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Relationship between Organic-C and Available-P Due to Tidal Fluctuation in South Kalimantan

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ABSTRACT

Tidal fluctuation creates different soil chemical properties which is totally deviate from normal circumstances. Organic matter decomposition occurs with limited O2 supply, hence disturbing Carbon cycle which has a central role in the process and nutrient mineralisation. The research aimed was to describe the relationship between organic-C and available-P due to tidal fluctuation in South Kalimantan. Ten undisturbed composite samples were collected in top-soil and sub-soil. Results showed that there was no direct effect from organic-C in P availability as in other mineral soils. However, there was an indication that the relationship was influenced by maturing process of the soil. In other words, the relationship between organic-C and available-P was typical for every type of swampland and was not related to the tidal fluctuation.

Keywords: Available-P, organic-C, P-transformation, tidal water fluctuation

INTRODUCTION

Tidal swamp lands in South Kalimantan are the most important areas for food security program in the province and the neighbourhood. South Kalimantan has no active volcano, yet the region still manages to be among the top ten highest rice producers in Indonesia (BPS 2006 cited by Wurjandari and Syam 2007). Those productive areas are located in Barito Kuala and Banjar Regencies, as well as Banjarmasin City, and are well known as rice-belt to support South, Central, and East Kalimantan (BPS Kalimantan Selatan 2001). Banjarese local knowledge on soil and water management from these areas has been known and survived for centuries (Watson and Willis 1985). The areas contribute around 30% provincial rice production and second highest production after irrigated rice field (Dinas Pertanian Tanaman Pangan dan Hortikultura Provinsi Kalimantan Selatan 2011; Hidayat 2010). Nevertheless, increasing demand from population boom and land conversion creates pressure to the equilibrium and tends to be unmanageable. Hybrid-seed introduction always failed as farmers are unfamiliar with fertilisation as an integral part of the program. Therefore, an updated knowledge on plant nutrition in such kind of environment is important, especially in relation to land characteristics.

Water fluctuation due to tidal movement creates typical chemical characteristics which are different from common conditions. Soil pH and redox potential are key components for tidal wetlands to function in agrichemicals or nutrients availability. Tides, seasons, and drainage systems correspond to daily, annual, and longer-term dynamics are conflicting factors in interpreting and characterising the soils (Jansen *et al.* 1992; Anda *et al.* 2009). When submerged, soil pH values are between 6 to 8 and drop drastically when oxidized (Seybold *et al.* 2002). Organic matter decomposition occurs in O_2-deprived conditions which disrupt C cycle. Whereas the cycle is a central point of other nutrients mineralisation processes (Cresser *et al.* 1993) in ecosystem. Furthermore, C mineralisation itself has an important role in phosphate adsorption (Leytem *et al.* 2002; Sinaj *et al.* 2002) due to organic ligands which react with sesquioxides to avoid P fixation and P adsorption in the soil (Iyamuremye and Dick 1996; Haynes and Mokolobate 2001). Consequently, water fluctuation was hypothesised to affect P availability and its transformation in soils, either due to pH-affected P solubility or mineralisation through ligand exchange.

The research aimed was to describe the relationship between organic-C and available-P due to tidal fluctuation in South Kalimantan, Indonesia.

MATERIALS AND METHODS

Study Sites

The study was conducted as soil sample description. There were four locations of sampling, *i.e.* (1) soils which always inundated, either in low or high tides (submerged, Type A), (2) soils which only inundated when high tide and dry when low tide (fluctuate, Type B), (3) soils similar to number 2 but higher altitude (Type C), and (4) soils which were not inundated and dry, either in low and high tides (aerobic, Type D). The division of the area was according to Kselik (1990). All four locations were purposively sampled in two layers (top- and sub-soil; 0-30 and 30-60 cm), so that all samples were 10 × 2 (horizons) × 4 (water fluctuations) = 80 individual samples (Table 1). All locations must be undisturbed lands (mostly at the edge of primary or secondary canal, no farming activities noticed and recorded) and sampled with auger, 50 to 150 m apart for each replicate. Canals usually had a width between 4-6 m, enough to transport rice with a motorcycle, carriage, or even small truck (pick-up).

Experimental Design

In statistical term, the experiment was conducted in factorial Completely Randomised Design with tidal types (Type A, Type B, Type C, and Type D) as the first factor, and soil horizons (top and sub-soil) as a second one.

Preparation of Soil Samples

Samples were air-dried in weaved-bamboo container (*nyiru*), and stacked in racked drying room. Samples were sieved with diameter of ≤ 2 mm and kept in glass jars for further laboratory analyses. Soil parameters of C and P were determined by standard methods (Walkley & Black for organic-C, 1 *N* HCl for total-P, and Bray-I for available-P) in Physics and Chemistry Laboratory of Soil Department, Faculty of Agriculture, Lambung Mangkurat University.

Data Analysis

Statistical analyses were performed with GenStat 6.0, especially ANOVA and mean comparison (LSD = least significant different 5%) for the above mentioned factors. While regression and correlation analysis was calculated with SPSS 16 when needed for organic-C, total-P, and available-P.

RESULTS AND DISCUSSION

Results from data analyses (ANOVA) showed that there were variations among parameters in every sampling location (tidal types). Hence, statistical procedures with GenStat 6.0 and SPSS 16 were needed in order to see the difference.

Results from statistical procedures showed that only tidal types related to organic-C content in the soil. While sampling depth or interaction of both were not significantly different. Type of tidal, from Type A to Type D, had different organic-C concentrations and the trend was increasing from Type A to Type D (Table 2). This was also recorded

Table 2. Mean comparisons for organic-C concentrations in all tidal type lands in Barito Kuala Regency.

Tidal-type lands	Organic-C concentrations (%)
Type A	2.36 a
Type B	3.30 b
Type C	2.27 a
Type D	3.40 b

Values followed by different letters represent significant difference according to LSD 5% (0.719%).

Table 1. Tidal types, horizons, and number of samples for laboratory analyses.

Tidal-type lands	Villages	Depth (cm)	Number of samples
Type A (submerged)	Tamban	0-30	10
		30-60	10
Type B (fluctuate)	Mekarsari, Anjir	0-30	10
		30-60	10
Type C (fluctuate)	Mekarsari, Anjir	0-30	10
		30-60	10
Type D (aerobic)	Kolam Kanan, Barambai	0-30	10
		30-60	10
Total			80

Table 3. Mean comparisons for total-P concentrations in all tidal-type lands in Barito Kuala Regency.

Tidal-type lands	Total-P concentrations (%)
Type A	0.23 a
Type B	1.00 b
Type C	0.99 b
Type D	1.27 b

Values followed by different letters represent significant difference according to LSD 5% (0.567%).

Table 4. Mean comparisons for available-P concentrations in all tidal-type lands in Barito Kuala Regency.

Tidal-type lands	Available-P concentrations (mg kg^{-1})
Type A	18.5 a
Type B	20.6 a
Type C	45.2 b
Type D	40.4 b

Values followed by different letters represent significant difference according to LSD 5% (8.60 mg kg^{-1}).

for total-P (Table 3). The availability of P, expressed in available-P, similar to organic-C and total-P concentrations, was significantly different due to tidal types as presented in Table 4.

Scattered diagram between two correlated parameters is expressed in Figure 1. Meanwhile, similar diagram between total-P and available-P can be seen in Figure 2. The trend of relationship between organic-P with total-P and available-P in both figures confirmed the correlation among parameters expressed in Table 5, especially with r = 0.43** (between organic-C and total-P) and r = 0.42** (between total-P and available-P).

An interesting phenomenon was recorded on the increase of correlation coefficient (r) between organic-C and available-P (Table 6). The increase was in line with the decrease of water fluctuation effect on the land.

In order to know whether the relationship was related to cause-effect cycle, multiple regression analysis was performed with the assumption that organic-C affects P-availability in tidal swampland. Linear regression was chosen for simplicity and performed with all soil samples available.

The regression equation was as follows:

Available-P = 25.80 + 7.92 total-P – 0.55 organic-C, where R^2 = 0.15.

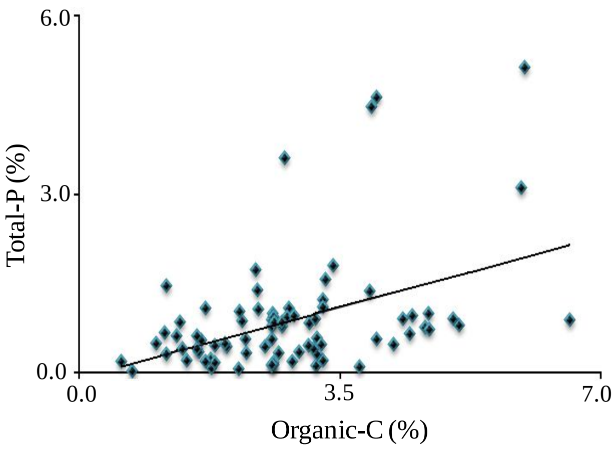

Figure 1. Scattered diagram between organic-C and total-P in all soil samples from tidal swampland of South Kalimantan. Straight line is trendline for the relationship.

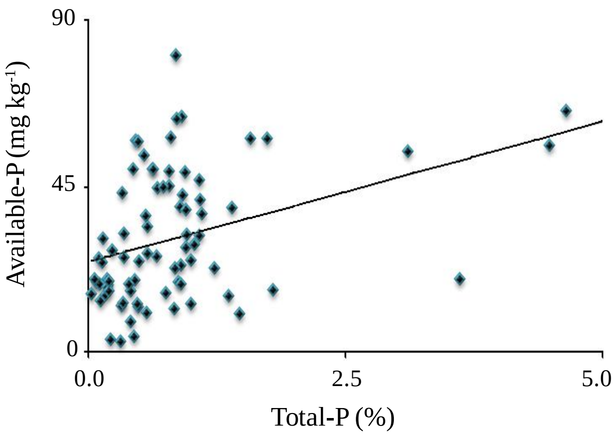

Figure 2. Scattered diagram between total-P and available-P in all soil samples from tidal swampland of South Kalimantan. Straight line is trendline for the relationship.

This equation was not in accordance that available-P is dependent on total-P and organic C in its transformation process in mineral soils. There were more variables affecting the overall process. In this research, time was really an important variable as expressed in Table 6.

From analysis of variance and mean comparison it can be concluded that organic-C, available-P, and total-P tended to increase as tidal type changing from Type A to Type D. In other words, when water fluctuation was not occurring, mineralisation process was more intensive as O_2 supply was abundance.

Organic-C concentration was not correlated to available-P, even though had a significant correlation with total-P (Table 5). It can be assumed

Table 5. Pearson correlations for all related parameters in soil samples from all tidal types in Barito Kuala Regency.

	Organic-C	Total-P	Available-P
Organic-C	1.00	0.43**	0.15
Total-P	0.43**	1.00	0.42**
Available-P	0.15	0.42**	1.00

** = Significantly different at 0.01 level acoording to Pearson Correlation.

Table 6. Correlation coefficients between organic-C and available-P in all tidal types in Barito Kuala Regency.

	Tidal type lands			
	Type A	Type B	Type C	Type D
Correlation coefficients	-0.01	0.24	0.31	0.35

that there was no significant cause-effect relationship between organic-C and available-P in the area, in contrast as reported by some researchers (Condron *et al.* 1990; Yusran 2005; Yusran 2010b). Ligand exchange process might not occur to explain the strong relationship between organic-C and available-P, especially in soils with intensive weathering mechanism (Iyamuremye and Dick 1996; Haynes and Mokolobate 2001; Yusran 2010a) nor chelating process (Haynes and Mokolabate 2001; Tiessen *et al.* 1998).

The increasing positive correlations were recorded between organic-C and total-P in every type of tidal area as the coefficient (r) was higher from Type A to Type D (Table 6). In line with those correlations, similar correlations were also found between organic-C and available-P but with lower r values. Hence, the more developed the soils, which characterised by higher land altitude from sea surface, the stronger the relationship between organic-C and total-P, as well as available-P.

According to regression analysis, the equation can be expressed as, the availability of P in tidal swampland was highly dependent ($P < 0.001$) on total-P concentration, but independent ($P = 0.744$) from organic-C, both simultaneously. These relationships were also previously related in correlation analysis.

CONCLUSIONS

Organic-C concentration had no role in P transformation process to phosphate in tidal swampland, even though the indication toward such role existed. The availability of P, expressed in available-P, did not significantly depend on total-P concentration in soils. It was predicted that soil formation process will make the relationship stronger, but not the water fluctuation. In other words, the relationship between organic-C and P availability in tidal swampland was typical and different from type to type of land. Therefore, common P transformation which affected by organic-C in mineral soils was not found in tidal swampland.

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REFERENCES

Anda M, AB Siswanto and RE Subandiono. 2009. Properties of organic and acid sulfate soils and water of a ‘reclaimed’ tidal backswamp in Central Kalimantan, Indonesia. *Geoderma* 149: 54-65.

Condron LM, JO Moir, H Tiessen and JWB Stewart. 1990. Critical evaluation of methods for determining total organic phosphorus in tropical soils. *Soil Sci Soc Am J* 54: 1261-1266.

Cresser M, K Killham and T Edwards. 1993. *Soil Chemistry and Its Applications.* Press Syndicate, The University of Cambridge. Cambridge, USA.

Dinas Pertanian Tanaman Pangan dan Hortikultura Provinsi Kalimantan Selatan. 2011. *Laporan Tahunan.* Dinas Pertanian Tanaman Pangan dan Hortikultura Provinsi Kalimantan Selatan, Banjarbaru (in Indonesian).

Haynes RJ and MS Mokolobate. 2001. Amelioration of Al toxicity and P deficiency in acid soils by additions of organic residues: a critical review of the phenomenon and the mechanisms involved. *Nutr Cycl Agroecosys* 59: 47-63.

Hidayat T. 2010. Kontestasi sains dengan pengetahuan local petani dalam pengelolaan lahan rawa pasang surut Kalimantan Selatan. [Dissertation]. Institut Pertanian Bogor, Bogor (in Indonesian).

Iyamuremye F and RP Dick. 1996. Organic amendments and phosphorus sorption by soils. *Adv Agron* 56:139-185.

Jansen JAM, W Andriesse, H Prasetyo and AK Bregt. 1992. *Guidelines for soil survey in acid Sulphate Soils in the Humid Tropics; The Main Problems Considered*. AARD and LAWOO. ILRI, Wageningen, The Netherlands.

Kselik RAL. 1990. Water management on acid sulphate soils at Pulau Petak, Kalimantan. In: *AARD/LAWOO Papers Workshop on acid sulphate soils in the humid tropics*. Bogor, November 1990. AARD, Bogor. pp. 249-276.

Leytem AB, RL Mikkelsen and JW Gilliam. 2002. Sorption of organic phosphorus compounds in Atlantic coastal plain soils. *Soil Sci* 167: 652-658.

Seybold CA, W Mersie, J Huang and C McNamee. 2002. Soil redox, pH, temperature, and water-table patterns of a freshwater tidal wetland. *Wetlands* 22: 149-158.

Sinaj S, C Stamm, GS Toor, LM Condron, T Hendry, HJ Di, KC Cameron and E Frossard. 2002. Phosphorus exchangeability and leaching losses from two grassland soils. *J Environ Qual* 31: 319-330.

Tiessen H, E Cuevas and IH Salcedo. 1998. Organic matter stability and nutrient availability under temperate and tropical conditions. *Adv Geoecol* 31: 415-422.

Watson GA and M Willis. 1985. Farmers' local and traditional rice crop protection techniques: Some examples from coastal swamplands, Kalimantan, Indonesia. *Indon Agric Resour Develop* 7: 25-30.

Wurjandari D and M Syam. 2007. *Data penting padi dunia dan beberapa negara Asia: Luas panen, produksi, hasil, konsumsi, varietas, pupuk.* Pusat Penelitian dan Pengembangan Tanaman Pangan and IRRI, Bogor (in Indonesian).

Yusran FH 2005. Soil Organic Matter Decomposition: Effects of Organic Matter Addition on Phosphorus Dynamics in Lateritic Soils. [Thesis]. The University of Western Australia.

Yusran FH. 2010a. The relationship between phosphate adsorption and soil organic carbon from organic matter addition. *J Trop Soils* 15: 1-10.

Yusran FH. 2010b. The balance between respiration and leaching, and phosphorus mobility in lateritic soils. *J Trop Soils* 15: 245-254. doi: 10.5400/jts.2010.15.3.245.