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Layer Depths-Based Soil Chemical Properties on Oil Palm Area in East Kotawaringin, Central Borneo

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Abstract

The objective of this research is to assess the variation of soil chemical properties based on soil layer depth on oil palm plantation area. This Research conducted at oil palm plantation area in East Kotawaringin District, Central Borneo. Soil sample is collected and subjected to laboratory-based soil analysis. Soil sample is obtained from four soil layer depths in the representative site of the plantation area management activity. Forest area with vegetative coverage nearby the plantation site is also included within research area scope. The result indicates that the deeper soil layer from soil surface increase the soil pH (pH H_2O and pH KCl) (lowering acidity). Otherwise, other soil chemical properties decreased, such as exchangeable-hydrogen and exchangeable-aluminium, exchangeable-base cations (calcium, magnesium, potassium and natrium), base saturation, cation exchange capacity, organic carbon, total nitrogen, phosphor-available and K_2O HCl 25%.

Keywords: soil chemical, soil layer depth, oil palm plantation.

1. Introduction

Oil palm as one of commodity contributes to foreign exchange of the country from agricultural sector. It showed a very rapid development in the last two decades compared to other commodities. Based on the results of the land suitability assessment, opportunities of oil palm development in Indonesia is still widely open, especially on the island of Sumatra, Kalimantan (Borneo), Sulawesi and Papua (Mulyani *et al*., 2003). The development of oil palm plantations has impacts on the shrinkage of forest cover, deforestation, declining biodiversity, decrease of water catchment areas and forest degradation. Forest degradation as a result of the development of oil palm plantations caused decrease quality of chemical properties and soil fertility, which in turn could potentially lead to a decrease impacts on soil productivity.

Nutrient uptake from the soil to the oil palm plantation crops required for the formation of the entire plant tissue including harvested tissue components (fresh fruit bunches). Amount of nutrients that transported to the harvested fresh fruit bunches and nutrients are immobilized in the tissue of stems, roots and leaves that reach the equivalent of 116.2 kg N , 16.1 kg P, 285 kg K and 22.0 kg Mg per ha per year (Tarmizi and Thayeb, 2006). The nutrients absorbed from the soil is not only from the top layer (*top soil*), but also absorbed by plants from deeper layers in accordance with the age of the plant. Besides, oil palm crop fertilization activity and accumulation of organic matter from litter of plant canopy is more concentrated in the surface layer of the soil, but the activity of soil organisms and leaching processes can only move the fertilizer nutrients and organic compounds into deeper layers. Therefore, changes in soil chemical properties due to the activities of oil palm plantation land management (such as land clearing, planting land cover of legume crops, maintenance of appropriate age of the plant and application of wastewater treatment plant of palm oil for fertilizer) is predicted to varied according to the depth of the soil layer. Based on the problems mentioned previously, the research is aimed to assess the variation of soil chemical properties based on soil layer depth at oil palm plantation area in East Kotawaringin District, Central Borneo.

2. Material And Method

Soil sampled from the oil palm plantation in East Kotawaringin District, Central Borneo. Soil sampled from plantation site that represent the activity of the plantation area management including forest area with vegetative coverage nearby the plantation site (Table 1). Each representative sample is taken from three points (as replication) on different spatial distance. Each sample is subtracted from four soil layer depths (Table 2). The sampling of each layer is composited using stainless pipe with diameter 2”. Composite soil sample from each layer depth were sampled for ± 1 kg and then analyzed in laboratory.

Table 1. Soil Sampling Site

Plantation Site	Oil Palm Age (year old)	Description
1	0	Unopened forest area
2	0	Opened forest area for 1 year and has not planted yet
3	3	No LCC, unapplied liquid waste
4	3	LCC planted, unapplied liquid waste
5	5	No LCC, unapplied liquid waste
6	5	LCC planted, unapplied liquid waste
7	7	No LCC, unapplied liquid waste
8	9	No LCC, unapplied liquid waste
9	14	No LCC, unapplied liquid waste
10	16	No LCC, unapplied liquid waste
11	16	No LCC, applied liquid waste by flat bed

Note: LCC = *Legume Cover Crops* (*Mucuna brachiata*)

Table 2. Soil Layer Depth of Soil Sampling

Layer	Soil Layer Depth (cm)
I	0 – 25
II	25 – 50
III	50 – 75
IV	75 – 100

The soil analysis is conducted at Laboratory of Institute for Agricultural Technology – Balai Pengkajian Teknologi Pertanian (BPTP) of Yogyakarta. The parameters of soil chemical characteristics include: pH soil (pH H_2O and pH KCl), cation exchange capacity analyzed by NH_4OAc extraction method. Base saturation analyzed by NH_4OAc extraction method, C-organic rate analyzed by oxidation method (Walkley and Black). N-total analyzed by Kjehdahl method, P-available analyzed by Bray I, K_2O analyzed by HCl 25% extraction, bases-exchangeable (Ca, Mg, K and Na) analyzed by NH_4OAc extraction method. Aluminum-exchangeable analyzed by NH_4OAc extraction method, and hydrogen-exchangeable analyzed by NH_4OAc extraction method. Data of laboratory analysis for each layer are averaged and standard deviations were calculated. Results are then compared between the averages of single layer with other layers in accordance with the purpose of the research.

3. Results And Discussion

Soil type in this research is categorized as ultisol ordo, and according to Soil Research Center (1983), it is classified into podsolic group. Preliminary result showed that soil type surround the research area has low fertility rate (Basuki, 2008). The current research found that soil layer depth influenced pH, N-total, C-organic, P-available, K_2O HCl 25%, base cations of Ca, Mg, K, Na-exchangeable, cation exchange capacity, base saturation, hydrogen-exchangeable and aluminum-exchangeable.

3.1 Soil Acidity and Cation Exchange Capacity

Soil acidity or soil reaction that show acidity or alkalinity, is symbolized by pH - the negative logarithm of H^+ ions in gram per liter of soil solution. Average rates of soil acidity (pH H_2O and pH KCl) and cation exchange capacity from four soil layer depths are indicated in Table 3, and its change pattern is illustrated in Figure 1 and 2.

Table 3. Average Rates of Soil Acidity and Cation Exchange Capacity on Four Soil Layer Depths

No	Layer	Soil Acidity		Cation Exchange Capacity (me/100 g)
		pH H_2O	pH KCl	
1	I (0-25 cm)	4.40 ± 0.22	4.02 ± 0.14	17.04 ±0.44
2	II (25-50 cm)	4.56 ± 0.11	4.10 ± 0.11	16.58 ±0.43
3	III (50-75 cm)	4.67 ± 0.23	4.12 ± 0.12	16.22 ±0.45
4	IV (75-100 cm)	4.77 ± 0.26	4.16 ± 0.18	15.91 ±0.45

Source: Result of soil laboratory analysis.

The result of soil acidity showed that the lowest pH is found at layer I (0-25 cm) with pH H_2O of 4.40 and pH KCl 4.02, and followed by the increase of layer II (25-50 cm), layer III (50-75 cm), and layer IV (75-100 cm) respectively (Fig. 1).

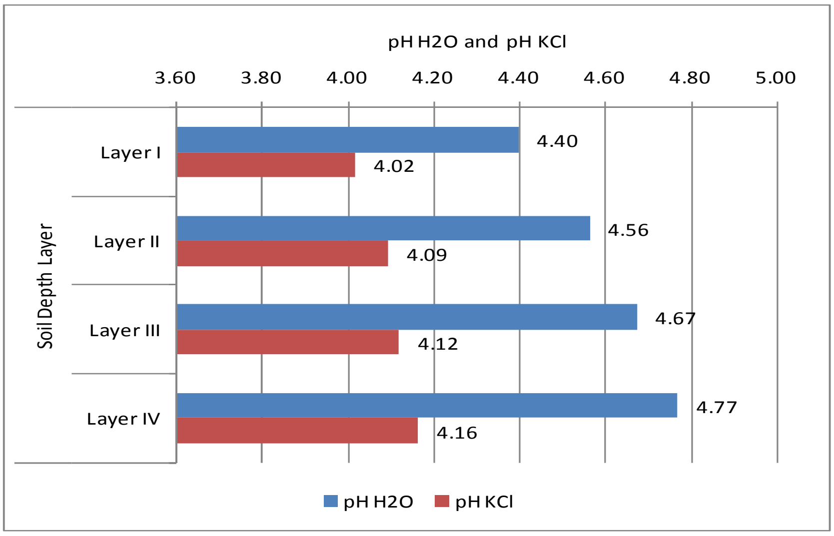

Figure 1. Average Rates of pH H_2O and pH KCl on Four Soil Layer Depths

The increase of pH soil from Layer I to Layer II, III and IV is because the highest level of H^+-exchangeable and Al^{3+}-exchangeable ions are found initially at Layer I, followed by others. These both acidity ions source represent the outcome of the weathered clay mineral (Hardjowigeno, 1993; Nyarko, 2012; Nweke and Nsoanya, 2013), and the most weathered mineral remains at Layer I as followed by other Layers. Based on the order of weathering, the contribution of H^+ and Al^{3+} ions is the highest at Layer I (with the lowest pH), followed by Layer II, III and IV.

Compared to pH H_2O and pH KCl, it is shown that pH KCl is a bit lower than pH H_2O by difference of 0.5 of pH unit. The lower rate of pH KCl is meant that in the soil capture complex, aluminum is displaced by potassium from KCl extractor salt. The hydrolysis of aluminum by potassium will contribute to hydrogen ion so that pH KCl is measured lower (Thunjai et.al., 2007; Gavriloaiei, 2012).

Cation exchange capacity is the number of exchangeable-cations adsorbed in colloid surface, it is the consequence of the negative charge on the soil adsorbtion complex that can be exchanged with cations in the soil solution. Cation exchange capacity represents the ability of the soil to supply nutrient or gross guide about the type of mineral clay and the presence of organic material (Rashidi and Seilsepour, 2008). Cation exchange capacity of the soil layer decreased by 20.03 me/100 g of soil to 19.58 me/100 g soil in layers II and 19.22 me/100 g of soil on the layer and III then become 18.91 me / 100 g of soil in layer IV (Figure 2). The pattern of changes in the soil cation exchange capacity can be described as organic ingredients that are a source of organic colloids in the layer I (0-25) cm the highest value, followed by layers II, III and IV. Organic colloids or commonly referred as humus is the source of negative charge of soils derived from the dissociation of H^+ ions at the carboxylic group (-COOH) and hydroxyl or phenol (-OH) in the humus. With the increasing amount of negative charge on the soil, then higher cation exchange capacity of the soil (Tisdale *et al.*, 1999; Syekhfani, 2010). Organic colloid content sourced from organic material at Layer I (0-25 cm), which is the highest and it is followed by Layer II, III and IV.

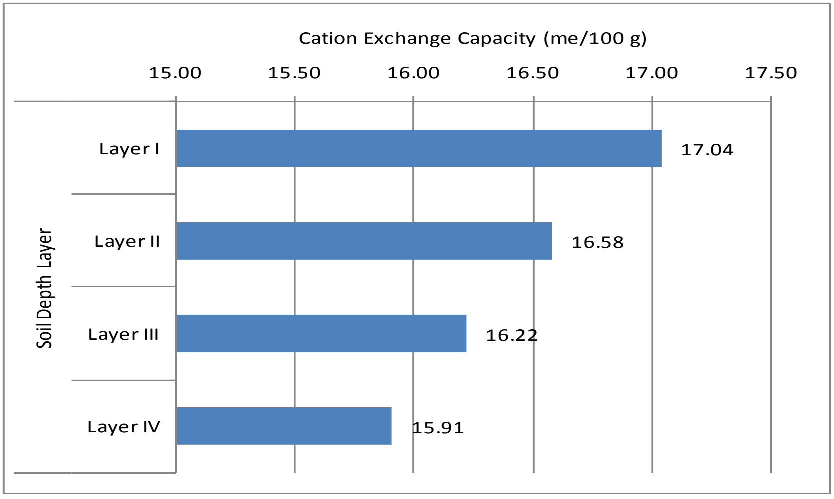

Figure 2. Average Rates of Cation Exchange Capacity on Four Soil Layer Depths

3.2 Hydrogen-Exchangeable, Aluminum-Exchangeable, and Base Saturation

Different from the change pattern of soil acidity, the change pattern of H-exchangeable, Al-exchangeable, and base saturation is decreasing from Layer I toward Layer II, III and IV (Table 4). The highest average rate of H-exchangeable and Al-exchangeable is observed at Layer I (0-25 cm), with H-exchangeable 0.08 me/100g and Al-exchangeable for 0.12 me/100g.

The deprivation of H-exchangeable and Al-exchangeable (Fig. 3) from Layer I to Layer II, III and IV caused by the weathering main source of H^+ and Al^{3+} ions in the soil that from the clay mineral.

Table 4. Average Rates of H-exchangeable, Al-exchangeable and Base Saturation on Four Soil Layer Depths

Layer	H-exchangeable (me/100g)	Al-exchangeable (me/100g)	Base Saturation (%)
I	0.08 ± 0.01	0.12 ± 0.02	27.92 ± 3.11
II	0.07 ± 0.01	0.11 ± 0.01	26.84 ± 2.44
III	0.06 ± 0.01	0.10 ± 0.01	24.93 ± 2.21
IV	0.05 ± 0.01	0.09 ± 0.01	23.71 ± 2.96

Source: Result of soil laboratory analysis.

In consistent to the change pattern of H-exchangeable and Al-exchangeable, base saturation also showed that the highest rate is observed at Layer I with 27.92 %, and it declines orderly at Layer II, Layer III and Layer IV (Fig. 3). The reason is that the highest content of Mg, K and Na-exchangeable is found at Layer I as the result of the most advanced mineral weathering, followed by Layer II, III and IV. The decrease of base cations from Layer I toward Layer II, III and IV causes the reduction of base saturation rate from Layer I toward Layer II, III and IV. Besides, the reduction of base saturation is also caused by the increase of cation exchange capacity from Layer I toward Layer II, III and IV. Base saturation rate is inversely related to cation exchange capacity rate of the soil.

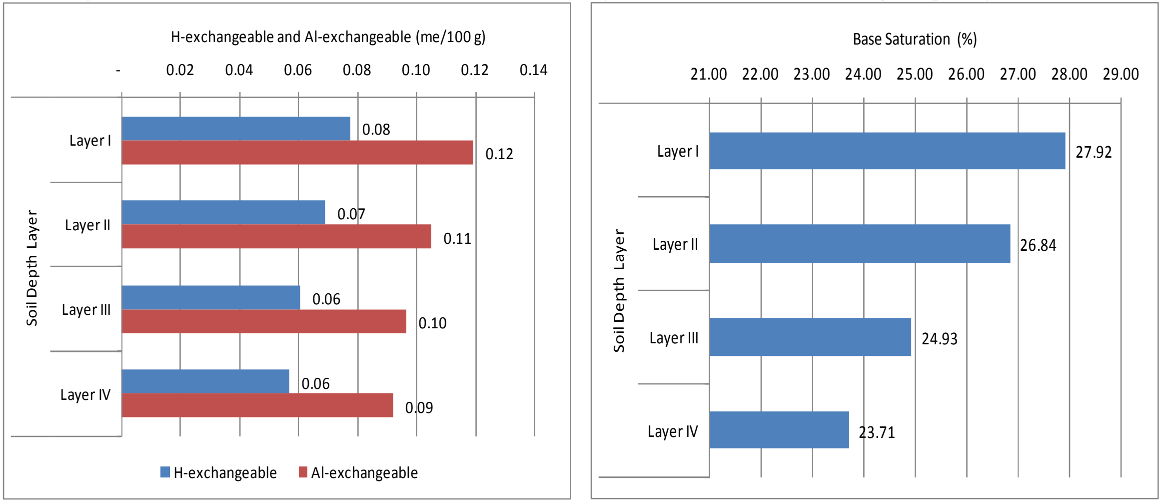

Figure 3. Average Rates of H-exchangeable, Al-exchangeable and Base Saturation on Four Soil Layer Depths

3.3 N-total, C-organic, P-available and 25 % K_2O HCl

According to Flaig (1984), in the natural condition, nutrient enters the soil through the decomposition of organic matter such as the remnant of dead plant tissue. In the agricultural system, farmers empower this nutrient with harvest residue, dung or other organic sources. The substances of N, P and S are the primary components that composed organic material, while cations of K, Ca and Mg, and other heavy metals in plant tissue remain as the complex compound. Handayanto and Hairiah (2007) assert that the substrate for soil humus may develop from the residues of plant and animal and also soil organism.

The average rates of N-total, C-organic, base cations, P-available and K_2O HCl 25 % in the soil have similar change pattern (Fig. 4 and 5) with the highest rate found at Layer I and then it decreases orderly at Layer II, Layer III and the lowest at Layer IV (Table 5).

High content of C-organic (organic material) at Layer I is evident because the main source of soil organic material is litter remnants from the residues of plant and animal. The litters are found mostly in soil surface which then decompose to create humus and mix with the most top layer of soil. Organic material content will decrease at deeper layers (toward Layer II, III and IV).

Table 5. Average Rates of N-total, C-organic, P-available and K_2O HCl 25 % on Four Soil Layer Depths

Layer	N-total (%)	C-organic (%)	P-available (ppm)	K_2O HCl 25 % (mg/100g)
I	0.14 ± 0.02	2.55 ± 0.49	14.70 ± 3.58	18.61 ± 7.50
II	0.06 ± 0.01	1.20 ± 0.49	5.70 ± 1.76	11.48 ± 5.36
III	0.05 ± 0.01	0.90 ± 0.49	4.03 ± 1.55	9.03 ± 4.40
IV	0.04 ± 0.01	0.59 ± 0.35	2.70 ± 1.05	6.55 ± 3.92

Source: Result of soil laboratory analysis.

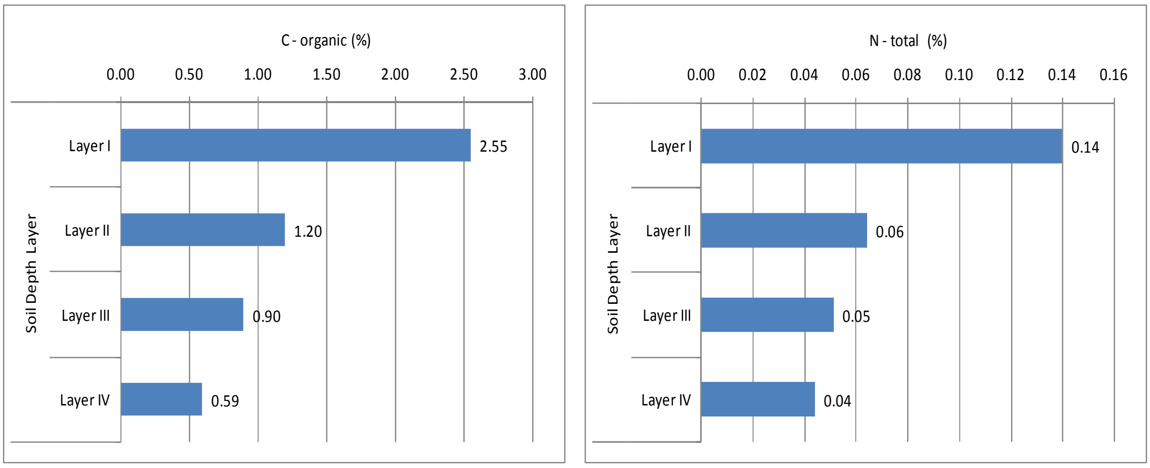

Figure 4. Average Rates of C-organik and N-total on Four Soil Layer Depths

In parallel with the change of organic material content, the contents of N-total, P-available and K_2O HCl 25 % are also the highest in Layer I but it decreases toward deeper layer (Layer II, III and IV). It is because one source of N-total, P-available and K_2O HCl 25 % is coming from the decomposition of organic material (Flaig, 1984; Rezig *et.al*., 2012). Oil palm plantation area is often applied nitrogen, phosphor and potassium fertilizers on the soil mostly through Layer I. Therefore, the highest content of the materials is found at Layer I and then it decreases toward the deeper layers (Fig. 5).

The decomposition of N-organic from organic material is run through several stages such as aminisation, ammonification and nitrification (Handayanto and Hairiah, 2007). The nitrogen contribution to soil from the decomposition of organic material and from fertilization may produce the highest N-total distribution at Layer I but the distribution is reducing in deeper layers (Layer II, III and IV).

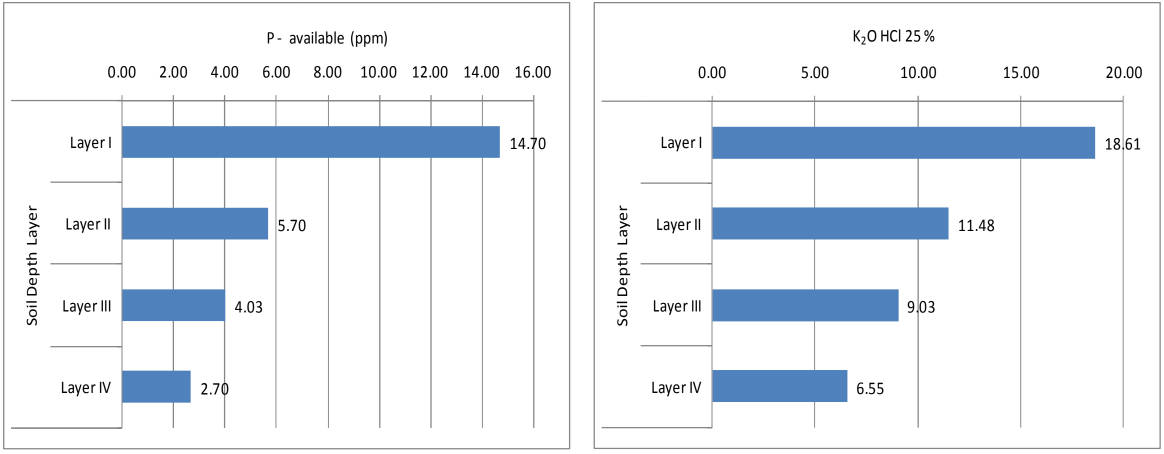

Figure 5. Average Rates of P-available and K_2O HCl 25 % on Four Soil Layer Depths

Phosphor (P) in the soil is seen in two forms, i.e. P-organic and P-inorganic. The form of P-organic comes from the residues of plant, animal and microorganism. P is represented by ester compounds developed from orthophosphate acid, such as inositol, phospholipids, nucleate acid, nucleotide, and phosphate sugar. Inositol, phospholipids, and nucleate acid are dominantly found in the soil. Inositol phosphate has one, two, three, four, five or six P atoms in each unit. Phospholipids is phosphate acid combined with lipid. Nucleate acid as DNA and RNA assembles 1 % to 10 % of P-organic total (Tisdale *et al*., 1999). Microorganism cells are enriched with nucleate acid, and if the organism dies, the nucleate acid is ready for mineralization. The availability of P-organic for plant greatly depends on the activity of microorganism to mineralize it. Phosphatase mostly produced by soil microorganism (especially the heterotrophic one), it is need an enzyme to release P from P-organic bond. The nutrient-available is then influenced by the absorption of nutrient, leaching, and type and quantity of fertilizers (Simanjutak, 2008). The availability of potassium is not only determined by the concentration of K-dissolved and K-exchangeable in the soil, but also by cation exchange capacity, the concentrations of calcium, magnesium, ammonium, natrium, iron, aluminum and pH soil (Agbenin, 2003; Larson, 2007).

3.4 Base Cations of Ca, Mg, K and Na

The highest content of base cations-exchangeable (Ca, Mg, K, Na) is in Layer I but it decreases in deeper layers (Table 6). It is because one source of base cations (Ca, Mg, K, Na) is from the weathering of clay mineral (Hardjowigeno, 1993). Based on the weathering rate, Layer I is one with the most advancing weathering, therefore it produced the highest level of base cations followed by Layer II, III and IV (Fig. 6).

Table 6. Average Rates of Base Cations-Exchangeable (Ca, Mg, K, Na) on Four Soil Layer Depths

Layer	Ca-Exchangeable (me/100g)	Mg-Exchangeable (me/100g)	K-Exchangeable(me/100g)	Na-Exchangeable (me/100g)
I	4.26 ± 0.33	0.47 ± 0.06	0.08 ± 0.02	0.08 ± 0.04
II	3.90 ± 0.41	0.38 ± 0.08	0.06 ± 0.02	0.04 ± 0.01
III	3.61 ± 0.38	0.33 ± 0.08	0.04 ± 0.01	0.03 ± 0.01
IV	3.38 ± 0.48	0.29 ± 0.08	0.03 ± 0.01	0.02 ± 0.01

Source: Result of soil laboratory analysis.

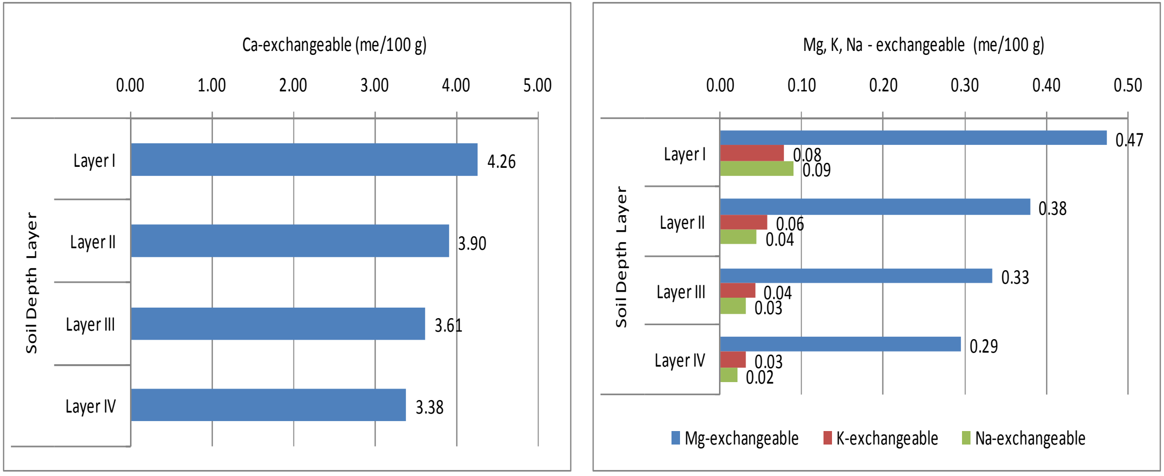

Figure 6. Average Rates of Base Cations-exchangeable (Ca, Mg, K, Na) on Four Soil Layer Depths

In addition to the weathering of clay mineral as the carrier of calcium, magnesium, potassium and natrium, it seems that base cations (Ca, Mg, K, Na) develop from the decomposition of organic material (Soemarno, 2010). The highest distribution of organic material at Layer I is followed orderly by Layer II, III and IV. It is then understood that the content of base cations (Ca, Mg, K, Na) is the highest at Layer I but it decreases in orderly manner toward Layer II, III and IV.

5. Conclusion

We concluded that the change of soil chemical properties in the oil palm plantation area is varied based on soil layer depths. The deeper soil depth from the surface, the greater pH soil (pH H_2O and pH KCl) (acidity decreased). In contrast, other soil chemical properties such as H-exchangeable and Al-exchangeable, base cations-exchangeable (Ca, Mg, K and Na), base saturation, cation exchange capacity, organic carbon, N-total, P-available, and K_2O HCl 25 % are decreasing.

References

Agbenin, J.O. (2003). Soil saturation extract composition and sulfate solubility in Tropical Semiarid Soil. *Soil Science Society of America Journal*, 67: 1133-1139.

Basuki. (2008). Evaluation Status of Soil Fertility of Red Yellow Podsolic on Several Village in East Kotawaringin, Central Borneo. *Lamina*, 4 (1): 1-8.

Flaig, W. (1984). Organik Matter and rice: Soil Organic Matter as a Source of Nutrients. International Rice Research Institute. Philippines. 631 p.

Gavriloaiei, T. (2012). The influence of electrolyte solutions on soil pH measurements. Rev. Chim. (Bucharest). 63(4): 396-400. http://www.revistadechimie.ro

Handayanto, E. & Hairiah, K. (2007). Soil Biology: Fundamental of Health Soil Management. Pustaka Adipura.

Yogyakarta. 194 p.

Hardjowigeno, S. (1993). Soil Classification and Pedogenesis. Akademika Presindo. Jakarta. 274 p.

Larson, D. (2007). Calcium is the King of Crop Nutrients. Agri-Energy Resources. USA.

Mulyani, A., Agus, F. & Abdurachman, A. (2003). Suitability of land for palm oil in Indonesia. Workshop on System Integration Palm Oil – Cow.

Nweke, I. A. & Nsoanya, L. N. (2013). Soil pH an indices for effective management of soils for crop production. *International Journal of Scientific & Technology Research*. 2 (3): 132-134.

Nyarko, F. O. (2012). Ameleorating soil acidity in Ghana: a concise review of approaches. *ARPN Jounal of Science and Technology,* 2: 143-153.

Rashidi, M. & Seilsepour, M. (2008). Modeling of soil cation exchange capacity based on soil organic carbon. *ARPN Journal of Agricultural and Biological Science*. l.3 (4): 41-45.

Rezig, A. M. R., Elhadi, E. A. & Mubarak, A. R. (2012). Effect of incorporation of some wastes on a wheat-guar rotation system on soil physical and chemical properties. *International Journal of Recycling of Organic Waste in Agriculture*, 1:1. doi:10.1186/2251-7715-1-1.

Soil Research Centre. (1983). Term of Reference: Classification of Land Suitability. Project of Agriculture Research to Support Transmigration. 23 p.

Simanjutak, B.H. (2008). Availability and Absorption of Kalium by *Arachis hypogaea*. L with The Administration of Organic Matter, Nitrogen and Calsium on Alfisols. PhD Thesis. Graduate Program, Faculty of Agriculture, University of Brawijaya. Malang. 317 p.

Soemarno. (2010). Nutrient in Soil and The Management. Graduate Program, University of Brawijaya Press. Malang.

Syekhfani. (2010). Relation of Nutrient of Soil, Water and Plant. Sepuluh November Institute of Technology Press. 206 p.

Tarmizi, A. M. & Tayeb, M. D. (2006). Nutrien demands of tenera oil palm planted on inland soils of Malaysia. *Journal of Oil Palm Research*. Vol 18 : 204-209.

Tisdale, S.L., Nelson, W.L., Beaton, J.D. & Havlin, J.L. (1999). Soil Fertility and Fertilizers: an Introduction to Nutrient Management. Sixth Edition. Macmillan Publishing Company. 499 p.

Thunjai, T., Boyd, C. E. & Dube, K. (2007). Pond soil pH measurement. *Journal of the World Aquaculture Society*. 32 (2): 141–152. doi: 10.1111/j.1749-7345.2001.tb01089.x