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HYDROLOGY OF TROPICAL PODZOLS IN KALIMANTAN

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ABSTRACT

Three Soil Profile of Tropical podzols in Kalimantan heve been studied in order to understand its role to hydrology the lowland of Kalimantan.. Tropical podzols widespread in Kalimantan on flat to gently sloping lowland.. Morphology of the three observed profiles show the different stages of soil development. However, permeability of B-horizons of the three soils has reduced significantly. The reduction of soil permeability takes place as the consequences of the accumulation of aluminum/iron-organic complexes and clay minerals in B-horizon during Podzolisation. In developed podzols, both Bh and Bt horizons may behave as impermeable layers. Whereas in juvenile podzols, as shown by the profile of Kasongan, the role accumulated clay at Bt-horizon is more important than that of organic complexes in Bt-horizon. Therefore water infiltration into this soils and beneath groundwater is very limited. The physical properties of the soils indicates that almost all of rainfall in the lowlands of Kalimantan is immediately transforms into surface run-off, peat water or soil water. The physical properties of soils recommends that water resources management concept of podzols area and it surrounding require particular approach adapted to hydrological characteristics.

Key words: tropical podzol, Kalimantan

1. INTRODUCTION

Wetland is one of marked scenery in Kalimantan. Wetland culture of inhabitant appears not only at the estuarine and coastal area, but also spreads until hundreds of kilometers inland. It is well known that the real Kalimantan people, mainly Banjaresse, is very familiar to river and inundated land. Since the nature of vegetation cover is thick tropical forest, growth very commonly on peat or muddy surface, the fluvial network of rivers, streams, creeks and channels provide the preferred navigable axis for travel circulation of traditional people. Water leads also to the problem for regional development in Kalimantan. By its abundance, the constructions require special design to solve either direct problems such as inundation, water table etc. or indirect such as peat thickness, erosion, corrosion, etc. Therefore any activity concerning land development, mainly in the lowlands, always deal with the problem of hydrology. So far, the success of the important development in Kalimantan, such as timber exploitation, transmigration settlements establishments including the reclamation of one million hectares of peatlands for rice fields at the middle of 1990's, is not always as have been expected due to several natural constraints, among others, hydrological properties. In fact, the general properties of regional hydrology in Kalimantan is still little conceived.

The result of soil study in Lowland of Kalimantan show some important remark that soil properties of the area give a significant influence to the hydrology of this ecosystem. The objective of this review is to give the illustration how far the physical property of the soils, mainly tropical that of podzols, affect the hydrology of the lowland in Kalimantan.

2. MATERIAL AND METHODS

2.1 Geographic setting

Morphology of Kalimantan is characterized by vast extension of low lying plain which occupy the largest part of the island. The general feature of the island is dominated by flat and gently sloping relief, except in the mountainous chain of Meratus complex situated at the center part. The physiography of lowland consist of peat lands and wetlands, covered naturally by dense tropical rain forest. Drainage of the area shows an imbedded pattern, characterized by meandering channels and oxbowlakes.The climate is warm and humid. The average of annual precipitation in most part varied between 2500 to 3000 mm.

Geologically, the island of Kalimantan posses the vast extent of sedimentary rock. Quartenary sediments, where wetlands commonly occur, widespread from coastal area until the gently sloping transition to the high mountains that may distant up to 200 km inland. The formation actual low lying land of Kalimantan started by the end of sea level rise at about 5000 years BP. (Prasetyo et al.,1990). Based on geomorphological characteristics, Hirakawa, (2000) differentiated unconsolidated sediments in lowland plain of Kalimantan into: (1). Residual and weathering products of hard rock basement which is distributed mainly at the border of Meratus complex and around local outcropped basement commonly found at higher plain between 150 to 200 m asl. These landform is associated by red-yellow podsolic soils, represents sequence of "inselberg and pediments". (2). Kerangas plain, consists of arkose sand product of podsolization sand deposits, and (3) Holecene alluviation: River terraces and meander belts along river channel including deeper topogenous peat land accumulated on vast abandoned (drowned) drainage basin.

Humid climate is favorable to plant growth and maintain soil humidity, or even inundation, which is furthermore lead to organic matter accumulation on soil surface. The decomposition of organic matter produce acidity of water that percolate into soils induce to podzolisation. The product of podsolization is red yellow podsolik complex spread out mainly at higher and sloping area, whereas podzols (tropical podzols) occupy flat area. Except the high content in clay, yellow podzolik does not shows a special influence to hydrology. On the contrary, podzols shows some importances to the development of wetland in Kalimantan. Siefferman, (1980) estimate that humid climate of Kalimantan have took place since at least 30.000 years ago, therefore the occurrence of tropical podzols profile is supposed to be extended as submerged paleosoils that is actually covered by peat and younger alluvial deposits.

2.2 Methods

Three soil profile described in this report was observed at different location: at a gold mining excavations in (1) Mandor area, West Kalimantan, and in (2) Kasongan area, Central Kalimantan, whereas another profile was observed at excavated canal/ditch in (3) Kalampangan, Central Kalimantan. Composite and undisturbed samples have been taken from each horizon of observed profile for chemical and physical analyses. Major elements of mineral fraction and Fertility Analyses have been carried out following the method elaborated at the laboratories of R&D center for Geotechnology - LIPI. Mineralogical analyses have been carried out using Philips XRD analyzer with Cu-Kα radiation at two°/min rotation speed. Soil Physical properties have been analyzed at the laboratory of soil Physics in University of Agriculture Bogor.

3. RESULTS

3.1 Soil Morphology:

For most cases it is very difficult to dig a fresh pit for observation of complete tropical podzols profile in Kalimantan due mainly to high water table and to the great depth the solum. The soil profiles described below is an example of profiles which could be observed: two profiles were observed at an excavation where the water was pumped for gold mining in Mandor area, west Kalimantan and in Kasongan central Kalimantan, and one profile was observed at excavated canal/ditch at Berengbengkel central Kalimantan (Table 2). The complete morphology of podzols profile is summarized in Table 1. Normally, not all horizons could be identified in the field. Some horizons may be unidentifiable or lack due to the stage of their developments or erosion.

A-0 horizon could be presents as very thick peat deposits at inundated area. At undulating area, A-0 is thinner or lack. A1 and A3 normally thinner, whereas A2 and B-2 are generally thicker. The total thickness of soil profile in flat area may reach seven-eight meters, whereas at undulating area solum is generally less thick than in the flat area. In the dry undulating area, white sandy A-2 horizon could appear as soil surface. Moreover at severely eroded area, often all A-horizon was completely removed and B-horizon sinks at soil surface. In fact, the thickness of solum is not only related to topograpphy, the most important factor that determine the thickness of podzols are development stage. Douchafour (1977) noted that shallow podzols is related to juvenile stage of development.

Table1. Summarized Morphological characteristic of Tropical Podzols Profile.

Horizon	
A0	Vegetation litter or peat layer
A1	Mixture of organic and mineral fractions
A2 or E	White sands and silt consist of mainly quatrz., weakly structured or often structureless
A3	Transition A to B Horizon
Bh, or spodic, or placic	Mixture of sands and complex Allumunium and iron-organic, loose and structureless black brown sands, silt, and clay when wet and become hard, if dry.
Bt	Kaolinitic layers or sandy sediments and becoming Bt. Horizon if clay content is considerable.
B/C	Weathered parent materials containing freshly weatherable minerals.
C	parents materials.

Table 2. Horinzons depth and composition in observed profiles

	Profile location		
	Mandor West Kalimantan	Kalampangan Central Kalimantan	Kasongan Central Kalimantan
Horizon	depth (cm)		
A_0	0 - 5	0 - 150	0 - 10
A_1	5 - 20	150 - 170	10 - 30
A_2	20-100	170 - 300	30 - 80
A_3	100 - 110	-	-
B_1	-	-	-
B_2 : Bh	110 - 300	300 - 340	80 - 100
Bt		340 - (?)	100 - 250
B_3	-	-	-
C	>300	-	>250

The thickness of E Horizons in the profiles of Mandor and Kalampangan (150 and 130 cm) indicate that these soils are more developed than that of Kasongan (50 cm). The soil profile of Mandor shows a trace of important peat oxidation and erosion or: the thickness of A0 and A2 horizon seems very reduced comparing to B-2 which is theoretically the product of accumulation of leached materials from A-horizons. The morphology of Kasongan profile indicate that the development stage of this soil is younger than previous profiles. Since Bt horizon is much more thick than Bh horizons, it seems that this soils is developed on reworked parent materials.

3.2 Chemical and Mineralogical Properties.

Major elements composition and mineralogical properties (Table 3 and 4) represent the evidence of podzolisations in observed profiles. SiO_2 is clearly predominant in chemical composition in all horizons of all soil profiles (Table 3) that shows the acid character of soil parent materials is very marked. For every profile, the maximum content of SiO_2 is always found at E horizons, and reach over 90% of total content, showing that this horizons have intensively leached (elluviated). Whereas the trace of accumulation (illuviation) of transported material from A in B horizons appear by increasing content in Aluminum and less distinctly by iron. The increasing content of iron and aluminum is accompanied by increasing crystal H2O and/or lost of ignition (LOI). This support the assumption that a part of transported materials are illuviated as organic complexes or oxy-hydroxide such as haematite goethite or gibbsite. It is to be note that the trace of Aluminum and iron illuviation is less marked in Kasongan profile.

Table 3. Chemical composition of major elements (%)

Horizon	SiO_2	Al_2O_3	Fe_2O_3	MnO	TiO_2	P_2O_5	CaO	MgO	Na_2O	K_2O	H_2O	LOI
A1	89.86	1.83	0.04	-	0.62	0.97	0.11	0.02	0.06	0.49	0.79	3.53
A2/E	91.95	1.70	0.43	0.02	0.75	1.35	0.02	0.02	0.58	0.58	0.19	1.20
B	88.41	3.50	0.93	-	0.98	0.88	0.06	0.01	0.48	0.49	1.51	4.05
1E	91.62	7.13	0.08	0.001	0.25	0.13	-	0.006	0.02	0.07	0.17	0.49
1Bh	83.60	11.21	0.08	-	0.38	0.17	-	0.006	0.01	0.07	0.46	4.33
1Bt	75.57	11.04	0.55	0.006	1.18	0.14	-	0.002	0.17	0.29	0.49	10.99
2A1	84.45	11.12	0.01	0.006	0.61	0.15	-	0.009	0.01	0.09	0.29	0.23
2A2	97.91	-	0.08	0.001	0.81	0.17	-	0.001	0.01	0.09	0.23	0.52
2Bh	85.43	6.77	0.09	0.002	0.93	0.15	-	0.003	0.02	0.09	0.36	6.27
2Bt	82.16	12.39	0.11	0.003	0.39	0.17	-	0.002	0.17	0.18	0.26	3.96
2B/C	92.86	-	0.18	0.001	0.25	0.14	-	0.003	0.18	0.27	0.39	5.61
2C1	57.43	19.16	0.69	0.007	1.02	0.10	-	0.014	0.49	0.16	1.03	20.65

XRD diagrams shows that quartz is the only mineral could be detected in A horizons of Kasongan and Kalampangan. Kaolinite presents in B Horizons. Weatherable minerals found were Plagioclas Feldspar at B/C horizon and illite (or a species of mica) at Bt horizon in Kasongan profile.

3.3 Physical Properties:

The analyses results of some physical properties of profiles from Kasongan and Kalampangan (Table 2). In general, Bulk Density of soils tend to increase from A to B-Horizons, whereas porosity and permeability tend to decrease. The percentage of very rapid drainage pores shows also the decreasing tendency from surface to B-horizons. This property could signify that both process of eluviation at A-horizons and illuviation at B-horizons occured in a constant volume. The transported materials from A-horizons was deposited at porespace of B-horizons and reduce the porespace.

Sandy soils is normally related to high porosity. However, it is not the case of these soils. Even though grain size analyses results that soil texture was predominated by sand fraction, the finer particles fill the inter-granular pore space in such a way that the continuity of porosity is reduced. In kerangas forest, soils have such a bad drainage that inundation and flooding usually happen after heavy rainfall. After physical properties of the soil, B-horizons particularly Bh or Bt are the zones, of minimum porosity that restrain water infiltration into deeper layer. This low permeability characteristics (tested by 5 cm thick undisturbed samples) could become much more important with greater thickness and could behave as impermeable at a certain expanse

Table 4. Mineralogical composition

Location	Horizon	Quartz	Felspar	Kaolinite	Illite
Kalampan-gan	E	+++	-	-	-
	Bh	+++	-	-	-
	Bt	++	-	++	-
Kasongan	A1	+++	-	+	-
	E	+++	-	-	-
	Bh	+++	-	-	-
	Bt	++	-	++	+
	B/C	++	+	++	-

+++: Abundant; ++; Many; +: Few ; - : Undetected

Table 5. Some physical characterisics of soil horizons in the Kalampangan and kasongan profiles.

	Ho ri- zon	Depth (cm)	Bulk Den- sity	Poro sity (%)	drainage pore (%)			Avail- able water (%)	Perme ability (cm/h r)	De- scrip tion
Location					v.rapi d	rapi d	Slow			
Kalampan- gan	A0	0-150	0.22	85.3 3	11.54	3.73	2.01	29.94	39.67	Peat
	E	170- 300	1.53	42.2 6	11.40	18.5 9	3.69	6.42	37.05	
	Bh	300- 340	1.89	30.0 0	1.03	4.83	3.94	11.28	0.02	
	Bt	340-	1.33	49.8 1	4.52	2.10	2.25	11.01	0.80	
Kasongan	A1	10-30	1.38	47.9 2	7.00	13.2 5	10.4 6	8.43	23.03	
	A2	30-80	1.58	40.3 8	15.42	19.6 0	1.64	1.41	77.75	
	Bh	80-100	1.73	34.7 2	0.07	2.06	7.80	7.20	44.12	
	Bt	100- 250	1.73	34.7 2	2.78	1.92	2.82	8.60	1.03	
	B/ C	250-..	1.43	46.0 4	0.31	1.69	3.67	7.88	0.02	
	C1		0.87	67.1 7	5.28	3.09	1.61	19.81	0.82	

4. DISCUSSION

Morphology of the three observed podzols profiles show different development stage. However, permeability of B-horizons of the three soils has reduced significantly. The reduction of soil permeability take place as the consequences of the accumulation of aluminum/iron-organic complexes and clay minerals in B-horizon during Podzolisation. In developed podzols, both Bh and Bt horizons may behave as impermeable layers. Whereas in juvenile podzols, as shown by the profile of Kasongan, the role accumulated clay at Bt-horizon is more important than that of organic complexes in Bt-horizon.

The podzols was defined at the end of last century by Russian scientists to name the ash soil of taiga. Podzols, (or spodosols acorrding USDA Soil Taxonomy term), occur frequently in the tropics. It differs from those in temperate climate by great thickness of their solum that is normally also named as *giant podzols*. Tropical podzols are the best developed in the lowland under continually wet climate (Mohr et al., 1972) with acid coarse-textured unconsolidated parent materials (Duchafour, 1977). Podzolisation, as described by many authors(Mohr et al, 1972; Duchafour, 1977; Buol et al, 1980) could be summarized as a soil development process characterized by acid leaching. The acidity is originated mainly from organic compounds. Percolation of acid solution transports the ions of Aluminum and iron and any other cations under forms or either organic-complexes or free ions to depth. Humic compounds accumulate in Bh Horizons, whereas other free ions accumulate as secondary clays and frequently form Bt Horizon or precipitated into various secondary minerals along the percolation column. The remnant of elluviation horizon is found as quartz rich, fine white sands of A2 or albic horizons.

Podzolisation is the major phenomenon in Kalimantan. Podzols are a climatic climax soils that have reached the end of development at the state of equilibrium with vegetation. The younger stages is red-yellow podzolic that in Kalimantan is found at less weathered parent materials at the hilly areas. The typical podzols of Kalimantan is found under kerangas forest where each soil horizons has clearly differentiated, mainly into O, A1, A2, and Bh, whereas the others horizons, such as Bt and transition horizons, is not always clearly appear (Tabl. 1).

The amount of water Infiltration into the soils is determined by the least permeable layers within the soils. In the case of podzols, even though the major constituents of mineral fraction are sands, the accumulation of iron and Aluminum organic complex in Bh Horizon and Clay in Bt. Horizon has diminished the porosity, therefore these horizons is became the major restrain for water infiltration. The soil absorbs water only at the layers above these horizons. At the sloping area, and also the sloping spread of these impermeable layers, the lateral percolation may occur. Since the Podzols of Kalimantan occupy mainly on flat and gently sloping area, in most area the percolation of water table will be very weak, even stagnant. When the upper part of the soils has already saturated, therefore all rain water that reach the soil surface will be transformed into surface run off or inundation water. The recent study on water balance in upper catchment of Sebangau River have been conducted by KAYAMA *et al.* (2000). The results shows that most of rainfall is transformed into surface run off (59,8 %) and evapotranspiration. Whereas groundwater storage (<10%) is transformed into ground water level change. TANAKA *et al.* (2000) have studied the isotopic composition on water collected from rain water, lake water, river water and ground water from peat ponds, and wells of the lowlands of Kalimantan. The results shows that ground water was found to be isotopically lightest among the water samples, and rain water collected in both dry and rainy seasons was heaviest of all. Its indicate that ground water has to be originated from the water supply other than the local precipitation. Isotopic properties of water indicate that in situ rainwater recharges negligible amount to the ground water. Most of groundwater originated from the remote recharge area in the upstream of the area, mainly of the high altitude as shown by isotopically light characteristics. The chemical composition of water above, beneath, and within Bh and Bt Horizons shows also different chemical composition (SUHERMAN et al., 2000). Even though groundwater of Kalampangan contain high soluble organic matter (humus)in all depth untill 12 m, solutes composition is significantly different. The water above Bh and Bt Horizon have higher Electrical Conductivity and Acidity. The solutes composition of Bh and Bt water is characterized by high content of magnesium replacing Ca which is the main cation in surficial and deeper groundwater.

5. CONCLUSION

The above studies suggest that the permeability of podzols is low due to the development of illuviated (Bt and Bh) horizons by which water infiltration to deeper layer is hampered. The great extent of Podzols in Kalimantan importantly influence the hydrology the area and its surrounding. This area supply high amount of surface run off, subsurface water, and/or peatwater to the coastal and the lower elevated wetlands. Under vegetation cover, due to the high humidity, podzols terrain is still productive for peat accumulation, that characterize the chemical properties of water by high content of humus and acidity. Whereas under open condition, high water flow may cause severe erosion due to the loose property of sandy A2 Horizons, mainly when covering peat was removed. The particular hidrological properties of podzols terrain and its surrounding recommends that water resources management concept of the area require a special approach adapted to the characteristics of the environment. Deep groundwater exploitation in this area have also to be evaluated, mentioning that podzols terrain is not a good recharge area. Surface and subsurface water is still to be considered as the most important resources.

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