Available at : https://ejournal.unib.ac.id/index.php/terrajournal ISSN 2621-0207
DOI : https://doi.org/10.31186/terra.6.1.40-45

TERRA
Journal of Land Restoration

Effect of Slope and Distance from Oil Palm Stands on Soil Water Content

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ABSTRACT

This study aims to study the effect of land slope and distance from the main crops on soil water content at the end of the rainy season. The research location is located at position 3°41'51.8"S - 102°18'58.0"East in Talang Tengah I Village, Pondok Kubang District, Central Bengkulu. The research was conducted in February - April 2021. Soil analysis was done at the Soil Laboratory, University of Bengkulu. The study used a completely randomized block design with two factors. The first factor is the slope of 0-3% and 30%. The second factor is the distance of the cutting slope from the main oil palm tree, namely 1.5; 2.0; 2.5; 3.0; 3.5; and 4.0 m. Data were analyzed using ANAVA and LSD at 5% level. The results showed that the slope of the land and the distance between the slopes had a significant effect on the soil water content. The soil water content in both gravimetric and volumetric methods on slopes of 0-3% is higher than on slopes > 30%. The water content at a distance of 1.5 to 3 m from the tree of oil palm is lower than at a distance of 3.5 – 4.0 m.

Keywords: groundwater, gravimetry, slope, volumetric

INTRODUCTION

Water is necessary for plants to grow. Plants can absorb water available in the soil. However, the water needs of each plant are different. Maryani (2012) states that the availability of water in the soil must be sufficient to meet the water needs of plants. If the available water is not sufficient for the needs of plants, as a result, water as a raw material for photosynthesis and transportation of nutrients to the leaves will be hampered, which will have an impact on plant yields (Muis, 2013). The science of hydrology explains that there are three types of water, namely groundwater, rainwater, and surface water (Sudarmadji, 2013). One of the factors that influence plant growth and development is groundwater (Chairida, 2017). The ability of the soil to store water is an indicator related to the critical level of land in supplying water for plant growth.

The water needs of oil palm plants require around 1,500-1,700 mm/year, which is equivalent to the average annual rainfall to meet the growth and production of oil palm plants. Oil palm requires relatively large amounts of water compared to other plantation crops (Harahap & Darmosarkoro, 1999). Soil physical properties play an important role in oil palm production, especially when linked to the soil's ability to store water (Sunarti *et al*., 2008). One of the soil's physical properties that is the main limiting factor for oil palm production is the availability of groundwater/soil moisture. The availability of water in the soil depends on the speed at which water is absorbed and transferred from the surface to the subsoil. The ability of the soil to hold water is influenced by its physical properties of the soil. Water deficit will cause drought stress on oil palm plants.

Characteristics of groundwater related to the soil's ability to hold water in very critical conditions. when the higher the value of the water content in dry wind conditions, the greater the soil's ability to store water for plants when experiencing drought (Hermawan, 2004). Several previous studies have found a close relationship between soil water content and the slope of the land. On land with a slope of 60-100%, the ability of the soil to store water under field capacity conditions drops to 0.26 g g^{-1} in the dry season and 0.27 g/g during the rainy season (Yanping *et al*., 2008). Apart from the slope, the position of the upper, middle, and lower slopes also affects the groundwater characteristics. Yasin & Yulnafatmawita (2018) reported an increase in available soil water content for plants of up to 28% at the bottom of the slope compared to positions above it. Thus it appears that there is a direct relationship between the slope of the land and humidity. Steeper slopes have lower water content due to surface runoff or faster water movement compared to flat, sloping, or wavy slopes (Banjarnahor, 2018).

Vertical movement of water can dissolve soil materials and cause soil materials to sink and accumulate on the downslope. The position of the slope also affects the amount of surface runoff. The more water that flows, the higher the speed at the bottom of the slope (Saribun, 2007). The results of research by Hermawan *et al*. (2014) showed that there was a very close negative linear relationship between the slope of the land and the growth and yield variables of the oil palm plants observed. About 70% of the variation in stem diameter, 60% of the variation in plant height, 62% of the variation in the number of FFB per tree, and 72% of the variation in FFB weight can be explained by the variation in slope. Limiting the slope of the land to the suitability of land for oil palm will affect the amount of land and water management costs to obtain optimum growth and yield.

The amount of water in a certain area is affected by the amount of water entering (input) and leaving (output) in a certain period. The physical properties of the soil are affected by differences in land use and turn affect the properties of water retention and movement in the soil. This causes differences in the dynamics of soil water content. The potential of water resources in the form of stored water available in the soil is very much needed in agricultural hydrology and water management in the framework of agricultural development. Ground surfaces with good coverage can have an impact on the availability of groundwater reserves, to meet the demand for raw water for agriculture, groundwater is an alternative (Saputra, 2016). Monitoring of soil profile moisture content can be done automatically in the field using an electrometer developed by Hermawan (2005). Soil water content can be determined directly by measuring the difference in soil weight (called the gravimetric method) and indirectly by measuring other properties that are closely related to groundwater (Gardner, 1986). One of the physical properties that are the main limiting factor for oil palm production is the availability of water. So by doing this research it is expected to be able to know the effect of the slope and distance during the rainy season from the main tree of mature oil palm.

The purpose of this study was to study the effect of land slope and distance from the main plant on the groundwater profile at the end of the rainy season.

MATERIALS AND METHODS

This research was conducted from February to April 2021. The research location is located at position 3°41'51.8"S - 102°18'58.0"East in a smallholder oil palm plantation in Talang Tengah I Village, Pondok Kubang District, Central Bengkulu Regency (22 km from University of Bengkulu). All soil samples were analyzed at the Laboratory of Soil Science, Faculty of Agriculture, University of Bengkulu.

This study used a randomized completely block design (RCBD) with two factors. The first factor is the slope of the land which consists of two slopes, namely 0-3% and > 30%. The second factor was the six distances that cut the slope from the oil palm stands, namely: (1.5; 2.0; 2.5; 3.0; 3.5; and 4.0 m). Each treatment combination was repeated three times on different plants to obtain a total of 36 experimental units.

The equipment used in this activity includes an oven, sample ring, copper cup, hydrometer, ombrometer, sensor cable, electrometer, and scales. While the materials used in this study are intact soil and disturbed soil.

The observation point for data collection was determined based on the results of field observations so that the observation point was determined which consisted of 6 mature palm trees with an age of 18 years. Three tree stands from a slope of 0-3% and three trees from a slope > 30%. Each oil palm stand on a 0-3% slope is relatively close to the stands on a 30% slope.

A sampling of disturbed soil and undisturbed soil at each observation point was carried out to a depth of 30 cm with 10 cm depth intervals. Soil samples were brought to the Laboratory of Soil Science, Faculty of Agriculture, University of Bengkulu for soil density analysis.

At each observation point in the field, a pair of adjacent copper sensor cables were installed and inserted into the soil at a depth of 0-10 cm, 11-20 cm, and 21-30 cm, at the top the cable was stripped 3 cm and the bottom cable was stripped 10 cm. so that the copper is in contact with the ground. The cables are inserted into the ground at intervals of 10 - 30 cm depth so that the depth is 30 cm. So that there are 3 pairs of cables in each soil profile (Figure 1).

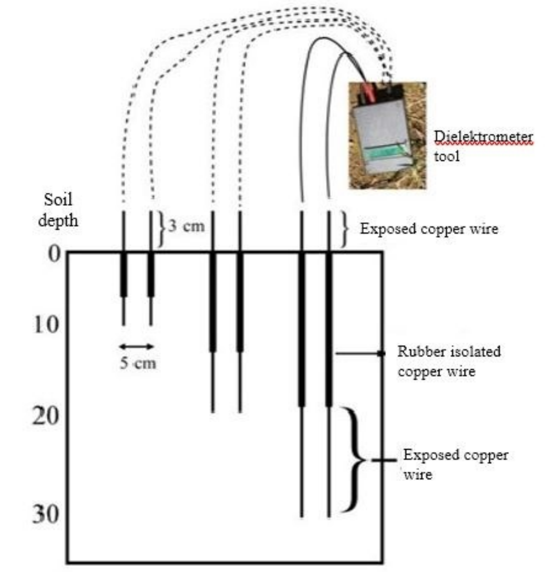

Figure 1. Sensor cable installation

Determination of soil water content begins with measuring the dielectric properties in the form of soil electrical impedance (Z, unit of kilo ohm) by planting sensor cables into the soil. The soil water content is measured directly using an electrometer as described by Hermawan *et al*. (2017). The electrometer is a device for measuring soil impedance. The working mechanism of the electrometer is illustrated in Figure 1, a pair of wires is prepared, rubber on the ends 10 cm peeled and then inserted into the soil according to the desired depth. Approximately 3 cm of the top of the cable is left above the ground level, connected to an electrometer, then the device is turned on to read the electrical impedance of the ground (symbol Z, unit kΩ) at depths of 0-10, >10-20, and >20-30 cm. The Z value read on the Dielectrometer LCD screen is then converted to a soil water content value (symbol θ, unit g/g) using the equation $\theta = 0.65\mathbf{Z}^{-0,2}$ obtained through field research on the same land by Hermawan *et al*. (2017).

Z measurements were carried out periodically 2 times a week for 8 weeks. If there is no rain for a long period, measurements are taken once a week until sufficient information is obtained to describe the redistribution of precipitated water in the soil profile during the drainage period (discharge phase).

The main soil variables measured from disturbed and intact soil samples are Gravimetric soil water content (%). Gravimetric water content is a direct determination of soil water content. Gravimetric water content is measured periodically at depths of 0-10 cm, 11-20 cm, and 21-30 cm using a dielectrometer and is carried out 2 times a week for 8 weeks (Hermawan *et al*., 2019); Volumetric soil water content ($cm^3\ cm^{-3}$). Volumetric water content is the result of gravimetric water content which has been converted to a volumetric value where the volumetric water content is the multiplication of the gravimetric water content and the unit weight of the soil at the same depth (Hermawan, 2004).

The supporting variables observed included: C-organic (%). C-organic measured only on the slope taken from several points and analyzed by the Walkey & Black method; Texture. The texture is analyzed using a hydrometer; Rainfall data. Daily rainfall data from February to April 2021 were taken in Talang Tengah I Village, Pondok Kubang District - Central Bengkulu, measured directly in the field using an Ombrometer (Soil Science Laboratory, Faculty of Agriculture, University of Bengkulu).

The main variable data measured were analyzed using Analysis of variance (Anava) followed by LSD at the 5% level.

RESULTS AND DISCUSSION

The soil order in this study was Ultisol, during sampling, there were 14 rainy days. The research was started by determining 6 main points of oil palm plants in the productive category with the age of 18 years. The plants used consisted of three trees on a slope of 0-3% and three trees on a slope > 30%. The main trees of mature oil palm were selected purposively (selected only plants that bear fruit), based on the results of interviews in the field, the yield of FFB harvested on oil palm plants is around 15-20 kg per tree. Gravimetric water content measurements were carried out 2 times a week for 8 weeks with intervals of 10 cm to 30 cm depth measurements.

The results of the analysis of variance showed that there were no significant differences in the interaction between treatments on both the gravimetric and volumetric water content. However, independently the slope and spacing of the plants had a significant effect on the gravimetric and volumetric water content (Table 1).

Tabel 1. The analysis of variance on the effect the slope of the land and distances that cut the slope from the oil palm stands

Source of variance	F value		F 5%
	Gravimetri	Volumetri	
Slope	23.52 *	5.33 *	4.32
Distances	3.87 *	14.42 *	2.66
Interaction	0.47 ns	1.42 ns	2.66

Note : * = significant ; ns = non-significant

The slope of the land has a significant effect on the gravimetric water content. The gravimetric water content on a slope of 0-3% (L1) is higher than that of a slope > 30% (Figure 2). Likewise, volumetric soil water content has the highest water content on the slope of 0-3% (L1) (Figure 3). This is influenced by the amount of organic matter or covers litter on the 3% (L1) slope. In other words, the higher the C-organic content of the soil, the higher the organic matter content (Kusumawati & Prayogo, 2019). The low value of the water content at > 30% (L2) can be caused by the steep slope. Steeper slopes have lower water content due to surface runoff or faster water movement compared to flat, sloping, or wavy slopes (Banjarnahor *et al*., 2018).

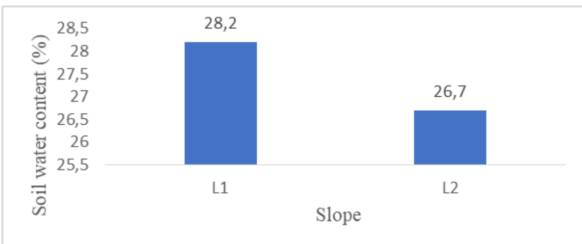

Figure 2. Gravimetric soil water content on two different slopes

Several studies have shown that reduced soil water content on more sloping land is closely related to the different hydrological patterns below the soil surface between flat and sloping land. On sloping land, the movement of precipitating water that enters the soil profile does not only occur vertically as on flat land but also laterally parallel to the land surface and moves downwards (Lee & Kim, 2019). This could be due to the vertical movement of water which can dissolve soil materials and cause soil materials to sink and accumulate on the downslope. The position of the slope also affects the amount of surface runoff, the more water that flows, the higher the velocity at the bottom of the slope (Saribun, 2007).

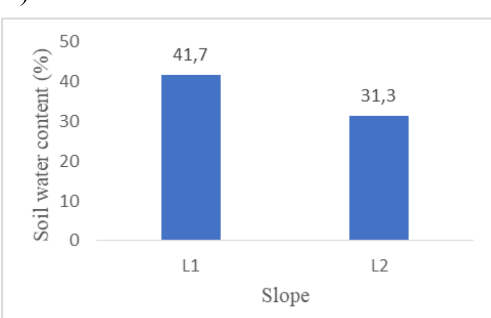

Figure 3. Volumetric soil water content on two different slopes

Water content is closely related to soil organic matter because it can increase the soil's ability to absorb water. An increase in soil pore space is followed by an increase in soil organic C- (Saputra, 2016). Evapotranspiration is also one of the factors that cause a decrease in soil water content on each slope. Evapotranspiration is a combination of evaporation and transpiration cycles. The combination of these two processes can affect the water content in the soil which is needed in plant metabolic processes (Surdiantoro *et al*., 2012). So that the circulation of water and air from the atmosphere into the soil becomes unbalanced which results in micro-pores dominating the soil. The availability of water in the soil depends on the ability of the soil to absorb and transmit water received from the soil surface to the subsoil. The ability of soil to store water is influenced by soil texture and organic matter (Jumin, 2002). Water content is closely related to soil texture, if the soil has a more sand fraction, more macro pores will be formed. This causes the movement of water and other substances in the soil to be strong. The increase in clay content in the soil is gradually followed by a decrease in water content (Suparding *et al*., 2018). Tetegan *et al*. (2011) stated that different sand content in the soil will provide a different ability for the soil to hold water so it can affect water content.

Groundwater is one of the physical properties that directly influence plant growth and other aspects of human life. The amount of groundwater is termed the groundwater content, namely the amount of water contained in the soil. Usually expressed in mass percent or volume percent (Hakim *et al*., 1986). For agricultural scientists, soil water content is one of the important variables of the investigated plants. To determine the soil water content of a wet soil sample, there are four methods used, namely gravimetrically, tension or suction, electrical resistance (resistance block), and neutron scattering (Hakim *et al*., 1986).

Volumetric and gravimetric soil water content concerning distance shows that soil water content has a value that varies according to the distance from the oil palm trunk. In general, the soil water content at a distance of 1.5 m to a distance of 3 m tends to be lower and then increases at a distance of 4 m from the plant because at a distance of 1.5 m to 3 m the water demand for oil palm is increasing. It can be seen that the farther from the plant stem, the fewer the roots, and the water content will increase as shown in Table 2. The maximum absorption of groundwater by the roots of the oil palm occurs at a distance of 1.5 to 3 m from the stem which is probably caused by root development maximum in this range. The lack of roots at a radius of 1.5 m from the stem causes soil moisture to remain high, while at a distance of 4 m, there are also few roots because they are close to the farthest point from the planted oil palm tree with a distance of 9 m x 9 m and a canopy radius of 4.5 m (Hermawan *et al.*, 2019).

Table 2. Soil water content at various distance from oil palm stands

Water content (%)	Distances (m)					
	1.5	2.0	2.0	3.0	3.5	4.0
Gravimetric	27.5 ab	27.6 ab	27.5 ab	27.5 ab	26.3 b	28.0 a
Volumetric	36.8 b	36.9 b	36.3 b	36.8 b	36.8 b	44.0 a

Note : The numbers followed by different letters in the same row are significant different at LSD 5%

Water content is the difference between water input from precipitation that infiltrates the soil plus the results of condensation and adsorption minus water lost through evapotranspiration, runoff, percolation, and lateral seepage (Hanafiah, 2004). Rain intensity indicates whether or not heavy rain. Large rainfall intensity means that large amounts of water are poured out in a short time, the water droplets are large and will cause even greater erosion, due to large surface runoff, while water absorption will be hampered (Hanafi, 1988). The rate of absorption of water into the soil through infiltration is influenced by the physical properties of the soil, especially texture, and structure. Infiltration rates are several times higher in sandy soils than in clayey soils or if the same soil has fallen to the surface so that the soil is unable to transmit it into the soil.

Observing the average soil water content in seventeen observations, the highest water content was obtained in the 5th observation (Figure 3) both at L1 and L2. This observation occurred during high rainfall. To obtain a rainfall value of 35 mm. L1 is farther from the plant stem, and the value of soil water content increases (Figure 4). This can occur due to the absorption of soil water content by the roots at the closest distance from the oil palm plant, but this is different from L2. At L2 the value of soil water content was high at the first observation and then decreased at the next observation. This can happen because L2 at a distance of 1.5 m has higher soil moisture compared to L1. The first observation is that L2 has a higher water content value.

The rate of absorption of water into the soil through infiltration is influenced by the physical properties of the soil, especially its texture and structure (Pramono & Adi, 2017). According to Rahim (2013), the infiltration rate is several times higher in sandy soil than in clay soil or if the same soil has a good structure and is open, especially on the surface. The speed at which the rate of infiltration of a soil type in the field can be seen with the naked eye by observing the dynamics of the water that falls to the ground surface.

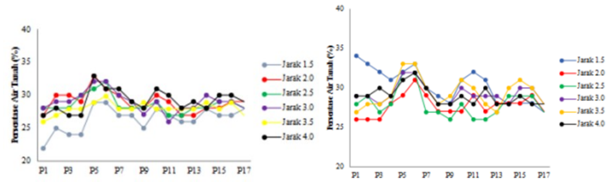

Figure 4. The average soil water content at a distance different from the palm tree during observation

CONCLUSION

Based on the research results, it can be concluded that the slope of the land affects the gravimetric and volumetric water content, the steeper the slope of the land, the lower the soil water content. The distance from the oil palm plants also affects the gravimetric and volumetric water content. The soil water content at a distance of 1.5 m – 3 m from the plants is lower than the soil water content at a distance of more than 3 m.

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