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Changes of Peat Chemical Characteristics which is Converted from Oil Palm to Corn Plantation Areas in Kinali, West Pasaman Regency, West Sumatra

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Abstract— The decline in production prices and land ownership shifts have caused people to choose to convert oil palm plantations into corn plantations. Changes in land cover from plantation crops to annual crops is potentially to reduce the chemical properties of peat. This study aims to identify changes in the chemical properties of peat on land for conversion of oil palm to corn plantations. This research was carried out from May to September 2021. Observations and peat sampling were carried out using the Transect method, perpendicular from the drainage channel based on a distance of 2m, 200m, and 400m from the main canal in maize conversion age < 2 years, (3) maize planting aged conversion 2 years. For each land use, 3 sample points were taken with 2 replications at a depth of 0-20 cm and 20-40 cm. The chemical properties of peatlands that have been converted from oil palm plantations to corn plantations include pH 4.18-4.98, water content 163.76-495.81%, ash content 15.5-72.12%, C-Organic 16.18-49.02%, N-Total 1.25-6.92%, P-Total 5.56-255.87 ppm, P-Available 0.63-157.43 ppm, K-dd 0, 38-1.98 me/100g, Na-dd 3.97-13.84 me/100g, Ca-dd 12.26-23.12 me/100g, Mg-dd 14.66-50.84 me/100g , CEC 63.30-498.16 me/100g, total acidity 570-600 cmol/kg^{-1}. After land conversion, the quality of peatlands increased, especially at the age of conversion <2 years and decreased with increasing age of land conversion.

Keywords: age of conversion, chemical properties, corn plantation, peatland.

1. Introduction

Peatland is one of the marginal land types chosen by the government and the community to expand agricultural areas. According to [5] West Sumatra has peat area of 100,687 ha in total, where 35,140 ha are located in Pasaman Barat Regency. The peatland that was converted from oil palm plantations to corn plantations amounting 276 ha. Oil palm is the primary commodity developed in West Pasaman. However, due to economic factors and technological limitations in peatland management, many palm plantation areas have been converted to corn areas. In addition, the selling price of palm oil is no longer profitable recently since it fluctuates at the lower end, while for corn the price is relatively stable [11].

The quality of peatlands can be destabilized due to the level of decomposition of peat material. When different types of land cover, such as plantation crops are replaced with annual crops, this can lead to reduced canopy cover. The reduction of land cover causes the decomposition rate to be faster due to radiation heat from the sun. In addition, an increase in the number of drainage canals will cause the decomposition of organic matter to be faster as well. [10] explained that water loss due to peat

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drainage causes physical maturation of the peat material, resulting in the shrinkage of the material and the entry of air into the peat layers, which will change the peat's nature to become more aerobic.

The conversion of peatland causes changes in the canopy cover area which in turn will cause changes in land quality. According to [4] the conversion of peat from natural forests into oil palm plantations aged 26 years caused an increase in the soil pH from 3.23 to 3.42 at pH H_2O. The content of C-organic decreased to 17.66%. There is a decrease also in N-total, P-available and basic cations contents. An assessment of the chemical properties of peat related to total acidity is deemed required to investigate changes in the quality of peatlands in corn plantation areas converted from oil palm. Based on the background detailed above, this study aims to identify the total acidity the corn plantation area converted from oil palm plantations in Kinali, West Pasaman Regency, West Sumatra.

2. Method

2.1 Research methods

This research was conducted by a survey method. Peat sampling was carried out using the transect method, perpendicular from the drainage canals on oil palm land aged 15 years, corn with land conversion age < 2 years, corn conversion age ≥ 2 years. For each land use, three sample points were set up with two replications at the depths of 0-20 cm and 20-40 cm and at a distance of 2 m, 200 m, and 400 m from the canal. The number of peat samples was 36 pieces. Peat samples were taken using a drill at the set distances. The samples were put in plastic and labelled, prepared and then analysed at the Laboratory of the Department of Soil, Faculty of Agriculture, Andalas University, Padang.

2.2 Analysis of Peat Chemical Properties

Determination of total peat material nutrients includes analysis of water content % by weight, C-organic, and ash content using the *syringe* method. The pH H_2O ratio 1:4, N-total were determined using Kjeldahl method. P-total by the HCl 25% method and P-available by the Bray-1 method and were measured using spectrophotometry. Cation Exchange Capacity (CEC) was determined using 1N Ammonium Acetate washing method pH 4.0. Cation bases was resolved using saturation extraction method ammonium acetate 1N (NH_4OAc) pH 4.0 as measured by AAS (Atomic Absorption Spectrophotometer*)*. The total acidity of the soil was ruled using the $Ba(OH)_2$ absorption method with a potentiometric titration approach. The sample is reacted with $Ba(OH)_2$, centrifuge. The sample's filtrate containing $Ba(OH)_2$ is titrated with a standard acid solution (HCl 0.1 M) to pH 8.4.

2.3 Data processing

The data obtained were compared with a table of criteria for the chemical properties of peat soil. The findings are then presented in a descriptive form, where each data from each analysis were correlated to determine the extent of changes in peatland quality.

3. Result and Discussion

RESULTS

A . General Condition of the Area and Characteristics of Peat

Kinali Subdistrict is located in the West Pasaman Regency area, 30 km from West Pasaman capital, namely Simpang Ampek. The research location is at 00^o 03' North Latitude – 00^o 11' South Latitude and 99^o 45' East Longitude – 100^o 04' East Longitude with an altitude of 0-1332 m above sea level and a total area of 482.64 Km^2. Luhak Nan Duo District borders Kinali District in the north, Tigo Nagari in Agam District in the south, Tigo Nagari District in the east, and the Indonesian Ocean in the west.

Based on the data from BMKG Climatology Station Class II Padang Pariaman, Kinali District has an average rainfall of 2297 mm/year from 2013 to 2020 with the lowest average rainfall occurs in June (107 mm) and the highest one is in October (493 mm). From the data, it can be seen that the number of wet months is more dominant than the dry ones. The climate types are based on the comparison value (Q) between the average number of dry and wet months with a Q value of 0.023. The climate zone in Kinali District belongs to climate type A, which is very wet.

Based on the soil type map of Kinali Subdistrict, West Pasaman Regency, Kinali Subdistrict has a soil of the order Histosol with a great Troposaprist group covering an area of 15,459 ha. The peat samples used in this study were taken on soils of the order Histosol with the great group Troposaprist. Troposaprist is part of the great group in the sub-order Saprist. The sub-order Saprist is Histosol which has organic material that has undergone complete decomposition, with a fiber content of less than 1/6 part and volume weight of > 0.2 g/cm³ [12]. This soil is found in areas where the groundwater level tends to fluctuate (Figure 2). Troposaprist has several soil properties including deep effective depth, low fiber content, advanced peat maturity (sapric) [14].

From interviews with local farmers, peatlands in Kinali District were originally natural forests, then converted into oil palm plantations. However, in the last few years, some of the oil palm lands that had expired contracts with private companies were returned to the community and converted into cornfields. The land management was under the control of KUD Kinali. The following are some of the peatlands uses observed in this study:

1. Oil Palm Plantation

Oil palm is the most significant contributor to plantation commodities in West Pasaman Regency, with an area of ±121,800 ha of oil palm plantations and production reaching 1,865,431 tons in 2019 (BPS, 2020). Conventionally, these plantations are managed by local farmers by applying inorganic (urea) and organic (manure) fertilizers every year, and some are left unfertilized after planting. Organic material in the form of palm fronds is allowed to rot on the soil's surface by stacking it around the roots of the oil palm. The groundwater table is relatively shallow, around 37-39 cm with a peat depth of ±3 m.

2. Palm Oil to Corn Plantations Conversion

Corn is one of leading commodities in West Pasaman Regency, with harvested area reaching 50,936 Ha in 2019. In Kinali District, production was reaching 95,820 tons in 2019 [18] The groundwater level on this land is rather shallow, around 35-50 cm, with a peat depth of ±3.4 m. The cornfield in this research location was previously planted with oil palm, but in recent years it has been converted to corn because the selling price of corn is higher and stable than the price of oil palm.

The area of land converted from oil palm plantations to corn plantations is 276 ha. The transfer of land ownership from private companies to plasma parties managed by KUD makes the age of peat conversion vary. The land use conversion was carried out gradually to see how successful the planting of corn on peatlands is. This causes the age difference in the converted lands. There are corn plantations with a conversion age of ≥ 2 years (Figure b) and corn plantations with conversion age of <2 years (Figure c).

B. Change of Chemical Properties In Pasaman Peatland.

a. pH Value and Soil Water Content

The pH and water content of peat are important characteristics that indicate the ability of the soil to provide nutrients for plant growth on peatlands. In Figure 3, peat in oil palm plantations has a pH ranging from 4.09-4.37; corn plantations ≤ two years had a pH ranging from 4.38 to 4.99, and ranging from 4.32-4.60 for corn plantation ≥ two years had a pH ranging, as shown in Figure 3. Based on the age of land conversion, the pH value of corn plantations ≤ two years is higher than corn plantations ≥ two years, meaning that the pH tends to decrease with increasing age of corn conversion. This is due to the addition of organic matter i.e. corn biomass crop residues so that there is a contribution of organic acids from root exudates. In line with [15] statement, peat reaction is closely related to the content of organic acids.

The water content in peatlands shows the ability to absorb and store water, which is 13 times of its weight, this is very different from mineral soils. The water content of peatland in oil palm plantations ranges from 163.76% - 486.92%; corn cropping ≤ two years ranged from 195.15-495.81%; corn cropping ≥ two years ranged from 185.09-495.58%. There is an increase in water content in corn plantation compared to oil palm. This is related to the increase in the water level of the peat, where the higher the water level, the more water content of the peat is (as can be seen in Figure 2). In addition, it is also caused by water consumption of corn plants is smaller than of the oil palm plants. In line with [14] opinion, the decrease in groundwater level shows a reduction in soil water content. The more profound the groundwater, the lower the soil moisture in the top layer is.

b. Ash and C-organic Content

Ash content is the residue from the oxidation or combustion process of organic matter contained in the peat. The greater the mineral content in peat, the higher the ash content. In Figure 5 it can be seen that the peat ash content in oil palm plantations ranges from 31.47-72.12%; corn cropping ≤ two years ranged from 15.50-66.35%, and ranged from 24.44-68.66% for and corn cultivation ≥ 2 years. There is a decrease in ash content after the conversion of peatland from oil palm to corn plantations. This indicates that the peatlands in oil palm plantations have undergone a mineralization process so that the mineral content of the land becomes higher. Based on conversion age, corn plantations with a conversion age ≥ 2 years had higher ash content than corn plantations with a conversion age ≤ 2 years. This is related to the age of land management. [1] argues that land management actions for a long time will accelerate the maturation of peat material so that the peat ash content becomes higher.

In Figure 5, it can be seen that the C-organic content of peat in oil palm plantations ranges from 16.18-39.75%; in corn plantations ≤ two years ranged from 19.51-49.02%, and in corn crops ≥ two years ranged from 18.18-43.33%. There was an increase in organic C levels after land conversion from oil palm plantations to corn plantations. This is due to the peatland of corn plantations, the addition of organic matter from root biomass left after harvesting. This causes the organic C content in peatland corn plantations to be higher than in oil palm plantations.

c. N-Total

Organic matter is the primary source of N in the soil. Besides that, N in the soil can also be sourced from air, fertilizer, and rainwater absorbed by soil microorganisms. Figure 6 shows that the N-total peat content in oil palm plantations ranges from 1.25-4.10%; corn cropping ≤ two years ranged from 2.56-5.60%; and ranged from 1.79-6.92% for corn cropping ≥ two years. The N-total levels in all peatland uses are at the high-very high criteria. There was an increase in total N levels after peatland conversion from oil palm plantations to corn plantations. This is due to an increase in pH, ash content, and fertilizers in land management.

d. P-total and P-available

Phosphorus is an essential nutrient that plants need in relatively large amounts (macronutrients). Figure 7 shows the levels of P-total of peat on the palm plantations ranged from 2.10 to 16.50 ppm, corn ≤ 2 years ranged from 24.90 to 255.87 ppm, and corn ≥2 years ranges from 6.53 to 86, 86 ppm. It was seen that there was an increase in total P levels after the conversion of oil palm plantations to corn plantations. This is due to an increase in pH, ash content, and the addition of fertilizers in land management so that the total P content increases. According to [17] *in* [2], organic matter contains N, P, and S in its components but it is not fast enough in providing nutrients for microbes and plants. So, soil must be through fertilization.

e. Cation Bases (Ca and Mg)

Ca and Mg are basic cations from the decomposition process of peat material. In figure 8, it can be seen that the levels of Ca peatland palm oil plantations ranged from 12.62 to 19.09 me / 100g.

For corn plantation ≤ 2 year, it is ranged from 12.26 to 23.12 me/100g, while for corn cultivation ≥2 years ranges from 12.71-22.16 me/100g. There was an increase in Ca levels after the conversion of the plantations. This is due to an increase in the ash content.

Based on the criteria, the Ca content in peatlands in the study area is classified as medium-high. The high Ca content also the effect of lime input provided by the farmers. Giving lime in the form of dolomite will help restore nutrients used by plants and meet nutrient needs for plants. The increase in Ca-dd value is thought to be due to the contribution of Ca elements originating from dolomite. The higher dolomite given can increase the pH and microorganisms' activity, resulting in the decomposition of organic matter. The decomposition of organic matter increases Ca-dd in peat soil. Figure 8 shows the Mg content of peat oil palm plantations ranges from 14,66-29,18 me/100g, planting corn ≤ 2 years ranged from 25.62 to 43.41 me/100g, and corn ≥2 years range 24,66- 50.84 me/100g. It was seen that there was an increase in Mg levels after the conversion of peatland from oil palm plantations to corn plantations. This is due to an increase in the ash content.

f. Cation Exchange Capacity (CEC) and Total Acid

Cations are positively charged ions. The cations in the soil are dissolved by the soil solution or the adsorption of the soil colloids. In Figure 9, oil palm plantations have a CEC of 63.30-172.99 me/100 g; corn plantation ≤ 2 years having 180 to 237.72 CEC me/100 g; corn cultivation ≥ two years have 163.42 to 222.04 CEC me/100 g. There was an increase in CEC after land conversion from oil palm plantations to corn plantations. This was due to a rise in pH and organic C in peatlands after conversion.

Humic acid's total acidity or exchange capacity is due to the dissociation of protons or the release of H^+ ions in the carboxylic and phenolic groups. The total peat acidity obtained in this study was 570-600 cmol/kg^{-1}. According to Schinitzer, in general, the total acidity of humic acid in acidic soils ranges from 570-890 cmol/kg^{-1} [8]. The high value of total acidity will affect the pH, C-organic, N, P, Ca, Mg, and CEC values of peat. The total acidity value indicates the cation exchange capacity and the strength to form complexes [8]. The structure of humic acid contains a lot of phenolic, carboxylic groups attached to an aromatic ring and a quinone bridged by nitrogen and oxygen. The presence of a carboxyl group in humic acid, which is larger than the phenolic group OH indicates that the pH-dependent charge in peat is influenced by the carboxyl group [3].

DISCUSSION

Based on the soil type map of Kinali Subdistrict, West Pasaman Regency, the peat samples in the order Histosol with the great group Troposaprist. Troposaprist is part of the great group in the sub-order Saprist. The sub-order Saprist is Histosol which has organic material that has undergone complete decomposition, with a fiber content of less than 1/6 part and volume weight of > 0.2 g/cm³ [12]. This soil is found in areas where the groundwater level tends to fluctuate (Figure 2). Troposaprist has several soil properties including deep effective depth, low fiber content, advanced peat maturity (sapric) [14]. The conversion of peat from oil palm plantations to corn plantations increases the pH of the peat. The increase in the pH was caused by the addition of fertilizers, drugs, and ameliorants on land by the farmers. This is in line with the statement of [7] that a mixture of manure and lime is able to raise the pH of peatlands. The increase in pH value is also caused by conversion and continuous land management.

There is an increase of water content in corn plantation compared to oil palm. This is related to increase in the water level of peat, where the higher the water level increasing water content of peat (as can be seen in Figure 2). In addition, it is also caused by water consumption of corn plants is smaller than of the oil palm plants. In line with [7] opinion, the decrease in groundwater level shows a reduction in soil water content. The more profound the groundwater, the lower the soil moisture in the top layer is.

Based on the age of land conversion, C-organic in corn plantation ≤ 2 years was higher than corn ≥2 years, meaning that C-organic decreased with increasing age of corn conversion. This is because the action of peatland management in a longer period of time can accelerate the rate of decomposition and the process of peat maturation so that the C-organic content of peat becomes lower. Based on the distance from the canal and the depth of the peat layer, in all land uses, the organic C content increased while the ash content decreased. This is due to an increase in water content. This increase in water content will inhibit the process of decomposition and mineralization, causing the ash content to decrease and the organic C content to increase.

Based on the age of land conversion, the total N-conversion rate in corn plantations ≤ 2 years was higher than that of corn plantations ≥ 2 years. It means that the longer the conversion age, the lower total N-conversion is. This is due to the decrease in organic C and the high N requirement of the corn plant. Based on the distance from the canal and the peat layer's depth, the total N content increased in all land uses. This is the result of an increase in organic C levels, contributing nitrogen for plant growth. In accordance with the research results of [15] the levels of N, P, and pH values tend to increase. The farther from the collector canal, the thicker the peat is.

Based on the age of land conversion, the P-total content in corn plantations ≤ 2 years was higher than in corn plantations ≥ 2 years. It means that the longer the conversion period, the lower P-total content. This was due to a decrease in organic C and a high demand for P from corn plants. Based on the distance from the canal and the depth of the peat layer, the total P-level increased in all land uses. This was caused by an increase in the peat's organic C-level, which contributed P for plant growth.

In Figure 7, it can be seen that the levels of P-available peatland palm oil plantations ranged from 0.63 to 15.39 ppm, corn plantation ≤ 2 years ranged from 21.50 to 157.43 ppm, and for corn cultivation ≥ 2 years ranged 8, 13-70.66 ppm. There was an increase in P-available levels after the land conversion. The increase is the result of rises in pH, ash content, P-total, and fertilizers in land management. The application of P fertilizer by farmers causes the available P content in corn plantations to be higher than in oil palm plantations.

Based on the criteria, the Mg content in the peatlands in the study area is classified as high. The high content of Mg is also due to the input of lime in the form of dolomite provided by farmers. Giving lime will help restore nutrients used by plants and meet nutrient needs for plants. The increase in the Mg-dd value is thought to be due to the contribution of Mg elements originating from dolomite. The higher the dolomite given, the higher the pH and the activity of microorganisms resulting in the decomposition of organic matter, the results of the decomposition of organic matter that increases Mg-dd in peat soil.

In addition, based on the CEC criteria, peatlands are classified as high. This is due to the negative *pH-dependent charge* (pH *dependence charge)* mainly of the carboxyl and phenolic hydroxyl groups, which serve as an exchange site. A high CEC value cannot describe a high base saturation value. This is because peatlands are basically dominated by hydrogen ions (H^+). According to [13] *in* [6], a high CEC indicates a high adsorption capacity of peat soil. However, the adsorption strength is weak, so that K, Ca, Mg, and Na cations that do not form coordination bonds will be easily washed out. The CEC of peat is mainly determined by the lignin fraction and relatively stable humic substances, including hydrophilic and aggressive humic acids which usually form stable complexes with metal ions. The high value of total acidity will affect the pH, C-organic, N, P, Ca, Mg, and CEC values of peat. The total acidity value indicates the cation exchange capacity and the strength to form complexes [8]. The structure of humic acid contains a lot of phenolic, carboxylic groups attached to an aromatic ring and a quinone bridged by nitrogen and oxygen. The presence of a carboxyl group in humic acid, which is larger than the phenolic group OH indicates that the pH-dependent charge in peat is influenced by the carboxyl group [3].

Conclusion

Based on the research, it can be concluded that: The conversion of peatland from oil palm plantations to corn plantations shows land improvements in terms of increasing water content, pH, C-organic, macronutrients, CEC, and decreasing ash content. It can be seen that there is an effect of the length of time for land conversion, where the longer the land is converted, the more land improvement leads to stability. The nutrient status of peat that was given macronutrient fertilizers on corn land use showed a significant effect on increasing macro-nutrient content compared to oil palm land, meaning that fertilizer input helped meet nutrient adequacy for plants. The rate of decomposition of peat in oil palm plantations is faster than in corn plantations. The high ash content indicates this in oil palm plantations and the maturity level of peat which is predominantly sapric. The high value of total peat acidity affects the pH, C-organic, N, P, Ca, Mg, and CEC values of peat.

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