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The soils physicochemical properties of monoculture land in several slopes at Northern Areas of Mount Talang

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Abstract. In the northern area of Mount Talang with some steep slopes (more than 30º), the local community implements an intensive monoculture agricultural system that can accelerate land degradation in the long term. Study was aimed to examine the soils physicochemical properties of monoculture land on several slopes in the northern foothill of Mount Talang. Survey method and soil sampling were implemented in this research, using a purposive random sampling toward the monoculture land on slopes> 45%, 25-45%, 15-25%, 8-15%, and the forest as control, at 0-20 cm and 20-40 cm depth. The results revealed that the soil texture that dominates the forest and monoculture cropping system is sandy loam. In addition, soil water content increases by the increased soil layer depth as well, with highest level observed in monoculture cropping system 25-45% (73.72%). Soil bulk density ranging from 0.4-0.6 g / cm^3, or have the same tendency at both soil depths. The total pore space of forest land and monoculture agricultural land is 75%, categorized as high. The highest soil organic C content was found in monoculture agricultural land with a slope of >45%. The value of pH for all land uses was 5.15-5.29 on acid criteria. The cation exchange capacity was above 40 me / 100g and the total N content is 0.8-1.6%, so both of them are categorized as very high. Based on the data, the soils physicochemical properties of monoculture cropping system on several slope classes similar to the forest. The land quality for monoculture cropping system is still maintained, even though it is on the upper slopes of the foothill of Mount Talang. However, in the monoculture cropping systems will trigger the loss of soil organic matter, so the addition of soil organic matter content should be prioritized, especially in the agricultural land management of this area.

Keywords: forest, monoculture crop system, mount Talang, slope.

1. Introduction

The soil with high fertility can increase the productivity of the plant, including horticultural crops. One of highly suitable area for horticultural crops is located in the foothill of Mount Talang located in Solok Regency, West Sumatra. Agriculture is considered the main source of livelihood for the local people in the foothill of Mount Talang. This area has cool weather and average rainfall of 3000 mm per year. In the northern footslope area of Mt. Talang, the topography condition is quite steep with slope more than 45%. In addition, there is some steep slope found. The steeper slope is not only increasing the quantity of surface runoff but also increasing water transport and energy. The farmers cultivate their monoculture horticultural crops with an intensive system without taking the plant residues back into soil. Monoculture system may provide an impact on soil quality degradation. It has been stated that continuous intensive soil management without additional organic matter will cause organic matter depletion in the soil. When soil organic matter has decreased, the potential of soil degradation will be higher since soil organic matter is critical for the formation of a good soil structure. A decrease soil organic matter content, plant root activity, and soil microorganisms will be related to a decrease in soil aggregate stability. The reduction of the three soil aggregate binding agents in addition to causing the soil aggregate to break down relatively easily into micro-aggregates or smaller particles also causes the formation of a crust on the soil surface (soil crusting) which has solid and hard characteristics when dry.

Land degradation is a decrease in the quality of the land and it can no longer provide the nutrients needed by the plant. In addition, erosion will take the nutrients and organic matter needed by plants to the lower areas. If this continuously happens, it will cause more land degradations, which will affect plant productivity. This research was aimed to examine physicochemical properties of the soil in monoculture cropping system in the northern area in the foothill of Mount Talang that has several classes of slopes. The changes of soil physicochemical properties will be controlled by forest as natural condition of land.

2. Materials and Methods

2.1 Materials
The soil sample was taken from horticultural cultivation land and the forest in the north foothill of Mount Talang, Solok. In addition, analyses were conducted in the Soil Science Laboratory of, Agriculture Faculty, Andalas University.

2.2 Purposive random plot selection
A survey method was implemented in this study. The soil sample was selected by purposive random sampling in a monocultural agricultural cropping system on four different levels of slopes, and also taking forest plot as a control. The observation points were selected on the same soil type, i.e. Inceptisol, and the monoculture cropping system with specific crops like chili or red pepper. The five (5) soil sampling points are as follows:

Table 1. Agricultural systems and slope classes in the research sites

No	Agricultural System	Slope Classes	Daerah/ Nagari	Coordinate system, height (masl)
1.	Monoculture	>45 %	Koto Gadang Guguak	-0º57’7”S ,100º38’8” E 1178,9 masl
2.	Monoculture	25-45 %	Koto Gadang Guguak	-0º57’5”S, 100º38’6” E 1138 masl
3.	Monoculture	15-25%	Koto Gadang Guguak	-0º57’6”S,100º38’6”E 1203 masl
4.	Monoculture	8-15%	Talang	-0º55’53”S, 100º39’21”E 929,0 masl
5.	Forest	>45% (control)	Batu Bajanjang, Lembang Jaya	-0º57’2”S,100º39’59” E 1049 masl

masl: meter above sea level

2.3 Soil Sampling
Soil samples were taken using two methods, namely intact or undisturbed soil sampling and disturbed soil sampling. Undisturbed soil samples were taken from 0-20 cm (top soil) and 20-40 cm (subsoil) depths with three replication for each slope class, and the samples were used for BD analysis.

Meanwhile, disturbed soil samples were taken by a soil core at 0-20 cm and 20-40 cm depths and replicated three times for each slope, and disturbed soil samples were used for texture, water content, soil organic matter, total nitrogen, pH, CEC.

2.4 Soil Analysis in the Laboratory

Before analyzing the samples, the first step was preparing the soil samples and the necessary tools and matters. Indicators of physical and chemical properties and the methods used in this study are listed in Table 2.

Table 2. The parameters used in analyzing soil and the method (in the laboratory).

No.	Parameter	Unit of Weight	Method
1.	Water content	% weight	Gravimetric
2.	Bulk Density	g cm^{-3}	Gravimetric
3.	Total of pore space	%	Gravimetric
4.	Texture	Textural Classes	Pipette and sieve
5.	C-Organik	%	Walkey and Black
6.	Total Nitrogen	%	Kjeldahl
7.	pH		Electrochemical
8.	CEC	me/100g	Leaching

2.5 Data Processing

Data were processed using Microsoft Excel 2013. After that, the data were presented in graph and table and compared with the criteria for each parameter.

3. Result and discussion

Some physical and chemical properties of soil in several slope types and soil depths, with the forest as a control for changes in soil properties, are as follows:

3.1 Soil Texture

Soil texture on different cropping systems, i.e. monoculture land and forest area at the footslope of Mt. Talang can be seen in Table 1. Medium-textured soils at the footslope of Mt. Talang dominate silt, both top soil and subsoil, except for monoculture land at 25-40 and 8-15% slopes, and the soil texture is clay at subsoil.

Table 3. The Textural Classes of the Soil in the Forest and Monoculture Agricultural Land (in several Classes of Slopes).

Land Use	Soil Depth (cm)	Fraction (%)			Soil Textural Class
		Sand	Silt	Clay	
Forest	0-20	31.7	46.8	21.4	Loam
	20-40	38.4	35.3	26.4	Loam
Monoculture (slope: >45%)	0-20	20.6	53.5	25.9	Sandy Loam
	20-40	16.9	53.1	30.0	Clay Loam
Monoculture (slope: 25-45 %)	0-20	18.8	50.7	30.6	Sandy Clay Loam
	20-40	16.2	45.8	38.0	Clay
Monoculture (slope: 15-25 %)	0-20	17.3	45.6	37.1	Sandy Clay Loam
	20-40	13.5	58.9	27.7	Sandy Loam
Monoculture (slope: 8-15 %)	0-20	22.5	51.5	25.9	Sandy Loam
	20-40	16.2	37.9	45.8	Clay

Soil texture significantly determines the water content of the soil. Meanwhile, high clay content will affect the higher ability of the soil in retaining water [5]. The higher the water content in the field capacity in combination with soil organic matter, will be improved in terms of the structure aggregation.

3.2 Water Content of the Soil

Soil water content resulting from different soil depth and slope levels on monoculture land systems is shown in Figure 1.

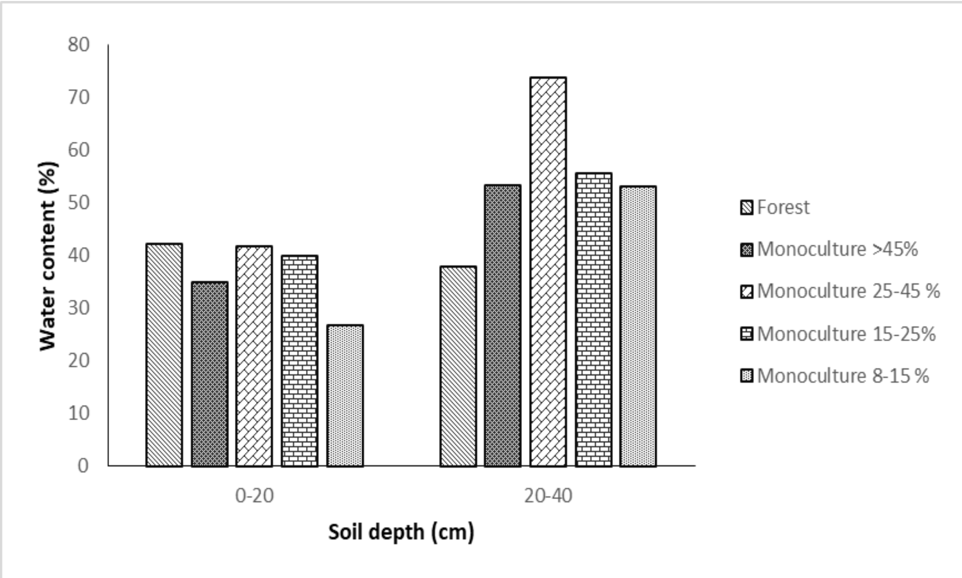

Figure 1. Soil water content in monoculture land at several classes of slopes and soil depths.

The relative water content among plots indicate variations resulting from monoculture land and forest. The soil water content in both landuse more than 30% w/w. Based on Figure 2, when soil layer depth is increasing, the soil water increases as well. Water content at 0-20 cm depth is higher than at 20-40 cm depth. For the soil at 0-20 cm depth, the low water content, i.e. 26.73%, is observed in monoculture system, with a slope of 8-15%. Soil water content at topsoil was lower than subsoil for each slope. Meanwhile, in the soil layer with 20-40 cm depth, the low water content, i.e. 37.67% was found in the forest. Soil water content in monoculture of 25-45% (73.72%) was much higher than slope monoculture > 45% (53.23%), slope 15-25% (55.45%), or slope 8-15% (52.95%).

Monoculture land has a higher water content than forest land, especially in subsoil layer. This is related to soil texture, which is considered to have high content of fine fraction in soil, especially soil at 20-40cm depth, and the highest water content is found in monoculture 25-45% with clay soil (Table 1). A fine fraction of soil has high water content. Figure 2 also shows that soil water contents in monoculture land were similar to forest soils, and it was higher in subsoils. It can be concluded that the ability of soil to retain water is still high, even though it is used for monoculture agricultural land. The retaining of water in subsoil was better, or in the other words, the soil can be supply much water in crop season on several classes of slopes. According to [5], the water content is strongly influenced by soil texture and soil organic matter, such as sandy clay loam texture and the available water in field capacity and permanent wilting point. Hence, the plants can be taken during the plantation phase.

3.3 Bulk Density of Soil

Soil bulk density is one of the physical properties of soil that can indicate the density of soil. The soil bulk density of monoculture agricultural and forest land at various slopes can be seen in Figure 3.

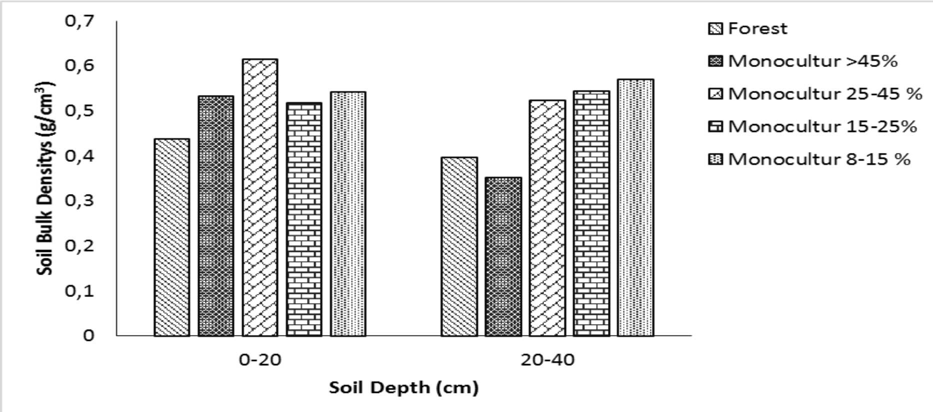

Figure 2. Soils bulk density on monoculture land with several slope classes and soil depths

Based on Figure 2, it can be seen that bulk density of soil ranges from 0.4-0.6 g / cm^3 and shows the same tendency at both soil depths with same criteria was moderate (0,6-1,14 g /cm^3). Soil volume weight at 0-20 cm depth in monoculture slopes 25-45% (0.614 g / cm^3) higher than forest (0.437 g / cm^3), monoculture agricultural land slopes> 45% (0.531 g / cm^3), slopes 15- 25% (0.518 g / cm^3), and 8-15% (0.542 g / cm^3). The bulk density of forest soil is the lighter ones (0.437 g / cm^3). Furthermore, the lowest soil bulk density was found in monoculture land use on slopes >45%. Monoculture forest and agricultural land are still found on the slopes on the foothill of Mount Talang, and they have similar physical properties. The lower bulk density of soil and the lighter the soil fraction, and this is related to the soil texture that dominant by silt fractions more than 35 % as shown in Table 1. And the consequence is the bulk density of the soil volume is lower. Mt. Talang is one of the active volcanoes in West Sumatra, and the land located around Mt. Talang is enriched by pyroclastic matter from the volcanic parent materials. The dominance of this volcanic matter makes the soil fractions around the mountain have lighter density, and it causes the soil to have lower density.

3.4 Total of Soil Pore Space

The total pore space of the soil indicates the number of pores or air spaces in the soil. Based on Figure 3, the total pore space of the soil was same with high criteria for each soil depth. The total pore space of the soil from forest land and monoculture is more than 75%. According to the criteria proposed, the above 75 % of total soil pore in the monoculture located at the foothill of Mount Talang can be categorized as high.

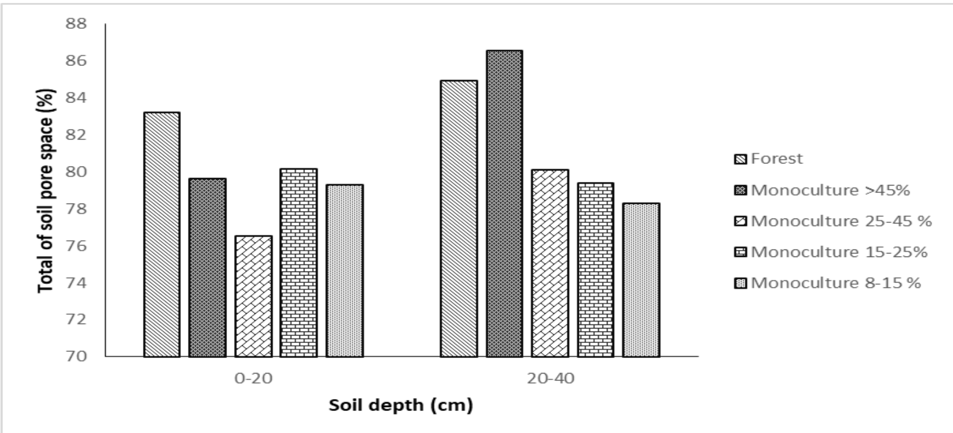

Figure 3. Total soil pore space on monoculture agricultural land on several slope classes and forest in each soil depths

Based on the texture explained in Table 1, the total pore space of the soil is strongly influenced by the composition of the soil fraction from the texture. The agricultural land at the footslope of Mt. Talang has good texture at 0-20 and 20-40cm depths. Total pore space of the soil depth 0-20 cm in forest plot (83.214%) is slightly higher than monoculture agricultural land with slope> 45% (79,622%), 25-45% (76,521%), 15-25% (80,177%), and 8- 15% (79,286%).

Based on the difference of total pore space monoculture agricultural land, the slopes are 25-45% lower than those with> 45%, 25-45%, and 8-15% slopes. Meanwhile, at a soil layer of 20-40cm depth, the total pore space in monoculture land use was> 45% (86.552%) higher than the total pore space of the soil in forest land (84.928%). Furthermore, the lowest total pore space of the soil is found in monoculture land use, on slopes of 8-15% (78.316%) due to the bulk density in monocultures 8-15% is higher than soil in forests and monocultures land on larger slopes (Figure 3). The lowest total pore space due to higher bulk density. According to [5], the soil pore distribution indicates the soil structure since it is critical for soil water and air systems.

A high total pore space of the soil (> 75%) allows this soil to have a good balance of pore drainage and aeration. Because the soil has a medium textured soils, it consequences to high total pore space of the soil and the soil can retain water better in the subsurface (20-40cm). Based on Figure 2, the water content is higher in subsoil. According to [3] the more the proportion of pore space (with larger size interval), the more stable the pores in the soil aggregate, and the more pore space can transfer water. Furthermore, [1] stated that the total pore space is closely related to the soils bulk density. Soil texture and soil organic matter content can affect the total pore space, since the higher the soil organic matter content, the lower of bulk density, and the total pore space will increase.

3.5 Soil Organic Matter Content

Soil organic matter content can be indicated from the total content of organic carbon in the soil. Based on Figure 1, the C-Organic content of the soil ranges from 0.3 to 1.13% and was categorized as low. In addition, soil organic matter content decreases by increased soil depth. In the top soil, 0-20 cm depth, soil organic matter content in forest land is 1.138%, higher than monoculture agricultural land, with slope> 45% (1.088%), slope 25-45% (0.831%), 15-25% (0.973%), and 8-15% (0.874%).

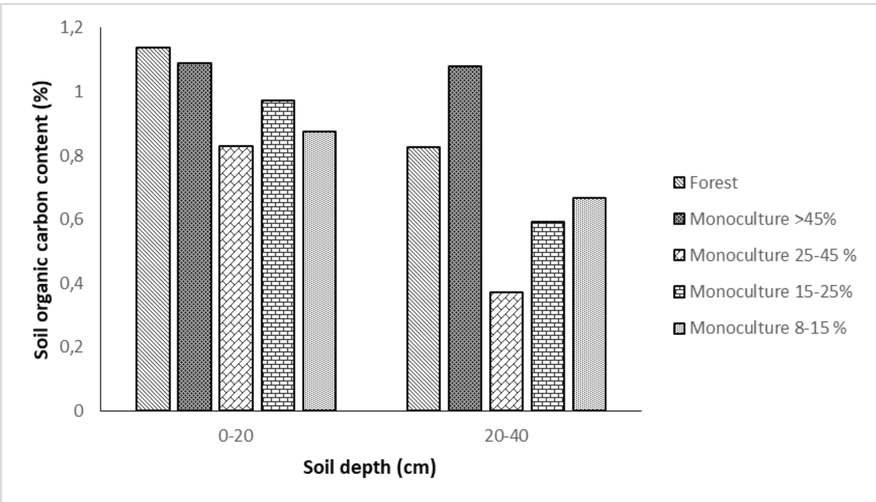

Figure 4. Soil organic matter content in monoculture agricultural land at several slope classes and soil depth

Based on the difference in slope in monoculture agricultural land with a slope> 45, it is higher than 25-45%, 15-25%, and 8-15%. At 20-40cm depth, the organic C content in monoculture land use was> 45% (1.078%), or much higher than the forest's C-Organic content (0.825%). Furthermore, the lowest organic matter content is found in monoculture land use on slopes of 25-45%, both at 0-20cm (0.831%) and 20-40cm (0.370%) depths.

Based on the results, it can be concluded that the top soil contains higher C-organic than the subsoil, especially forest soil, which is higher than monoculture agricultural land. If the values are converted to the corresponding organic matter content, in monoculture agricultural land and forest it is less than 2%. Hence, the soil organic matter content can be categorized as quite low, and it is necessary to pay attention to the management of organic matter, related to erosion mitigation [5]. Hence, the solutions are reducing the intensity of soil cultivation, adding fresh organic matter, returning the harvests, and using ground cover.

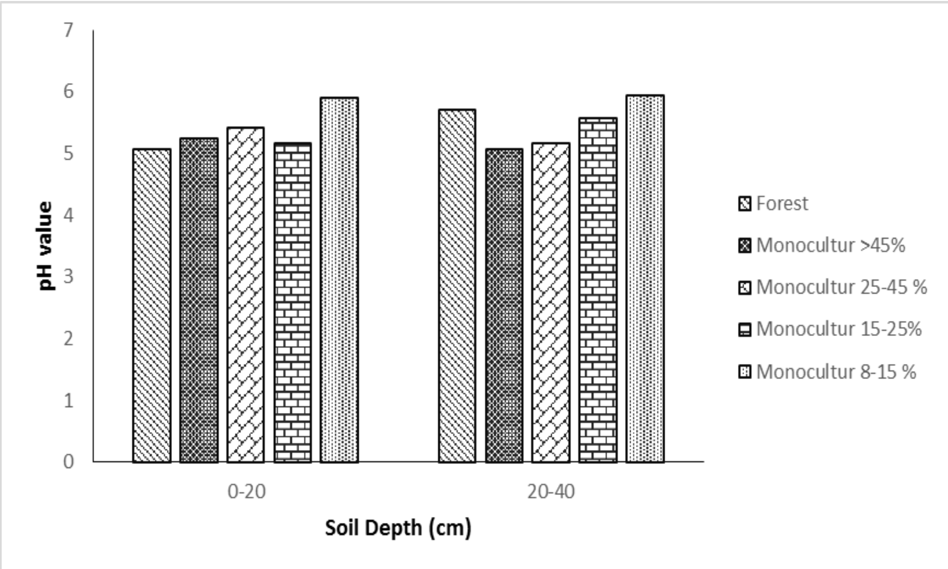

Figure 5. Soil pH value on monoculture land in several slope classes and soil depths

Based on Figure 1, the soil pH value based on the soil depth, the pH value was ranged from 5-5.9, it can be categorized as slightly acidic. While some crops grow best in the range of 6.0 to 7.0, others grow well under slightly acidic conditions [4]. The highest soil pH value was 5.90 on monoculture land with slope level 8-15%, while the lowest pH value, 5.15, was on monoculture land with a slope> 45%. The highest soil pH is found on agricultural land, with slopes of 8-15% with pH> 5.5. The solubility of the nutrients will affect plant growth, and it is closely related to soil pH. The pH range above is a general range for the pH of mineral soils in humid areas [5].

3.6 Cation Exchange Capacity of the Soil

Soil CEC value indicates the negative charge of soil colloids that retain cations in water membranes on its surface. Based on Figure 1, the CEC of the land is very high, such as > 40 me / 100g. Meanwhile, the soil CEC at topsoil higher than subsoil. Soil CEC at 0-20 cm of 115.142 me/100 g in the forest is higher than monoculture agricultural slopes> 45 (90.004 me / 100g), at slope 25-45% (96,116 me / 100g), 15-25% (85,148 me / 100g), and 8-15% (76,571 me / 100g). This is related to the influence of soil texture in forest land, such as clay soil in 0-20 cm depth.

Clay texture and high organic matter content and soil pH can increase soil CEC. [2] explains that cation exchange capacity is determined by the nature and amount of mineral and organic colloids contained in the soil. Based on the difference in the slope of soil CEC on monoculture agricultural land with a slope of 25-45%, it is higher than > 45%, 15-25%, and 8-15%. Meanwhile, in soil layer at 20-40cm depth, the CEC for monoculture land use was> 45% (111.677 me / 100g), and it is much higher than the CEC for forest soil (80.653 me / 100g), 25-45% (98.097 me / 100g) for monoculture agricultural land., 15-25% (90,804 me / 100g), or slopes 8-15% (94,118 me / 100g). Overall, the CEC of soil in the foothill of Mount Talang are high, because of the soil is thrive from volcanic matter that showed by soil bulk density was lightly, dominated by amorphous or non-crystalline and crystalline clay minerals that have high CEC about +20 to -150 me/100g [5]. This mineral content has a good impact on the chemical, physical and biological properties of the soil.

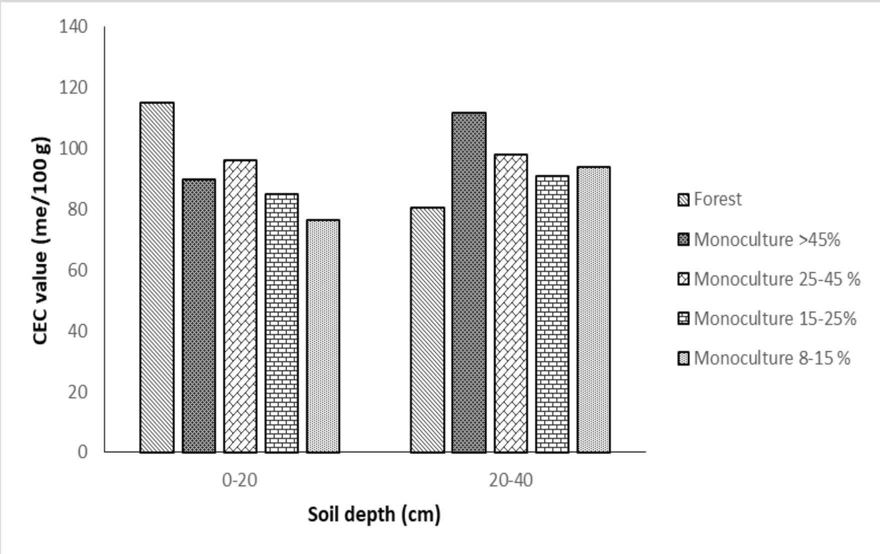

Figure 6. Soil cation exchange capacity in monoculture agricultural land on several slope classes and soil depths

3.7 Total Nitrogen

Total Nitrogen of the soil indicates the total amount of inorganic N and organic N. Based on Figure 1, total Nitrogen of the soil in monoculture agricultural land and forest is 0.8-1.6%, categorized as very high, especially at 0-20cm depth layers, and tends to decrease with increasing soil layer depth.

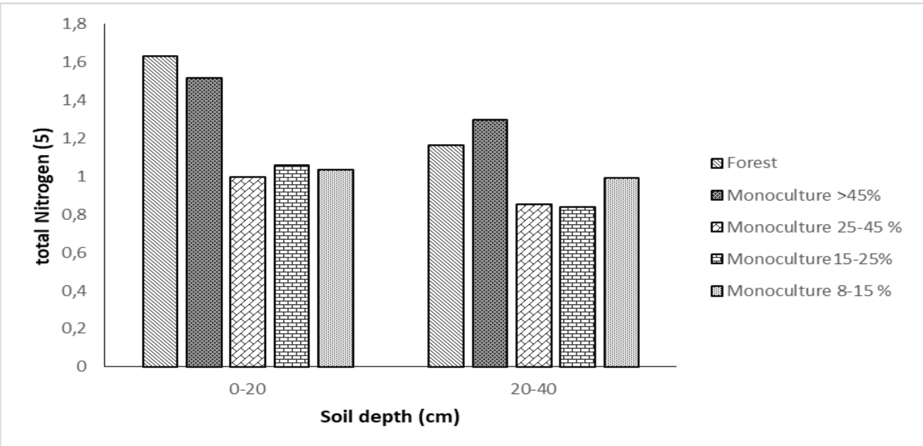

Figure 7. Total Nitrogen content of soil on monoculture agricultural land in several slope classes and soil

The total N content in the soil at 0-20 cm depth is higher than that of 20-40 cm depth. The total N content at 0-20 cm depth in the forest (1.630%) is higher than the monoculture agricultural land slope

> 45 (1.516%), 25-45% (0.996%), 15-25% (1.061%), and 8-15% (1,034%). Based on the difference on the slope of total N content in monoculture agricultural land with slopes> 45, it was higher than the slopes of 25-45%, 15-25%, and 8-15%. Meanwhile, at 20-40cm depth, the total N content in monoculture land use was> 45% (1.3%) higher than the forest organic C content (1.165%) and monoculture 25-45% (0.853 %), 15-25% (0.839%), and 8-15% (0.992%). Total nitrogen is mostly influenced by soil organic matter in the form of plant and animal remains, both decomposed and partially decomposed, heterotrophic biomass, and soil humus. Soil organic matter is the subject of decomposition from plant remains to stable humus, and the reaction of physical, chemical, and soil environmental factors that determine the stability of inorganic N for plants [2].

4. Conclusion

Based on the result, it reveals that the physicochemical properties of the soil on monoculture land in the northern area in the foothill of Mount Talang still was similar to the natural conditions, such as forest, especially in the 0-20cm soil layer. The soil texture that dominates the forest and monoculture land is sandy loam. Soil water content in monoculture 25-45% (73.72%) is categorized as the highest. Soil volume weight ranging from 0.4-0.6 g / cm^3, and it has the same tendency at both soil depths. The total pore space of forest land and monoculture land is 75%, categorized as high criteria. The highest soil organic C content is found in monoculture land with a slope of> 45%. The pH value for all land uses is 5.15-5.29 on slightly acidic criteria. Soil cation exchange capacity is very high, above 40 me / 100g, and the total N is 0.8-1.6%, categorized as very high which tends to decrease with soil depth. On the other hand, the C-organic is categorized as low (<2%). The soil physicochemical properties on monoculture land have not much change compare with natural condition like forest, even though it is on the upper slopes of the foothill of Mount Talang.

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