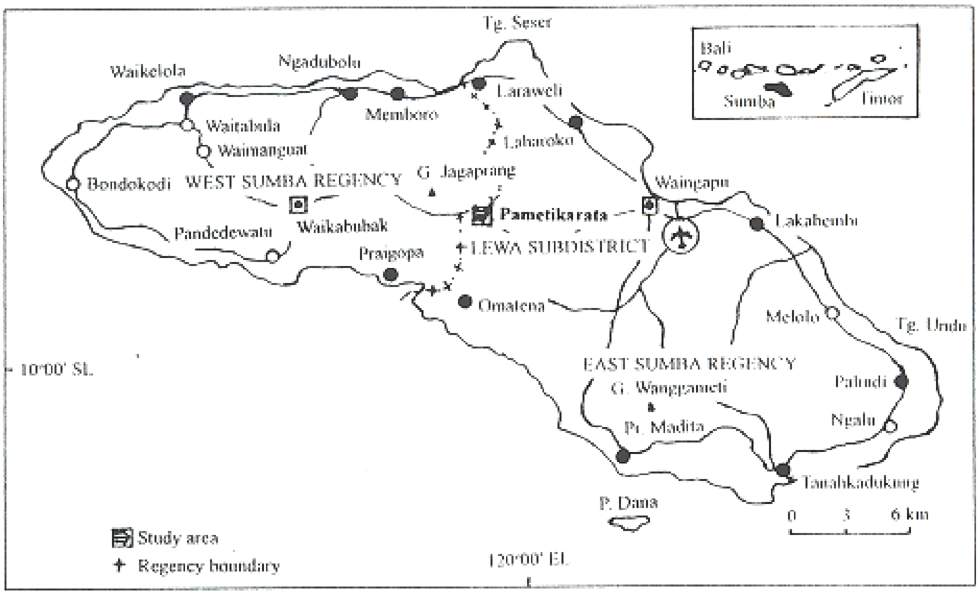


Fig. 1. Map of Sumba Island showing location of the study area, and map of East Nusa Tenggara Province (inzet) showing position of the island.

Table 1. The mean monthly rainfall, potential evapotranspiration (PET), Schmidt and Ferguson rainfall type, and Oldeman agroclimatic zone of Lewa, 1967-95.

Month	Rainfall (mm)	PET (mm)	Schmidt and Ferguson (1951)[1]			Oldeman *et al* (1980)[2]		
			Dry month	Wet month	Rainfall type	Dry month	Wet month	Agroclimatic zone
January	352	145						
February	305	139						
March	293	139						
April	169	134						
May	97	126						
June	39	114	2-7	5-9	D	3-7	2-7	C3
July	25	103						
August	18	108						
September	41	126						
October	106	143						
November	260	153						
December	338	147						
Annual	2,043							

[1]Dry month less than 60 mm month^{-1}, wet month more than 100 mm month^{-1}
[2]Dry month less than 100 mm month^{-1}, wet month more than 200 mm month^{-1}

In the studied area, management of rainfed rice field is very simple. Although in some areas water is available for irrigation at anytime, rice is planted once a year without fertilizers. Using buffalo and cow for plowing is limited, and crop maintenance is not applied. After harvest, the land is left fallow even though water is available and the soil is still moist. The land is then used for cattle grazing. Local people practice free grazing system in which they let the cattle freely in the harvested rice fields. This situation occurs perhaps due to the conflict of interests between farming and cattle herding system in the same area.

This paper aims to discuss the suitability and constraints of Pametikarata soils, East Sumba for food crop development based on soil properties and fertility.

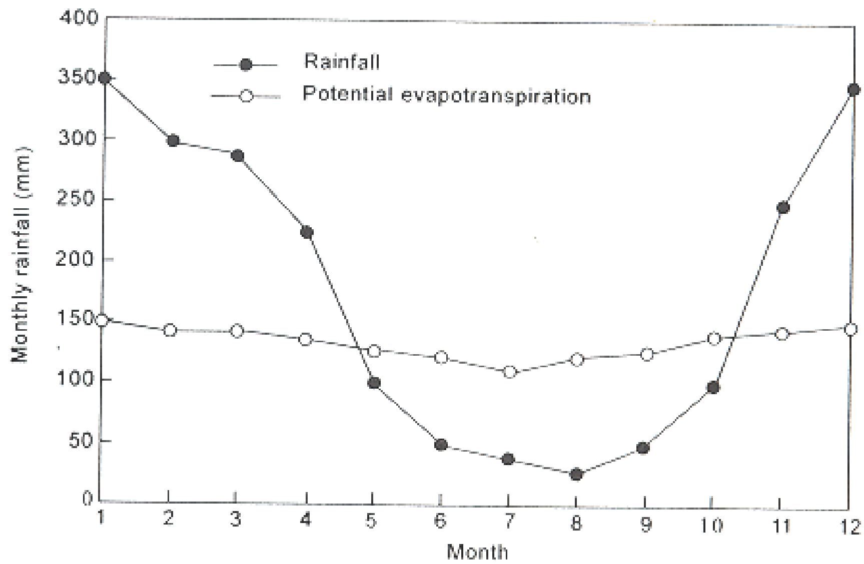
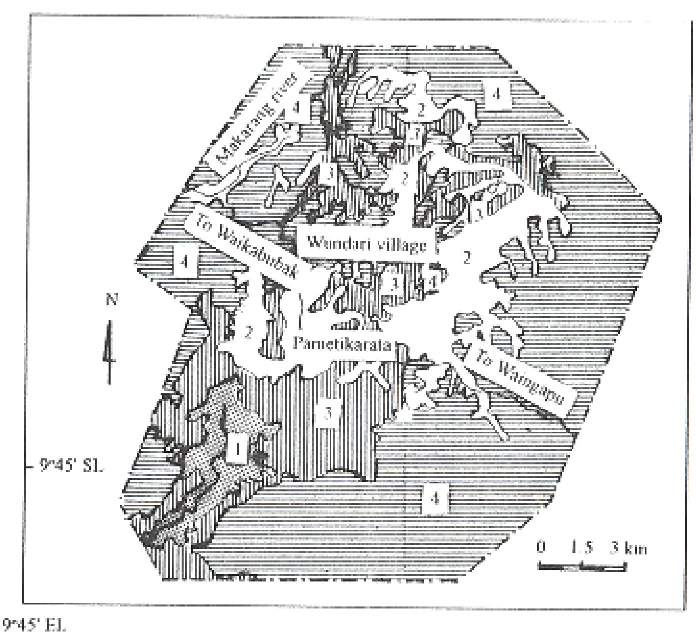


Fig. 2. Water balance of Pametikarata area.



Maping unit	Soil (Based on Soil Survey Staff, 1994)	Slope (%)	Relief	Landuse recommendation
1	Vertisols (Typic Endoaquerts) Inceptisols (Vertic Eutropepts)	1	Flat	Irrigated rice field
2	Vertisols (Udic Haplusterts) Inceptisols (Vertic Ustropepts, Oxyaquic Dystropepts)	1-3	Slightly flat	Rainfed rice field
3	Ultisols (Ustic Haplohumults) Mollisols (Vertic Argiustolls, Typic Argiustolls)	3-8	Undulating	Secondary crops
4	Entisols (Lithic Usthortents) Mollisols (Lithic Haplustolls)	>45	Hilly	Forest/conservation area

Fig. 3. Simplified soil map of Pametikarata area (Pusat Penelitian Tanah dan Agroklimat, 1997).

MATERIALS AND METHODS

Field observation and soil sampling conducted during the soil survey of the area and laboratory study were organized by the Center for Soil and Agroclimate Research in 1996. Soils were classified according to Soil Taxonomy (Soil Survey Staff, 1994). Soil profiles were selected to represent potential soil in the flat and undulating areas. Seven profiles consisted of forty one soil samples were used for study. Chemical and mineralogical analyses were done for soil identification and classification.

Soil samples were analyzed for the content of clay fraction and organic carbon, pH, potential P and K (25% HCl extraction), available P (Olsen *et al.* 1954), phosphate retention (Blackmore *et al.*, 1981), exchangeable cation and cation exchange capacity (CEC) (NH_4OAc 1N, pH 7), and exchangeable Al (KCl 1N). Unless mentioned all other soil analyses were conducted following the method described in Soil Survey Laboratory Staff (1991). Evaluation of the suitability and constraints of the soils for growing rice and secondary crops (maize, groundnut, soybean, and cassava) was done based on the method of Djaenudin *et al.* (1994), and fertility capability classification (FCC) was carried out according to the method of Sanchez and Buol (1985). Mineralogical composition of clay fractions was determined by X-ray Diffractometer. Clay samples were saturated by magnesium, magnesium + glycerol, potassium, and potassium + heating at 550°C. Cu tube was used and operated at 40 kV and 25 mA.

RESULTS AND DISCUSSION

Soil Properties

Chemical properties of representing soils of flat area are given in Table 2, while those for soils of undulating area are presented in Table 3. The soil properties are evaluated according to criteria commonly used in the Center for Soil and Agroclimate Research (Pusat Penelitian Tanah, 1982).

Soils of the flat area consisted dominantly of Vertisols (Typic Endoaquerts, Udic Haplusterts) and Inceptisols (Vertic Ustropepts, Oxyaquic Dystropepts), while those of the undulating area comprised of Mollisols (Typic Argiustolls, Vertic Argiustolls) and Ultisols (Ustic Haplohumults). The data show that all soils, except Vertic Argiustolls (Table 3) have heavy clay texture as indicated by the clay content of more than 60%. Heavy textured soils are dominated by montmorillonitic clay minerals which gives some problems on soil cultivation. Normally, the soils form cracks and become hard to very hard during dry season, and transform to muddy and very sticky during wet season.

Organic carbon content is high in the top soils and regularly decreases with the soil depth. In the flat area, soils exhibit acid to neutral reaction (pH 5.8-7.7) and in the undulating area the soils show acid to very acid reaction (pH 5.2-4.3). This probably occurs because leaching of bases in the undulating area is more active than that in the flat area, and the latter area receives the leached bases from the higher area.

Potential P content of soils in flat and undulating areas are generally high to very high, however available P is generally very low, because of P fixation phenomenon. In Vertisols (Typic Endoaquerts and Udic Haplusterts), P is fixed by Ca as Ca-P, but in the acid soils of Inceptisols (Vertic Ustropepts, Oxyaquic Dystropepts) and Ultisols (Ustic Haplohumults), beside Ca as possible fixation agent, P is also fixed by Al and Fe as Al-P and Fe-P. This finding is supported by the data of phosphate retention. Phosphate retention in soils dominated by exchangeable Ca, but does not show exchangeable Al, shows almost the same value with P retention in soils which are not dominated by exchangeable Ca, but have exchangeable Al.

The most important properties of soil with montmorillonitic mineralogy are high CEC and ability to shrink and swell. High CEC value increases soil ability to hold nutrient cations such as K^+, NH_4^+, Ca^{2+}, and Mg^{2+}. Unfortunately high content of montmorillonite causes restriction of root growth, especially in the dry season, when the soils shrink to form cracks and become very hard.

Exchangeable cation is dominated by Ca in both soils of the flat and undulating areas. However in the acid soils (Vertic Ustropepts, Oxyaquic Dystropepts, and Ustic Haplohumults), the amount of exchangeable Ca is less than those of the nonacid soils (Typic Endoaquerts, Udic Haplusterts, and Typic Argiustolls). This probably occurs because leaching of bases in the acid soils is more intensive than that in the nonacid soils. The domination of Ca in these soils is related to their parent material, that in this case, soils are developed from alluvium, tufaceous marl, limestone, and basaltic rocks (Prasetyo *et al.*, 1998).

Aluminum saturation in the acid soils ranges from 1 to 47%. The origin of exchangeable Al is related to clay mineralogical composition of which montmorillonite is present in the soils as the source of Al

Table 2. Soil properties of the flat area of Pametikarata, East Sumba.

Depth (cm)	Clay (%)	C (%)	H_2O pH	HCl (25%) P_2O_5	HCl (25%) K_2O ...(mg 100 g^{-1})...	Olsen P_2O_5 (ppm)	P-retention (%)	Exchangeable cations Ca	Mg	K	Al	Soil CEC	Al saturation (%)
								......(cmol (+) kg^{-1} soil)......					
Typic Endoaquerts, very fine, montmorillonitic, isohyperthermic													
0-20	92	8.3	6.8	64	12	22	57	79.19	1.45	0.22	0.05	73.4	-
20-40	91	2.1	7.4	46	7	3	71	71.24	0.98	0.13	-	69.3	-
40-70	88	0.7	7.5	47	7	5	70	60.21	1.51	0.13	-	62.8	-
70-110	84	0.7	7.7	71	11	5	na	66.39	2.12	0.16	-	65.8	-
110-155	85	0.6	7.3	61	8	6	na	56.92	2.15	0.15	-	62.1	-
Udic Haplusterts, very fine, montmorillonitic, isohyperthermic													
0-22	77	3.7	6.6	53	13	20	50	57.94	1.38	0.24	-	62.8	-
22-43	82	1.6	6.9	44	11	6	51	55.09	0.67	0.18	-	60.2	-
43-62	84	1.5	6.8	42	12	4	48	51.46	0.47	0.17	-	57.4	-
62-89	79	0.3	6.9	41	12	1	na	50.99	0.35	0.20	-	58.3	-
89-110	83	0.4	6.8	43	9	4	na	56.70	0.29	0.18	-	61.9	-
110-140	75	0.2	7.3	42	11	4	na	55.68	0.30	0.17	-	59.9	-
140-170	82	0.1	7.3	46	12	3	na	58.59	0.31	0.18	-	59.7	-
Vertic Ustropepts, very fine, mixed, isohyperthermic													
0-13	54	3.3	5.2	49	9	4	na	21.90	2.84	0.13	0.25	41.6	1
13-25	54	1.3	5.2	43	6	1	na	15.75	1.29	0.11	1.43	34.9	8
25-52	60	1.3	5.0	41	6	1	na	17.10	1.14	0.08	1.59	36.1	8
52-73	73	0.5	4.6	106	10	1	na	29.45	1.85	0.21	2.24	47.2	7
73-90	79	0.1	5.1	114	13	6	na	40.51	2.52	0.24	0.95	53.6	2
90-121	75	0.1	5.2	220	10	32	na	30.64	1.94	0.19	0.22	43.7	1
Oxyaquic Dystropepts, very fine, kaolinitic, isohyperthermic													
0-18	63	2.1	4.3	69	6	10	67	6.45	0.81	0.08	4.46	25.5	35
18-32	63	0.7	4.8	62	5	7	71	4.90	0.42	0.08	3.88	21.3	40
32-50	60	0.6	4.7	62	6	1	68	5.71	0.27	0.08	5.73	24.9	46
50-93	64	0.4	4.5	40	10	1	na	8.75	0.32	0.17	9.92	31.9	47
93-125	63	0.2	4.4	40	9	1	na	11.23	0.65	0.17	8.32	31.2	39
125-162	65	0.1	4.5	40	10	1	na	12.90	1.08	0.17	6.85	30.8	31

na = not analyzed

(Prasetyo *et al.*, 1998). In the acid condition, montmorillonite becomes unstable and releases Al from its structure (Buol *et al.*, 1980).

Cation exchange capacity of soils in the flat area ranges from 21.5 to 73.4 cmol (+) kg^{-1} soil and from 30.9 to 62.2 cmol (+) kg^{-1} soil in the undulating area. It seems that the amount of montmorillonite in the soils affects the value of CEC. In the acid soils (Vertic Ustropepts, Oxiaquic Dystropepts and Ustic Haplohumults, Table 2 and 3), the CEC of soil varies from 24.9 to 62.2 cmol (+) kg^{-1} soil. These values are apparently quite high for the normal acid soils. This is because of few to moderate amounts of montmorillonite in the kaolinitic clay mineral that contribute to a higher CEC value (Oxyaquic Dystropepts, Table 2) and approximately the same amounts of montmorillonite and kaolinite minerals in the mixed clay mineralogy (Vertic Ustropepts and Ustic Haplohumults, Table 2 and 3).

Land Suitability and Constraints

Land suitability and constraint for food crop development, i.e., rice, maize, groundnut, soybean, and cassava were evaluated according to the method of Djaenudin *et al.* (1994). The results are presented in Table 4.

The results indicate that for rice, maize, groundnut, soybean, and cassava, soils are grouped as marginally suitable (S3) and for cassava, only Typic Endoaquerts is not suitable (N1). In the flat area, the main constraint for growing rice is low nutrient availability indicated by n symbol, while in the undulating area despite nutrient, water availability indicated by w symbol is also a limiting factor. The general constraints for secondary crop cultivation in flat and undulating areas are low nutrient availability (n), rooting condition (r), and nutrient retention (f). Some soils in the flat area show phosphate retention

Table 3. Soil properties of undulating area of Pametikarata, East Sumba.

Depth (cm)	Clay (%)	C (%)	H_2O pH	HCl (25%) P_2O_5	HCl (25%) K_2O	Olsen P_2O_5 (ppm)	P-retention (%)	Exchangeable cations Ca	Mg	K	AL	Soil CEC	Al saturation (%)
				...(mg 100 g^{-1})...				......(cmol (+) kg^{-1} soil)......					
Typic Argiustolls, very fine, kaolinitic, isohyperthermic													
0-20	72	2.39	5.9	102	12	6	na	22.02	3.08	0.17	-	41.4	-
20-44	84	1.09	6.0	61	9	3	na	19.98	2.06	0.15	-	34.3	-
44-74	69	1.03	6.1	73	8	24	na	17.25	1.37	0.10	-	33.1	-
74-110	86	0.53	6.2	70	10	12	na	23.47	1.43	0.17	-	38.7	-
110-140	85	0.35	6.2	77	19	8	na	44.80	2.15	0.33	-	56.3	-
Vertic Argiustolls, fine silty, montmorillonitic, isohyperthermic													
0-20	36	4.24	5.8	57	19	10	na	58.63	3.11	0.19	-	49.4	-
20-55	19	2.58	6.0	45	17	9	na	39.98	2.54	0.23	-	52.9	-
55-95	39	2.06	6.0	41	15	5	na	41.66	1.97	0.19	-	51.0	-
95-115	40	1.43	6.6	41	14	5	na	35.94	1.69	0.17	-	47.1	-
115-140	39	1.15	6.5	40	14	2	na	33.88	1.69	0.21	-	42.7	-
125-162	65	0.14	4.5	40	10	1	na	12.90	1.08	0.17	6.8	30.8	-
Ustic Haplohumults, very fine, mixed, isohyperthermic													
0-15	69	3.36	4.7	42	13	4	na	9.03	5.01	0.19	2.0	59.2	12
15-28	72	2.65	4.9	33	10	2	na	5.60	3.53	0.10	4.1	51.3	29
28-57	91	2.01	5.0	23	12	1	na	5.88	2.61	0.11	7.7	44.8	45
57-83	87	1.05	5.1	22	19	1	na	7.47	3.12	0.13	8.5	48.0	42
83-105	86	0.74	5.0	28	24	1	na	8.22	3.33	0.17	7.9	48.1	39
105-157	79	0.60	5.0	30	20	1	na	9.92	3.81	0.14	11	62.1	43

na = not analyzed

Table 4. Land suitability class of Pametikarata soils for several crops.

Soils	Relief	Rice	Maize	Groundnut	Soybean	Cassava
Typic Endoaquerts	Flat	S3n	S3r,n	S3r,n	S3r,n	N1,r
Udic Haplusterts	Flat	S3n	S3n	S3n	S3n,r	S3n,r
Vertic Ustropepts	Flat	S3n	S3n,r,f	S3n,r,f	S3n	S3n,r
Oxyaquic Dystropepts	Flat	S3n	S3n,r,f	S3n,r,f	S3n,r,f	S3n,r,f
Typic Argiustolls	Undulating	S3n,w	S3n,r	S3n,r	S3n,r	S3n,r
Ustic Haplohumults	Undulating	S3n,w	S3n	S3n	S3n	S3n
Vertic Argiustolls	Undulating	S3n,w	S3n,w	S3n,r,f	S3n,r,f	S3n,r

Suitability class: S3 = marginally suitable, N1 = not suitable at the present time

Constraints: n = nutrient availability (N total, P_2O_5 and K_2O); r = rooting conditions (soil drainage, texture, and effective soil depth); w = water availability, f = nutrient retention (soil CEC, soil pH, organic-C)

problems, due to fixation either by Ca in nonacid soils or exchangeable Al in acid soils. Phosphate retention problem can be overcome either by fertilizing soils with high P dosage extended to the second planting season or saturating soil with P fertilizer to cover the anion absorption site of the soils (van Wambeke, 1992).

Growing rice in the flat area should consider water availability. For wet Vertisols (Typic Endoaquerts) that have a simple irrigation technique, lowland rice cultivation can be practiced all year around, while for the other Vertisols (Udic Haplusterts) and Inceptisols (Vertic Ustropepts and Oxyaquic Dystropepts) which occupied the same area, growing rainfed rice during the wet season is still possible. Growing rice in the undulating area, Mollisols (Typic Argiustolls, Vertic Argiustolls) and Ultisols (Ustic Haplohumults), is not suitable. The area is more appropriate for growing maize, groundnut, soybean, and cassava.

The other limiting factor for growing secondary crops is rooting condition (r), which is mainly caused by soil texture. Except for Vertic Argiustolls, all soils have heavy texture with clay content of more than 60%. High clay content dominantly composed of montmorillonite mineral is the reason for the crack formation during dry season which causes the roots difficult to grow. The less serious limiting factor is nutrient retention caused by acid soil reaction. This can be overcome by liming. Balanced fertilization and lime application especially for the acid soils would increase the land suitability class from the presently marginally suitable (S3) to moderately suitable (S2) or even very suitable (S1).

The results of evaluation for the main fertility related to the soil constraints for agronomic management are presented Table 5. The table shows that all soils are classified as C-soils, that is clayey soil with low infiltration and high water holding capacity. The soils are generally easy to puddle but difficult to restructure after puddling. In C-soils, particularly the Cv, the structure of aggregate is easily to break down during wet land preparation due to the presence of montmorillonite (Sanchez, 1973).

Soil humidity indicated by a d modifier is limited during dry season and generally acts as the main constraint for all soils, except for the wet Vertisols (Typic Endoaquerts). This soil is situated in the depression, has very shallow ground watertable and therefore has an aquic moisture regime, indicated by g modifier. The g modifier means that the soil is usually favorable for rice due to its anaerobic characteristic (Ponnamperuma, 1965).

Soils with v modifier have vertic properties, that cause shrink and crack during dry season. The vertic properties are originated from the presence of the dominant montmorillonite clay mineral in the soil.

Almost all soils have low to very low exchangeable K and only some soils show exchangeable K content of less than 0.20 cmol (+) kg^{-1} soil that becomes constraint for crop growth. It seems that low exchangeable K is inherited from soil parent material, which is naturally low in its K content. The low value of exchangeable K that is indicated by a k modifier, quantitatively defines soil with low inherent potentiality comparable to those soils having less than 10% weatherable mineral in their sand and silt fractions within 50 cm of the soil surface (Kawaguchi and Kyuma, 1977). The other constraint except for Vertisols (Typic Endoaquerts and Udic Haplusterts) is low soil acidity indicated by h modifier, in which soil pH ranges from 4.3 to 6.0, in both surface and subsurface horizons.

Alternatives of Problem Solution

The evaluation shows that soils of the flat and undulating areas are classified as marginally suitable (S3 class) for cultivation of rice and secondary crops. The main limiting factors are low nutrient availability (n), rooting condition (r), and nutrient retention (f). According to FCC, the general constraint for all soils is limited soil humidity during dry season (d). In the

Table 5. Fertility capability classification (FCC) of studied soils.

Soils	Relief	FCC class	Main constraints
Typic Endoaquerts	Flat	Cgvb	Aquic moisture regime, soil shrink and cracks during dry season, high pH
Udic Haplusterts	Flat	Cdvb	Soil humidity, soil shrinks and cracks during dry season, high pH
Vertic Ustropepts	Flat	Cdvh	Soil humidity, soil shrinks and cracks during dry season, low soil acidity
Oxyaquic Dystropepts	Flat	Cdhk	Soil humidity in dry season, low soil acidity, low exchangeable K
Typic Argiustolls	Undulating	Cdhk	Soil humidity in dry season, low soil acidity, low exchangeable K
Vertic Argiustolls	Undulating	Cdvh	Soil humidity, soil shrinks and cracks during dry season, low soil acidity
Ustic Haplohumults	Undulating	Cdvhk	Soil humidity in dry season, low soil acidity, low exchangeable K

C = clayey soil with low infiltration and high water holding capacity

Constraints and modifiers:

g = aquic soil moisture regime; d = soil humidity as a limiting factor during dry season; v = vertic properties causing soil shrinks and cracks during dry season; b = high pH of more than 7.3; h = low pH of 5.0-6.0; k = low exchangeable K flat area, the other constraints are: (1) low soil acidity (h) and either shrink and crack during dry season (v), (2) low exchangeable K (k) for Inceptisols, and shrink and crack during dry season (v) and high pH (b) for Vertisols. While in the undulating area, water availability (w), soil acidity, and low exchangeable potassium (k) are dominant constraints.

Due to relatively short wet season (about 4 months), the first solution is to select appropriate planting season that normally takes place in November to April. In the flat area, wet Vertisols (Typic Endoaquerts) that occupy depression with continuous supply of spring water as a source of water irrigation, are suitable for cultivating lowland rice twice a year. To avoid excess of water in the depression during wet season, drainage ditches should be constructed to divert water supply to the existing natural river. The other soils are more suitable for rainfed rice field during wet season, followed by secondary crops as soon as the rice is harvested. Shrink and crack constraint disappears during wet season as a result of swelling of the montmorillonite mineral. In the undulating area, planting secondary crop is only possible during wet season. Rice is not cultivated in this area. Low nutrient availability, particularly P and exchangeable K can be eliminated by adding sufficient P and K fertilizers.

The study concludes that although the area has short planting season, from the soil aspect, there is no serious problem arised on the development of food crops. However, the optimum land use for food crop development can be reached by planting rice twice a year in the flat area and rice plus secondary crops in the undulating area, and cattle grazing could be done with handle.

The common practice of the local people during planting season is growing food crops once a year. Immediately after harvest people let cattle (buffalo, cow, and horse) grazing freely in the agricultural land. Cattle grazing is part of the local people life style that forms their culture and therefore is not easy to change. Average ownership of animal per person is 4-7 for buffalos, 3-5 for cows, and 2-3 for horse, but some people may have more than 100 cattle (Sudharto *et al.*, 1995). Uncontrolled grazing causes farmers do not have opportunity to practice the second planting, although the soil is still moist and water is continuously available from the spring. To maximize the use of land for food crops, planting twice a year should be adopted and good management practices, such as balanced fertilizer, weed control, expansion of the use of spring water for irrigation must be practiced. Nevertheless, such agriculture practices and success of food crop development in Pametikarata can not be implemented as long as grazing system can not be controlled. Therefore, the alternative solutions for the success of food crop development in the Pametikarata include controlled grazing and agricultural system.

Controlled grazing

During the planting season, the common practice is cattle graze and stall within special nonagricultural areas called community owned barns. To have second planting season, the existence of cattle within the community barns should be extended until the end of the second harvest. Despite that, special grazing area should be created and prepared during the time when crops are grown in the field. Area recommended for this purpose is the land between Wundut village and Maharang river stretching to the northeast direction (Fig. 3).

Agricultural system

At the moment, abundant spring water is only used for limited irrigation particularly in the depression area. To maximize the utilization of the spring water, drainage ditches must be constructed to cover as large irrigation area as possible. By implementing this methods, two-time planting a year can be adopted. To protect the crops, if necessary fence surrounding irrigated rice field can be built. The rainfed part of the flat area is used once a year with a cropping pattern consisting of one time rainfed rice followed by secondary crops. The rainfed portion in the undulating area remains planted customarily with secondary crops among other maize, groundnut, cassava and/or soybean.

CONCLUSION

Soils in the flat area of Pametikarata are dominated by Vertisols (Typic Endoaquerts and Udic Haplusterts) and Inceptisols (Vertic Ustropepts). These soils are acid to neutral in reaction, high potential but low in available P and exchangeable K. Soil texture is mostly heavy clay dominated by montmorillonite that shrinks and forms cracks during dry season.

In the undulating area, the soils are dominated by Ultisols (Ustic Haplohumults) and Mollisols (Typic Argiustolls and Vertic Argiustolls). These soils show acid to slightly acid reaction, high potential but low in available P and exchangeable K. The clay is dominated by kaolinite with some montmorillonite.

Soils in both areas are marginally suitable (suitability class: S3) for rice and secondary crops. The limiting factor for rice cultivation is water availability and for secondary crops is nutrient availability, rooting condition, and nutrient retention. Following the FCC, the management constraints for most soils in the flat and undulating areas are limited topsoil moisture during dry season (except for Typic Endoaquerts), low exchangeable K, low soil acidity, and in some soil shrink and crack properties during dry season.

For the success of food crop development in the Pametikarata area, some alternative solutions are proposed, i.e., :

1. Controlled grazing by prolonging the time for the existence of cattle in the community barns until the end of the second harvest. In addition, special grazing area should be created during the time when crops are grown in the field or during the period of twice a year planting season.
2. Expansion of irrigated area by construction of drainage ditches to maximize the use of spring water as the source of irrigation. Implementation of twice planting season a year and improvement of cultivation technique including the use of new crop varieties, fertilizer, weed control, and integrated pest and disease management should be conducted.

REFERENCES

Adiningsih, J.S., M. Soepartini, A. Kasno, Mulyadi, dan W. Hartatik. 1996. Teknologi untuk meningkatkan produktivitas lahan sawah dan lahan kering. hlm. 297-322. Prosiding Temu Konsultasi Sumber Daya Lahan untuk Pembangunan Kawasan Timur Indonesia, Palu, 17-20 Januari 1994. Pusat Penelitian Tanah dan Agroklimat, Bogor.

Blackmore, L.C., P.L. Searle, and B.K. Daly. 1981. Methods for chemical analysis of soils. N. Z. Soil Bureau Sci. Rep. 10A Soil Bureau, Lower Hutt, New Zealand.

Buol, S.W., F.D. Hole, and R.J. McCracken. 1980. Soil genesis and classification. Oxford & IBH Publishing Co. New Delhi. 360 pp.

Djaenudin, D., Basuni, S. Hardjowigeno, H. Subagjo, M. Sockardi, Ismangun, Marsudi Ds., N. Suharta, L. Hakim, Widagdo, J. Dai, V. Suwandi, S. Bachri, dan E.R. Jordens. 1994. Kesesuaian lahan untuk tanaman pertanian dan tanaman kehutanan. Laporan Teknis No.7 Versi 1. Proyek LREP II, Pusat Penelitian Tanah dan Agroklimat. Bogor. 50 hlm.

Effendi, A.C. dan T. Apandi. 1981. Peta geologi skala 1:250.000 lembar Sumba, Nusa Tenggara Timur. Direktorat Geologi, Bandung.

Kawaguchi, K. and K. Kyuma. 1977. Paddy soils in tropical Asia: Their material nature and fertility. University Press of Hawaii, Honolulu. 258 pp.

Momuat, E.O. dan H. Malian. 1988. Prospek dan tantangan sistem usaha tani lahan kering iklim kering. Risalah Lokakarya Penelitian Sistem Usaha Tani. Pusat Penelitian dan Pengembangan Tanaman Pangan, Bogor.

Oldeman, L. R., Irsal Las, and Muladi. 1980. The agroclimatic map of Maluku, Irian Jaya, and Bali, West and East Nusa Tenggara. Contr. Centr. Res. Inst. Agric. Bogor.

Olsen, S.R., C.V. Cole, F.S. Watanabe, and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. US. Dept. Agric. Circ. 939.

Ponnamperuma, F.N. 1965. Dynamic aspects of flooded soils and the nutrition of the rice plant. p. 295-328. *In* IRRI. The mineral nutrition of the rice plant. Proc. Symposium International Rice Research Institute. The Johns Hopkins Press, Baltimore, Maryland.

Prasetyo, B.H., Sawiyo, dan N. Suharta. 1998. Pengaruh bahan induk tanah terhadap sifat kimia dan komposisi mineral. Studi kasus di daerah Pametikarata, Lewa, Sumba Timur. hlm. 17-30. *Dalam* U. Kurnia (Ed.) Prosiding Pertemuan Pembahasan dan Komunikasi Hasil Penelitian Tanah dan Agroklimat. Pusat Penelitian Tanah dan Agroklimat, Bogor.

Pusat Penelitian Tanah. 1982. TOR TIPE-A Survei Kapabilitas Tanah. Dukumentasi No: 1/1982. Proyek P3MT, Badan Penelitian dan Pengembangan Pertanian, Bogor. 50 hlm.

Pusat Penelitian Tanah dan Agroklimat. 1997. Pemetaan tanah tingkat semi detil daerah Pametikarata, Lewa, Kabupaten Sumba Timur, Propinsi Nusa Tenggara Timur. Laporan akhir. Pusat Penelitian Tanah dan Agroklimat, Bogor. 89 hlm.

Sanchez, P.A. 1973. Puddling tropical rice soils. Soil Sci. 115: 149-158.

Sanchez, P.A. and S.W. Buol. 1985. Agronomic taxonomy for wetland soils. p. 207-228. *In* Wetland soils: Characterization, classification, and utilization. Proc. workshop held on 26 March to 5 April 1984 at IRRI. Los Banos, Laguna, Philippines.

Soil Survey Laboratory Staff. 1991. Soil survey laboratory methods manual. SSIR Number 42. Version 1.0. United States Dept. of Agric., Washington DC. 611pp.

Soil Survey Staff. 1994. Keys to soil taxonomy. SMSS Technical Monograph No 6, 4th edition. Blacksburg, Virginia.

Schmidt, F.H. and J.H.A. Ferguson. 1951. Rainfall types based on wet and dry period ratios for Indonesia with Western New Guinea. Verh. 42. Jawatan Meteorologi dan Geofisika, Jakarta.

Sudharto, T., J. Triastono, E. Sujitno, A. Syam, dan Z. Zaini. 1995. Laporan Tahunan Proyek Penelitian Usahatani Lahan Kering TA 1994/1995. Pusat Penelitian Tanah dan Agroklimat, Bogor. 62 hlm.

van Wambeke, A. 1992. Soil of the tropics. McGraw-Hill Inc., New York. 343 pp.