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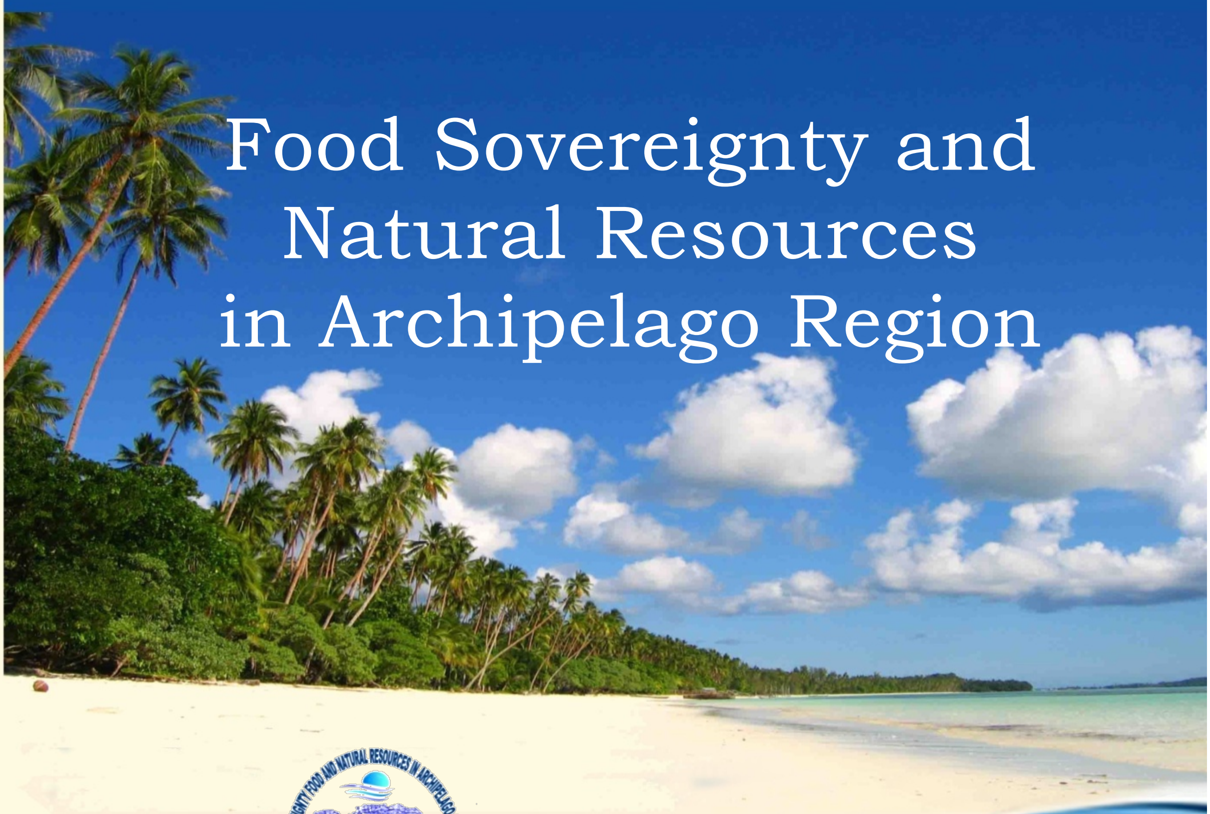

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PEMAMA

THE UTILIZATION OF ACID SULPHATE SOIL FOR AGRICULTURE

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1. Definition of Acid Sulphate Soil

Acid sulfate soil (AAS) is formed in marine or brackish environment (Bonswijk *et al*. 1995), the nastiest soils in the world (Dent & Pons, 1995). During the process of sedimentation, sulfate (SO_4^{2-}) of sea water is reduced by organic matter and reacted with iron (Fe) to form pyrite (FeS_2). Acid sulphate soil is land that has oxidized pyrite layer (sulfuric horizon) or unoxidized (sulfidic materials) at 0-50 cm depth from the surface (Widjaja-Adhi *et al*. 1992 & 1995; Suriadikarta & Setyorini, 2006). Widjaja-Adhi *et al*. (1992) has estimated the tidal swamp area in Indonesia reached 20.11 million ha which consists of 2.07 million ha (potential soil), 6.71 million ha (acid sulphate soil), 10.89 million ha (peatlands) and 0.44 million ha (saline soil), spreading across Sumatra, Kalimantan and Papua.

2. Characteristics of Acid Sulphate Soil and Its Effect on Crop

Based on the short explanation above it can be concluded the major limiting factor in AAS is the oxidized pyrite in sulfidic material. Pyrite oxidation caused decrease of soil acidity (pH) which did not support plant growth. According to Dent & Pons (1995), its pH downs (or downed) to 2.

Pyrite oxidation is a complete process that involves a number of a sequential chemical reaction, some of which are bacterially-mediated (Stumm & Morgan, 1996; Dent, 1986; Noor *et al*. 2008a), with 20-1000 minutes half time-oxidation (Stumm & Morgan, 1996). This process naturally occured due to the big difference between tidal and long dry season (Suriadikarta & Setyorini, 2006), soil cracks, plant roots or human activities (Suriadikarta, 2009), such as drainage and reclamation. Pyrite oxidation reactions occurred through two oxidants, Oxygen and Fe^{3+} ions by followed reaction (Dent and Pons, 1995; Green et al. 2006):

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \rightarrow Fe(OH)_3 + 2\ SO_4^{2-} + 4\ H^+ \quad (1)$$

$$FeS_2 + 14\ Fe^{3+} + 8\ H_2O \rightarrow 15\ Fe^{2+} + 2\ SO_4^{2-} + 16\ H^+ \quad (2)$$

The initial reaction produces H ions, so pH dropped <4. This condition resulting ferric ion (Fe^{3+}) ions in the second oxidant with a relatively rate quickly reacts. As a result, the soil pH will drop.

Pyrite oxidation process damaged the crystal structure of its mineral, released Aluminium from the crystal. This evidence was reported by Shamshuddin *et al.* (2004). Analysis using Scanning Electron Micrograph (SEM) shows the shape of oxidized pyrite before, which is hexagonal-shaped egg in which 1:2 ratio of Fe: S. When oxidized, damaged grain morphology and chemical changes could be seen from the change ratio Fe: S, the existence of Al, Mn and K that encourage acidification and release of Al and Fe atoms of the clay minerals.

The experiment results (Sudarmo, 2004) showed that the drying/ oxidation of sulfidic materials increased exchange able-Al because of decreasing soil pH, and increasing Al solubility. van Breemen's research (1976) using oxidized AAS indicated when soil pH dropped to 1.8 (initial pH 4), the concentration of Al^{3+} increased from 27 ppm to 1566 ppm. Further explanation stated that at very sour condition, kaolinite and beidelit minerals would be soluble and contributed to Al^{3+} in the soil solution, then increased exchangeable-Al. Activity of soluble Al^{3+} activity depended directly on the soil pH value. It increased 10 times per unit and decreased soil pH (Anwar , 2006). In Thailand's AAS, this concentration in the soil solution increased from 0.4 ppm at pH 5.5 to 54 ppm at pH 2.8 (Cho et al , 2002). According to van Bremen (1993) at very low pH (< 4), the solubility of Al $^{3+}$ is enough to triger the magnitude of Al^{3+} mobility in soil solution .

Icreasing of H^+ ions concentration in the solution will generally decrease the rate absorption of cations as a result of competition between same charged ions that affect ionic equilibrium solution. This changes affected to availability of plant nutrients (Alam *et al*. 1999).

Plant growth in acid soil is limited by a number of factors, including either the direct effect of pH (due to excessive concentration of H^+ ions) or indirect effect that induces toxicity of Al^{3+}, Fe^{2+} and Mn^{2+}, and/or insufficiency of Ca, Mg, P and Mo (Alam *et al*. 1999). At pH <4, the macro nutrients such as N, P, K, Ca and Mg become unavailable to plants, whereas the increase of availability of toxic Al becomes a limiting factor (Kochian, 1995 & Matsumoto, 2000).

3. Utilization Technology of Acid Sulphate Soil for Agriculture

Water Management

Water management is one way to manage AAS (Dent, 1986), for example maintanance the water level could control the rate of pyrite oxidation and acid production as well as irrigation and leaching (Bronswijk *et al*. 1995). This arrangement aims to maintain reductive conditions that are not exposed/ oxidized pyrite. Based on the results study of corn, Hatta *et al*. (2009) recommended the mounds, one way floodgates semi-automatic irrigation systems (for land overflow type A and B), whereas water conservation systems for types C and D. Noor *et al*. (2008b) reported shallow peatland management (60-100 cm depth) through combination of high tide and amelioration increased rice yields.

Alwi & Nazemi (2003) reported, the distance between the kemalir channel 7.5 m length and 20 cm depth resulted 1.71 tons/ ha soybean in AAS. Higher yields reported by Ghulamahdi *et al*. (2009) which 3.78 tonnes/ ha Tanggamus genotipe, 2.23 tonnes/ha Slamet, 1.81 tonnes/ha Willis and 2.02 tonnes/ha Anjasmoro. These results were obtained by the application of water-saturated technology.

Tolerant varieties

One strategy of successful management in marginal land is using genetic resources that have adaptive properties of the environment (von Wettberg & Friesen, 2010; Xiaobing *et al*. 2008). Koesrini & William (2004) reported soybean productivities of Lawit, Menyapa and Sibayak were higher than other varieties.

Based on experiment to rice, Humairil & Khairullah (2000) explained that election tolerant rice strains greatly affects to rice yields acquisition. According to Noor *et al*. (2007) tolerance of rice in AAS may be due to differences in the ability of plants to reduce Fe uptake.

c.3. Amelioration

Acid sulfate soil amelioration aims to improve the physical and chemical properties of the soil prior to fertilization (Suriadikarta & Setyorini, 2006). Some studies show that ameliorant increased the soil pH (Kurniawan, 2007; Raihan, 2007), availability of nutrients, soil water content, and soil permeability (Kurniawan, 2007).

Koesrini and William (2007) reported that 1-2 tonnes/ha lime increase the pH of AAS Barambai-South Kalimantan from 3.59 (very acidic) to 4.0 and from 4.1 to 4.0, and decreased exchangeable Al to 4.0 and 4.15 me/100 g from the initial value of 9.05 me/100 g. The results showed genotype MSC 9243-D-3 was very responsive to liming due to increasing 21.7% of yield, which was from 1.078 tonnes/ ha using 1 ton/ha lime to 1.311 tonnes/ha using 2 tonnes/ha lime.

Similar results were reported by Koesrini et al. (2001), 2 tonnes/ha lime in ASS KP-Unit Tatas Central Kalimantan increased 23.7% soybean yield higher than liming 1 ton/ha. Combination ameliorant dolomite and manure, 2 tonnes/ha + 2.5 tonnes/ha and 2 tonnes/ha + 5 tonnes/ha, respectively, increased initial pH from 3.5 to 3.64 and 3.66, respectively, and productivities 0.260 ton/ha and 0.214 ton/ha (William & Najib, 2007). This result is higher than the combination of dolomite and manure 1ton/ha.

The utilization of amelioration has been done to several crops, including rice (Muhammad & Indrayati, 2008), maize (Kurniawan, 2007; Raihan, 2007; Raihan 2008), peanuts (Hatmoko *et al.* 2007; Koesrini & Susilawati, 2008), eggplant (Fauziati & Nurita, 2007), radish (Lestari *et al*. 2007) and tomato

(Anwar, 2008). Some ameliorants used in AAS such as phosphate compounds (Damanik & Hanudin, 2008), mud sea/river and limestone (Sagiman, 2001; Koesrini & Susilawati, 2008; Najib *et al*. 2008; Muhammad *et al*. 2008; Muhammad & Indrayati, 2008), mineral soil (Mario, 2002; Barchia, 2002), zeolite (Murnita, 2001), stover mulch and manure (Anwar, 2008; Raihan, 2008) and straw compost (Anwar, 2006).

Anwar's experiment (2006) proved that straw composting reduced Al-exchangeable at 2 and 6 weeks after planting compared to initial value. At the time of planting, soil of exchangeable Al decreased by 19.95% (at doses of 2.7 tonnes/ha) and 25.28% (at a doses of 3.6 tonnes/ha). The greater dose of straw compost will donate more organic acids into soil to chelate Al^{3+} ions, then decreased its solubility. Rice straw and straw ash containing Silicon (Si) are highly enough to increase the resistance of plants in the environment and ameliorate the ferrous ion toxicity (Fu *et al*. 2012).

CONCLUSSION

Acid sulfate soil is potentially used in agricultural areas. Due to the nature of sulfidic material containing pyrite, oxidized pyrite will lower soil pH to be very sour. This condition triggers the toxicity of Al^{3+}, Fe^{2+} and Mn^{2+}, then lacks other nutrients avaliability. The results of many studies demonstrate a combination of water management technology, using tolerant crop and amelioration acid sulfate soil, can overcome these obstacles.

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