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IJERST

International Journal of Engineering Research and Science & Technology

ISSN : 2319-5991
Vol. 6, No. 2
May 2017

www.ijerst.com

Email: editorijerst@gmail.com or editor@ijerst.com

International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com
Vol. 6, No. 2, May 2017

Research Paper

EVALUATION OF SOME SOIL CHEMICAL PROPERTIES OF TIDAL SWAMP LAND AFTER LONG-TERM CULTIVATION

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Tidal land is an acidic soil and has low fertility due to high acidity and low nutrients. The objective of this research is to evaluate the tidal land after long-term cultivation. Twelve soil samples af arable layers were collected at four typologies which are A, B, C and D types. Soil variables observed were pH, total N, organic C, Cation Exchange Capacity, P, Al and H-exchangeable and basic cations. After long-term cultivation, these soils had still high organic carbon and cation exchange capacity but low pH, Ca, Mg and total N. Relatively, high content of nutrient was found on Na and P. To improve infertility, farmers applied NPK in high rate which were 1000 kg ha^{-1} for corn and 600 kg ha^{-1} for rice. This soils had low pH and low nutients. However these soil has potential to be cultivated for agriculture after improving pH and alleviating Al and pyrite.

Keywords: Tidal land, Acid sulphate soil, Macro elements, Pyrite, Land typology

INTRODUCTION

About 16.68 million ha mineral soils of tidal swamp land are distributed in Indonesia and from which about 4.19 million ha of acid potential soils have been reclaimed for agriculture and transmigration area and other of 5.34 million ha is still being used as agricultural development (Budianta and Windusari, 2016). Tidal swamp development in South Sumatra has been performed by Indonesian Government since 1969 which was started in PELITA I (The first five-year development phase) 1969-1974 period that Indonesian Government had opened the tidal swamps about 22,000 ha in the province of South Sumatra and Jambi (Koswara and Rumawas, 1984), but Bugis farmers from South Sulawesi had previously developed this area since 1930s (Imanudin *et al.*, 2010). Tidal swamp areas in South Sumatra are located along eastern coast of Sumatra and approximately covered 2.92 million ha (Euroconsult, 1995). This tidal swamp is usually used for rice growth because in wet

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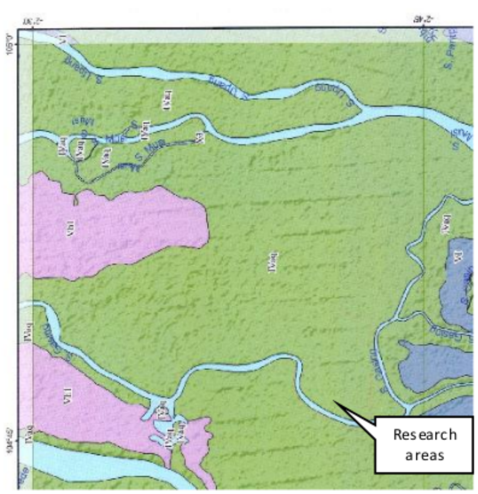
condition pyrite will be stable (Hairani *et al.*, 2005), but the most important constraint to rice growth on these soils were: (1) acidity (which includes the combined effect of pH, Al toxicity and P deficiency), and (2) Fe stress which was due to the combined effect of Fe toxicity and deficiency of other divalent cations such as Ca, Mg (Moore *et al.*, 1990). The total area of tidal swamp in South Sumatra that had been reclaimed is 373,000 ha and now this land is highly dependent on water supply from rainfall because high tide irrigation can not reach in the land (Imanudin *et al.*, 2010). The tidal swamp soil is characterized by poor chemical properties such as low soil pH and high in Fe and Al concentration (Masulili *et al.*, 2016) in combination with high rainfall and effect tidal movement make this area have excessive water in a certain period in the year (Purnomo *et al.*, 2008), especially in areas which have not been reclaimed. In these soils called acid sulfate soil (Dent, 1986), acid sulfate soil is formed in marine or brackish environment (Ilona *et al.*, 2012). Elements such as iron and aluminum are released to soil solution in large amount, while essential macro nutrients like phosphorus and nitrogen become fixed in the soil resulting in unavailable for plant growth (Dublin-Green and Ojanuga, 1988).

Acid sulfate soils with pH below 3.5 will have toxicities of H^+, Al^{3+}, SO_4^{2-} and Fe^{3+} causing a decrease in soil fertility due to low soil bases and essential macronutrients such as N, P,K,Ca,Mg (Hairani *et al.*, 2005; Ristiani, 2012; and Budianta *et al.*, 2012) with values of 0.18% N, 14 mg kg^{-1} P, 0.40 (cmol(+)kg^{-1}) K, 1.08 (cmol(+)kg^{-1}) Ca and 1.30 (cmol(+)kg^{-1}) Mg (Nursanti, 2014) and low essential micro element such as Mn, Zn, Cu and Mo (Fami and Hanudin, 2008). Due to low fertility faced in acid sulfate soils, food crops cannot grow optimal in these condition with low production (Hairani *et al.*, 2005), farmers should apply fertilizers in high rate. In this infertile soil, food crop will be produced in low quantity. Thus, the objectives of this study is to evaluate some soil chemical properties of tidal swamp land that has been cultivated more than 30 years for food crops (corn and rice) production in South Sumatra, Indonesia.

MATERIALS AND METHODS

Some soil samples were collected at arable layer from different tidal swamp typologies which are A, B, C, and D respectively. All soil samples were located in Banyuasin Regencey covered about 2,489.55 ha and distributed in Mulia Sari and Banyuurip Villages belonged to Telang II and divided into 12 soil samples (Figure 1). Geographically soil samples were taken in coordinates locations about S 02°41'24", E 104°45'25" for A, S 02°39'26" E 104°44'27" for B, S 02°39'44", E 104°44'027" for C, and S 02°38'37", E

Figure 1: Map of Agroecology in Location of Soil Samplings



104°43'16" for D land typologies respectively. All soil samples were taken in dry season and the A land typology condition was bare soil with some swamp grasses growth, meanwhile in B, C, and D typologies respectively were planted corn in mature condition. Farmers always fertilizes the rice with dosage of 600 kg NPK per ha and 1, 0 t ha^{-1} for corn crops.

The soil samples were then brought to the laboratory of Soil Science Department, Faculty of Agriculture, Universitas Sriwijaya to prepare for soil analysis. The samples were dried, ground and sieved with 0.5 mm sieve diameter. Variables observed were soil pH (1;1, soil:water (Tohmas, 1996), organic-carbon (Nelson and Sommers, 1996), total N (Bremner, 1996), P (Bray-I) (Kuo, 1996), K, Na, Ca and Mg-exchangeability (Ammonium acetate pH: 7.0 (Helmke and Sparks, 1996; and Suarez, 1996). Na and K determined by a flame photometer and Ca and Mg were determined by atomic absorption spectro photometer. Cation Exchange Capacity (CEC) was determined by extraction using the NH_4Oac pH:7 (Sumner and Miller, 1996) and Al-exchangeability were extracted by 1 N KCl (Bertsch and Bloom, 1996). Pyrite was determined by measurement of Sulfur (Tabatabai, 1996).

RESULTS DAN DISCUSSION

Landuse Condition at Soil Sampling Areas

Twelve soil samples of arable layer at the depth of 0-20 cm which were distributed in four distinguished typologies were collected from farming areas in the dry season, in August 2016. The sampling were taken from two transmigration areas of Telang II of Tanjung Lago, Banyuasin Regency, South Sumatra, Indonesia and located in Mulia Sari and Banyu Urip villages. Since 1981, this tidal swamp had been reclaimed and about 13,800 ha of the areas are potentially for agriculture (Marlina *et al.*, 2015). In the two places of soil samples consists of 4 different land typologies of swampy land which are A and B typologies located in Mulia Sari and C and D typologies were placed in Banyu Urip. The agricultural landuse in the vicinity of research area can be seen in Table 1.

The four types of swampy tidal land typologies in Mulia Sari and Banyu Urip based on the overflow of water consisted of (1) type A, flooded both during low and high level of tide, (2) type B, flooded only when high level of tide, (3) type C, never flooded even during high level of tide and the depth of ground water < 50 cm, and (4) type D, never flooded even during level high of tide and the depth

Table 1: Distribution of Agricultural Landuse in the Vicinity of Research Area (Intimulya Multikenncana, 2009)

No	Villages	Agricultural Coverage (ha)	Type of Crop
1	Tegal Sari	1,787.27	Coconut: 48.17 ha
			Oil Palm: 135.43 ha
			Ric : 1,603.40 ha
			Tertier blok average: 44 ha
2	Mulia Sari	1,057.70	All rice crop Tertier blok average: 44 ha
3	Banyu Urip	1,431.85	All rice crop Tertierblok average: 44 ha
4	Bangun Sari	1,431.85	All rice crop Tertier blok average: 44 ha
5	Sumber Mekar	785.93	All rice crop Tertier blok avergae: 44 ha

of ground water > 50 cm (Widjaja Adhi *et al.*, 1992; and Rahim *et al.*, 2015). During soil sampling at the two villages, conducted in dry season and in Mulia Sari, were found type A and B in south region at the nineteenth of south bridge and third of north bridge respectively (Rahmi *et al.*, 2015), meanwhile type C and D were obtained in Banyu Urip at the fourth of south bridge and at the fourth of north bridge respectively. With high rate fertilization in these Swamp lands, it was harvested around 4-7.5 t/ha rice in Mulia Sari. Meanwhile, type C of the swamp land in South Kalimantan was planted soybean, after the soil improved by liming and fertility and getting increase of soybean about 2.4 t/ha^{-1} (Wijanarko *et al.*, 2016).

Evaluation of Tidal Swamp Land After Longterm Cultivation

Tidal swamp lands are generally considered as a marginal and fragile ecosystems, but the lands have potential to be utilized for the development of food crops such as rice, soybean and corn, as well as horticulture crops like citrus and vegetables (Koesrini *et al.*, 2013; and Koesrini *et al.*, 2014). According to Widjaya Adhi *et al.* (1992), that wetlands are distinguished based on arrival, influences the tidal water in the rainy season and the influence of sea water in the dry season, is divided into three zones, namely: 1) tidal brackish (zone I), 2) tidal fresh water (zone II) and non tidal (zone III). The tidal land based on agro-ecosystem can be divided into four main typologies of potential lands, acid sulfate lands, peat lands and saline lands. 1) Potential land is a land of upper layer of 0-50 cm, has a low pyrite content of 2% and has not undergone a process of oxidation. 2) Acid sulfate land is a land that has a layer of pyrite or sulfidic at depth <50 cm and all the land that has sulfuric layer, although the depth of the layer piyrite > 50 cm. Pyrite layer is a layer or layers of sulfidic soil with the pyrite levels > 2%. Sulfuric horizon is a layer that shows the jerosite (brownlayer) or pyrite oxidation process pH (H_2O) <3.5. Acid sulfate land is divided into (i) actual acid sulfate land, and (ii) potential acid sulfate land that is not or has not undergone the process of pyrite oxidation. 3) Peatlands are wetlands that have a layer of peat and peat thickness is characterized by shallow peat (thickness 50-100 cm), peat medium (thickness of 100-200 cm), deep peat (200-300 cm) and deep peat (>300 cm). Muktamar and Adiprasetyo (1993) said that peats have great prospects for the cultivation of crops. For coconut and oil palm cultivation can be carried out on peat medium and deep. 4) Saline land is land that received saline brines influence, when under the influence of seawater/ salty over 4 months of the year and the content of Na in soil solution of 8% to 15%. Tidal swampland based hydrotopography divided into four types which require different management. Type A is the area of the swamp which is always a big tide overflow and small pairs. Type B is the only land with a tidal overflow. Type C is a land that is not overflowing with the tide, both pairs of large and small pairs, but the depth of ground water is less than 50 cm from the soil surface. Type D does not overflow tidal land both pairs of large and small pairs, but the depth of ground water for more than 50 cm from the soil surface. Based on agro-ecosystem, Mulia Sari and Banyu Urip have potential acid sulfate lands and tidal fresh water. Farmers plant rice, corn and coconut in their land to fulfill their life and getting income. To understand more the some soil chemical properties of tidal swamp after 30 years ago opening of these lands, it will be discussed in the next section.

Soil pH, H^+ and Al^{3+} Exchangeability

Soil acidity shown by low pH is one of the most factors affecting crop production, because some nutrients are difficult to be available for plant growth in acidic condition. Low pH in acid sulfate soil is due to natural process and/or due to roots that produce organic acids leading to low pH value (Tuyent et al., 2006). Acidic condition enhances the presence of trivalence cations (Al^{3+}), which are the most toxic of Al to plant (Kochian et al., 2005). In this tidal swamp showed that the soil pH level is below 5,0 after 30 years old cultivation with avalue of pH ranging from 4.0-4.59 (very acidic up to acidic) in all different land typologies in combination with high exchangeable H^+ and Al^{3+}(Table 2). The value of H^+ and Al^{3+} exchangeability were ranging from 0.65-1.0 Cmol(+) kg^{-1} and 1.77-4.49 Cmol(+)kg^{-1} respectively.

Lowest pH in combination with highest H^+ and Al^{3+} exchangeability were found in A land typology after rice growing (Table 2), it could be due to nitrification process from nitrogen fertilization causing decrease soil pH. The comparable result was found in acid sulfate soil derived from Merbok, Kedah, Peninsular, Malaysia that the soil had 4.26 Cmol(+)kg^{-1} Al^{3+} exchangeability (Elisa *et al*., 2016). In this regards, this low pH should be corrected it in order to become neutral. Sagala (2010) reported that soil pH derived from Banyu Urip had a value of 4.6, and after applying lime

Table 2: Soil pH, H^+ and Al^{3+} Exchangeability

No	Land Typologies	Soil pH (1:1)	H^+	Al^{3+}
			Exchangeability (Cmol(+) kg^{-1})	
1	A	4.05 + 0.07 (va)	1.00 + 0.16	4,49 + 0.66
2	B	4.59 + 0.22 (a)	0.65 + 0.13	2,27+ 0.13
3	C	4.44 ± 0.09 (va)	0.75 ± 0.19	2,03 ± 0.55
4	D	4.55± 0.08 (a)	0.87 ± 0.10	1,77 ± 0.36

Note: va: very acidic, a: acidic.

with adosage of 2.5 ton ha^{-1} increased soil pH up to 5.36. Other experiment showed that longterm NPK fertilization decreased soil pH about 0.54 unit (Czarnecki and Düring, 2015).

Organic Carbon (C_{org}) is an important chemical constituent of organic matter in a soil. Organic matter has the ability to reduce Al toxicity in the soil via chelation mechanism (Shamsuddin *et al*., 1994). High C_{org} and CEC were found in four different typologies of swamp land both in Mulia Sari and Banyu Urip (Table 3). The range of C_{org} was obtained about 44.11-62.57 g kg^{-1}, meanwhile the CEC was found with a value of 23.20-30.45 Cmol(+)kg^{-1}. Similar result was found by Sagala (2010) and Sagala *et al.* (2011) that acid sulfate soil from Banyu Urip was having 62.0 g kg^{-1} C_{org}.

The C_{org} is the most important factor for soil CEC, because soil component known to contribute to soil CEC are organic matter and clay and showing linear regression.The linear regression model based on soil organic carbon was used to predict soil CEC (Rashidi and Seilsepour, 2008). Based on these variables showed that this acidic soil has potential good fertility but low pH, meanwhile the low pyrite content in the arable layer of four different typologies were obtained between 0.22-0.39% (Table 3). Shamsudin *et al.* (1994) found that C_{org} of acid sulfate soils derived from Malaysia were ranging from 41.9-74.9 g kg^{-1} in acombination of pyrite between 0.02-0.60%. Czarnecki and Dûring (2015) reported that NPK fertilization in long-term treatment had given significant different on C_{org} and CEC compared to control and these variables were increased. The high CEC of these soil shows that the soil has great agricultural potential if it was not for the presence of pyrite. Keeping the soil under anaerobic condition all the

Table 3: Organic Carbon, Cation Exchange Cacapity and Pyrite Content

No	Land Typologies	Organic Carbon (g/kg)	Cation Exchange Capacity (Cmol (+)/kg	Pyrite (%)
1	A	51.97 + 9.77 (vh)	30.45 + 7.53 (h)	0.39±0.18
2	B	62.56 ± 6.52 (vh)	24.65 ± 6.64 (h)	0.22+0.03
3	C	44.11 + 7.11 (h)	23.20 + 2.511 (m)	0.31±0.05
4	D	55.43 ± 6.08 (vh)	30.45 ± 0.00 (h)	0.25±0.03

Note: vh: very high, h: high, m: moderate.

time is probably a logical practice under the present circumstances, even though the choice of crops is limited (Shamsuddin and Senik, 1978).

The fluctuation of basic calcium such as Na^+, Ca^{2+} and Mg^{2+}exchangeabilities were presented in Table 4. Very low amount of Ca^{2+} was obtained in all typologies with values of 0.79-1.83 Cmol(+)kg^{-1}. Lowest amount of Ca^{2+} and Mg^{2+}exchangeability were found in A land typology, it is due to possibility leaching out of these metals from the arable layer by flooding. Meanwhile, $Mg^{2+}$was found ranging from very low to low content with avalue of 0.15-0.90 Cmol(+)kg^{-1} (Table 4). Tuyen *et al.* (2006) reported that application of NPK fertilizer on long-term of paddy soil about 17 years old did not give any significant effect on Na^+, Ca^{2+} and Mg^{2+} exchangeability compared to no fertilizer (control). Very high amount of exchangeable cation with values of 0.80-1.99 Cmol(+)kg^{-1} was only found on Na^+ exchangeability in A and B typologies condition, it means that this pedogeneis of acid sulfate soil was really affected by saline water from the sea entering the tidal land during tide condition.

Very low total N was found in four different typologies with values of 1.48-1.67 gkg^{-1} (Table

Table 4: Some Basic Cations of Natrium,Calcium and Magnesium Exchangeability

No	Land Typologies	Na^+	Ca^{2+}	Mg^{2+}
		Exchangability(Cmol (+)/kg		
1	A	0.80+ 0.27 (h)	0.79+ 0.17 (vl)	0.15+0.06 (vl)
2	B	0.69±0.16 (m)	1.83± 0.17 (vl)	0.44± 0.04 (l)
3	C	1.99+1.13 (vh)	1.77+ 0.19 ((vl)	0.90+ 0.53 (l)
4	D	0.24±0.04 (l)	1.70± 0.27 (vl)	0.54 ± 0.17 (l)

Note: vl: very low, l: low, m: moderate, h: high, vh: very high.

Table 5: Macro Nutrients of N, P and K in Tidal Swamp Land

No	Land Typologies	Total N (g/kg)	P (mg/kg)	K Cmol(+)/kg
1	A	1.68+ 0.93 (l)	9.40 +2.32 (vl)	0.28± 0.13 (l)
2	B	1.87± 0.07 (l)	71.35±23.19 (vh)	0.79± 0.48 (h)
3	C	1.48+ 0.27 (l)	70.25+ 7.88 (vh)	0.32± 0.00 (l)
4	D	1.68± 0.24 (l)	58.95±12.54 (vh)	0.58± 0.08 (h)

Note: vl: very low, l: low, h: high, vh: very high.

5) and very low of P-Bray I was only obtained in A typology, other three typologies were found P in high content. Furthermore, K exchangeability was obtained ranging from low to high with a value of 0.28-0.79 Cmol(+) kg (Table 5). The low total N content after along term of tidal swamp cultivation for food crop was due to low pH which did not give any microbe chance to do mineralization of organic matter.

CONCLUSION

Tidal swamp land after 30 years opened,still have high organic carbon and high cation exchange capacity but low pH, and as well as low calcium, magnesium and total nitrogen respectively. Relatively, high content of nutrient was only found for Na and some P in soil. These tidal lands have potential to be cultivated for agriculture after improving soil pH and alleviating Al and absence of pyrite from arable layer.

ACKNOWLEDGMENT

The financial support provided by the Universitas Sriwijaya under excellent research professor profession award number 1023/UN9.3.1/LPPM/2016 is gratefully acknowledged

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