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Review

Soil Hydraulic Conductivity and Soil Water Retention of Inland Peat on Various Land Covers (Case Study: Natural Peat and Burnt Peat)

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Abstract: This research aims to examine differences in the rate of saturated soil hydraulic conductivity (permeability) and unsaturated soil hydraulic conductivity (infiltration) and soil water retention with various pressures in peatland with different land covers. The study was conducted from June to October 2021. The research was conducted at the LAHG-Sebangau and at the KHDTK-Tumbang Nusa, central Kalimantan, Indonesia. Based on the results of this study, at the HA site has the highest saturated soil hydraulic conductivity (permeability) rate at a depth of 0-10 cm was classified as rather fast. The lowest saturated soil hydraulic conductivity (permeability) rate of the HS site at a depth of 20-30 cm was classified as a rather slow. The highest unsaturated soil hydraulic conductivity (infiltration) rate was at the HS site at a depth of 0-10 cm was classified as fast, while the lowest was at the natural forest (HA) at a depth of 10-20 cm classified as very slow. The soil physical characteristics: Soil water content ranging from 474.769-631.364%, fiber content ranging from 8.00-22.67%, bulk density ranging from 0.12-0.19 g cm^{-3}, porosity ranging from 71.61-85.63% and the color of the soil is dark brown to very blackish red dark. Meanwhile, the ability of the soil to accommodate maximum soil water (saturated conditions) with the highest pF 0 is at the HK site at depth of 10-20 cm was 377,92 cm^3 cm^{-3}, while the lowest is in the HR site at depth of 0-0 cm is 31.11 cm^3 cm^{-3}. The ability of the soil in maximum soil water holding (water control conditions) at pF 4.2 is highest in the HS site at depth of 20-30 cm was 61.10 cm^3 cm^{-3}, while the lowest is in the HR site at depth of 0-10 cm was 13.30 cm^3 cm^{-3}. The soil porosity value in the HS site was higher than that of the HR site, which is 85,830 and 82,130%. The weight value of particle at the HS site was higher compared to other land cover ranging from 0.74-0.86 g cm^{-3}. The weight value of bulk density at the HS site ranging from 0.17-0.19 g cm^{-3} was higher than other land cover.

Keywords: Peatland, Permeability, Infiltration, Soil Water Retention, Land Cover and Soil Physical Characteristics

Introduction

Indonesia is a country with abundant natural resources, one of which is peat. Indonesia has an area of peatlands of about 14.9 million ha spread over the island of Sumatra 6.4 million ha (43.18%), the island of Kalimantan 4.7 million ha (32.06%), the island of Papua 3.6 million ha (24.8%) and mostly on the islands of

Sulawesi, Halmahera and Seram (BRG, 2017; Ramdhan and Siregar, 2018). The peat ecosystem is one of the ecosystems that has important roles and benefits for human life, which is currently being used for various development activities. These benefits include: Water supply and flood control, tourism potential, local community livelihoods (agriculture, plantations, fisheries), climate stability, biodiversity, as well as for education and research. In this case more than half (24.8 Mha) of the total area of tropical peat is in Southeast Asia (56%), especially in Indonesia and Malaysia, which based on their thickness (on average >5 m) are able to store C by 77% (Page *et al*., 2011).

Peat soil is soil that contains high concentrations of organic matter derived from partially or completely decomposed plants, under water and anaerobic conditions. Peat soil composed of litter derived from the leaves can increase the organic matter content of the soil. Inland peat soil is peat soil that is formed in areas that are not affected by tides but are influenced by rainwater (Suswati *et al*., 2011). It is known that the existing vegetation on a land has a role as a stabilizer of soil aggregates, where the roots of the vegetation can bind soil particles and are also able to withstand the impact of rainwater droplets that fall directly to the soil surface, resulting in the destruction of the soil. Soil can be prevented (Arifin, 2010).

One of the keys to success in good and sustainable peatland management is water management. Infiltration is a very important factor in the process of groundwater formation which functions as a balancer or determinant of the maintenance of groundwater sustainability. Water management on peatlands requires a proper understanding of the physical properties of peat soils. Peat has a high moisture content but it also dries easily. Larashati (2010) said that the water in the lower layer of peat soil is difficult to rise above the top layer, so that the top layer of peat often experiences fire. The ability of the soil to absorb water is an important factor that will influenc the availability of water in the soil. The physical properties of the soil are one of the factors that affect the entry of water into the soil. Water management is the main key to successful peat management and requires an understanding of the physical properties of peat soil (Indahyani *et al*., 2017). Most of the water in peat soil is in a condition that is not available to plants because peat is dominated by macro pores, most of the groundwater is in the form of gravity water and water which is very tightly bound by solid particles of peat soil (Kurnain, 2008).

The movement of water and the rate of change in water content in the soil is largely determined by the characteristics of the soil pores that make up the soil structure, such as pore distribution, pore continuity and pore tortuosity. As a result of various soil management that has been carried out by farmers, dry land soil has a very varied soil structure, so that it affects the characteristics of the pores. Bagarello *et al*. (2004) stated that differences in soil structure due to various managements can affect the ability of the soil to retain water and the movement of water, both saturated and unsaturated in the soil. As for Perfect *et al*. (2002) stated that the rate of water movement can affect the distribution of water and nutrient solubility in the soil, so that nutrients are evenly distributed in the root zone. The movement and distribution of water in the soil is also highly dependent on the nature of the falling rain (Edwards *et al*., 1992; Torr *et al*., 2004).

The movement of water in the soil or the hydraulic conductivity of the soil is divided into two, namely saturated hydraulic conductivity (permeability) and unsaturated hydraulic conductivity (infiltration). Soil hydraulic conductivity is the speed at which water can move vertically through the soil under certain conditions, which is generally relatively high in peat soils (BBSDLP, 2013). Infiltration is the process of moving water from the surface to the ground that enters the soil (Agustina *et al*., 2012).

The type of land cover greatly affects the physical properties of the soil. Different types of land cover cause the direct rainwater catchment area to decrease. Land cover is one of the factors that affect the ability of the soil to absorb water. The vegetation plays a role in stabilizing soil aggregates because its roots can bind soil particles and are also able to withstand the impact of raindrops directly on the soil surface so that soil destruction can be prevented. Differences in land cover types and differences in soil properties, which include the conversion of land from vegetation to land with minimal vegetation, have resulted in changes in the rate of saturated hydraulic conductivity (permeability) and unsaturated hydraulic conductivity (infiltration) in the soil (Sampurno and Thoriq, 2016).

This research was conducted to better understand the importance of measuring saturated soil hydraulic conductivity (permeability), unsaturated soil hydraulic conductivity (infiltration) and soil water retention. By measuring these two things, it can be seen the ability of the soil to conduct water and the movement of water in the soil (Rosyidah and Wirosoedarmo, 2013). Based on this fact, it encourages the author to conduct research and understand the importance of studying saturated soil hydraulic conductivity (permeability), unsaturated soil hydraulic conductivity (infiltration) and soil water retention on peat soils with different land cover types.

Methods

Study Site

This research was conducted in June 2021 September 2021 (dry season). We took soil sampling at the Tumbang Nusa special purpose forest area (KHDTK-Tumbang Nusa), Pulang Pisau regency, central kalimantan province from 3 types of land cover, namely, secondary forest

(HS), burnt peat (HK), revegetation/RePeat (HR) and then at the Natural Laboratory of Peat Swamp Forest (LAHG-Sebangau), Palangka Raya city, central Kalimantan province we took soil sampling from 1 type of land cover, namely natural forest (HA) (Fig. 1 and 2).

In the KHDTK-Tumbang Nusa area of 5,000 ha (4,963.97 ha). Based on the research from Mariaty and Santosa (2019) there are 19 dominant species in non-burnt areas at the Tumbang Nusa special purpose forest area (KHDTK-Tumbang Nusa), Pulang Pisau regency, central Kalimantan province, namely: Sasendok (*Ficus Deltoides* sp.), Milas (*Litsea oppositifolla*), pasir-pasir (*Stemonurus scorpiodes*), Nyatoh (*Palaqulum cochiearia*), Tarantang (*Campnosperma auriculata*), Jambu-jambu (*Syzlum* spp.), Madang Lengkuas (*Macanga populifolia*), Meranti Bunga (*Shorea teysmanniana*), Pintek (*Litsea Oppositifolia*), Pampaning (*Quercur suserices*), Galam Tikus (*Eugenia* sp.), Merapat (*Combretocarpus rotundatus*), Malam-malam/Kalampuri (*Diospryros malam*), Rahanjang (*Xylopia* sp.), Gerunggang (*Cratoxylon arborescens*), Manggis Hutan (*Garcinia cf. Bancana*), Darah-darah (*Horsflieldia* sp.) and Martibu (*Eugenia* sp.). Meanwhile there are 29 dominant species in non-burnt areas at the natural laboratory of peat swamp forest (LAHG-Sebangau), Palangka raya city, central Kalimantan province, namely: Tarantang (*Campnosperma auriculata* Hook), Rambutan Hutan (*Naphelium lappaceum*), Jambu-jambuan (*Eugenia* sp.), Tutup Kabali (*Diospyros pseudomalabarica*), Bintangur (*Calophyllum inophyllum*), Rengas Putih (*Gluta rengas*), Bangkinang (*Elaeocarpus glaber* BI.), Kambasira (*Ilex cymose*), Nyatoh (*Palaqulum* sp.), Kaja (*Dillenia excelsa*), Gantalam/Manggis Hutan (*Garcinia parvifolia*), Kayu Gula (*Litsea grandis*), Kamba Sira (*Ilex cymose*), Resak (*Cotylelobium melanoxylum*), Ehang (*Diospyros siamang* Bakh.), Meranti Padi (*Shorea parvifolia* Dyer), Kayu Kulat (*Cantieya corniculate*), Kayu Martibu (*Dectylociadus stenotachys*), Mendarahan (*Ardisia* sp.), Meranti Batu (*Shorea leprosula*), Kaja Laki (*Agiala rubigunosa*), Kayu Bintan (*Erycibe* sp.), Balangeran (*Shorea balangeran*), Ramin (*Gonystylus bancanus*), Parut (*Callophylum* sp.), Kayu Kacang (*Cantieya corniculata*), Beringin (*Ficus benjamina* L.), Gambir (*Uncaria* sp.) and Karurang/Mahang (*Macaranga triloba*). Beside of that at the burn areas at the Tumbang Nusa special purpose forest area (KHDTK-Tumbang Nusa), Pulang Pisau regency, central Kalimantan province, thera are 4 dominant species, namely: Merapat/Tumih (*Combretacarpus rotundatus*), Gerunggang (*Cratoxylon arborescens*), Belangeran (*Shorea balangeran*) and Jambu-jambuan (*Syzigium* spp.) and then in the burnt areas at the natural laboratory of Peat swamp forest (LAHG-Sebangau), Palangka raya city, central Kalimantan province, there are 2 dominat species, namely: Tempohoi/Tatumbu (*Syzygium* sp.) and Kayu kacang/kulat (*Cantieya corniculata*).

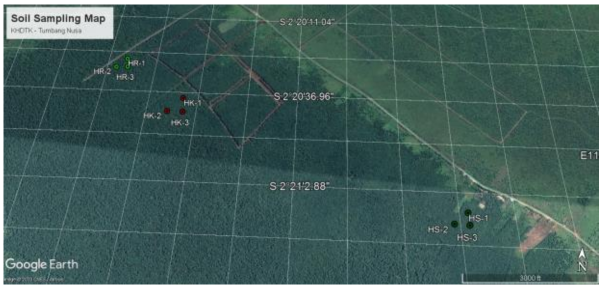

Fig. 1: KHDTK-tumbang Nusa research site

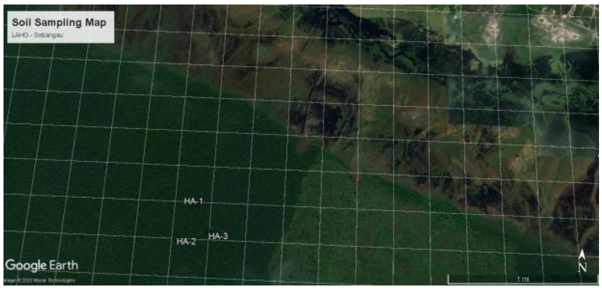

Fig. 2: LAHG-Sebangau research site

These areas (Tumbang Nusa special purpose forest area (KHDTK-Tumbang Nusa), Pulang Pisau regency, central Kalimantan province and the natural laboratory of peat swamp forest (LAHG-Sebangau), Palangka raya city, central Kalimantan province) located between the Sebangau and Kahayan rivers. This areas have a tropical climate with a minimum temperature of 21-33°C and a maximum of 36°C. The average rainfall is between 2,000-3,000 mm year^{-1}. The soil is dominated by the histosol order with an-organic C content of more than 18% (48.07%). The soils of this order are very poor in nutrients with a pH of less than 4. The thickness of peat soils ranges from 3-7 m with a hemic maturity level (33-36% fiber content) and a high bulk density value very low, namely 0.04-0.16. Meanwhile, the altitude of Tumbang Nusa special purpose forest area (KHDTK-Tumbang Nusa), Pulang Pisau regency, central Kalimantan province area is 0-5 m above sea level, with a slope of 0-18% (flat) (BPK Banjarbaru, 2012).

The LAHG-Sabangau is an area managed by UPT. peatland laboratory-CIMTROP, University of Palangka raya covering an area of 50,000 ha which is an area for research activities and other activities to support education and teaching which is in the TNS-Sabangau area.

Soil sample analysis was carried out at the laboratory of the department of agricultural cultivation, faculty of agriculture, university of Palangka raya, laboratory at the UPT. LLG centre for international cooperation in sustainable management of tropical Peatland/CIMTROP) university of Palangka Raya and the environmental and forestry research and development center (BP2LHK), Banjarbaru South Kalimantan.

The research materials were peat soil and aquades, while the tools were plessure plate extractor, sample ring 5.3 cm in diameter and 6 cm in height, Global Positioning System (GPS) Garmin GPSMAP 64 SEA, Munsell soil color chart book, small shovel, meter (5 m), Henherr analytical balance, DHG-9123A oven, 2 mm sieve, stationery and other laboratory equipment.

Procedure of Field Activity

Soil sampling was carried out using the Simple Random Sampling (SRS) method, which is a simple and random sampling method by setting 3 plots at each soil sampling location. Soil sampling locations in LAHG-Sebangau, namely in natural forest (HA) there are 3 plots, while in KHDTK-Tumbang Nusa, namely in secondary forest (HS), burned forest (HK) and revegetation/Re-Peat (HR) in totally there are 9 plots. Soil samples taken were undisturbed soil and disturbed soil with a depth of 0-10, 10-20 and 20-30 cm. The data collected includes saturated soil hydraulic conductivity (permeability) and unsaturated soil hydraulic conductivity (infiltration), soil water retention, soil moisture content, fiber content, volume of weight, soil porosity and soil color.

Determination of Soil Water Retention

Analysis of peat samples in the laboratory is carried out by means of peat samples that have been taken from the field with the sample ring first soaking part for 24 h to saturate the peat sample. Then the peat soil sample was weighed first to get the initial soil weight, then placed on a ceramic plate and given pressure, namely pF 2; pF 2.5; pF 3; pF 3.5; pF 3.7; pF 4; and pF 4.2. Then it was saturated for 48 h, after 48 h the peat sample was weighed again, then the soil water content was determined gravimetrically.

Soil water retention is expressed in the form of a curve, known as the pF curve. Determination of the water retention curve using the van Genuchten method, as follows.

Measured Soil Water Retention Values

The result of measuring soil water content in the laboratory is called gravimetric soil water content and can be calculated using Eq. (1):

$$\theta v = \theta m \times \frac{\rho b}{\rho w} \tag{1}$$

Information:
V = Volumetric of soil moisture content (% v or cm^3cm^{-3})
M = Gravimetric of soil moisture content (% w or g g^{-1})
B = Dry volume of weight (ρb dry = g cm^{-3})
W = Wet volume of weight (ρb wet = g cm^{-3})

Determination of Soil Porosity, Particle Density and Volume of Weight

Soil porosity is the ratio between the weight of the soil volume and the weight of the soil particles (Sajarwan, 2020). The soil porosity value is determined as the total pores calculated from Eq. (2):

$$\varphi = 1\, \frac{Volume\ of\ Weight}{Volume\ of\ Practicle} \times 100\% \tag{2}$$

The procedures of particle weight in this study used the immersion method, namely by filling a measuring cup with 30 mL (*V*1) distilled water which had previously been boiled (BBSDLP, 2006). Then add 20 g (*Ms*) of fine soil sample that has been oven dried and passed a 2 mm sieve, then stirred for a while. After 10 min, calculate the volume of the water and soil suspension *V*2. The weight of the particles is calculated using Eq. (3):

$$ps = \frac{Ms}{Vs} = \frac{Ms}{V2 - V1} \tag{3}$$

Information:
Ms = Mass of soil (g)
*V*1 = Aquadest (mL)
*V*2 = Volume of soil mass _ aquadest

The working procedure of volume weight is by using intact peat samples from profile observations taken with a sample ring. Then the peat soil sample was put in the oven at 105°C for 2 days. After being baked, the peat soil sample was weighed along with the sample ring. Calculate the volume weight with Eq. (4):

$$Bulk\ Density = \frac{Weight\ of\ Dry\ Soil}{Soil\ Volume}\ gcm^{-3} \tag{4}$$

Information:
Soil volume = $p.r^2.t$
T = Sample ring height (cm)
r = Radius (cm)
p = 3.14

Data analysis and regression analysis between environmental factors were analysis using microsoft excel©for windows, after that data were processed and displayed in the form of tables and graphs.

Results and Discussion

Characteristics of Saturated Soil Hydraulic Conductivity (Permeability) of Inland Peat at KHDTK-Tumbang Nusa and LAHG-Sebangau (Dry Season)

Saturated soil hydraulic conductivity (permeability) is defined as the speed at which a liquid moves in a porous medium in a saturated state. The saturated soil hydraulic conductivity (permeability) class of the soil was determined based on the Kohnke (1968). The value of saturated soil hydraulic conductivity (permeability) of each land cover with a depth of 0-10, 10-20 and 20-30 cm will be presented in Fig. 3.

The results presented in the graph above show the value for each land cover that in the HS site has the highest saturated soil hydraulic conductivity (permeability) value at a depth of 0-10 cm was 2.96 cm h^{-1} which is classified as medium and lowest criteria, at a depth of 20-30 cm was 0.93 cm h^{-1} which is classified as a rather slow (Kohnke, 1968). At the HK site has the highest saturated soil hydraulic conductivity (permeability) at a depth of 20-30 cm was 6.40 cm h^{-1} which is classified as rather fast and the lowest is at a depth of 0-10 cm was 3.39 cm h^{-1} which is classified as moderate. On the HR site has the highest saturated soil hydraulic conductivity (permeability) at a depth of 0-10 cm was 4.98 cm h^{-1} which is classified as slow and the lowest at a depth of 20-30 cm was 1.17 cm h^{-1} which is classified as criteria a bit slow. Then at the HA site the highest value of saturated soil hydraulic conductivity (permeability) at a depth of 0-10 cm was 6.76 cm h^{-1} which is classified as a rather fast and the lowest at a depth of 20-30 cm was 1.79 cm h^{-1} which is classified as a rather slow. Most soils, in fact soil hydraulic conductivity is not always constant, due to various chemical, physical and biological processes, soil hydraulic conductivity can change when water enters and flows into the soil. Soil with high hydraulic conductivity will be easily infiltrated by water, so it dries quickly. Thus, the dissolved material contained in groundwater will easily move in the soil along with the movement of water in the soil. On the other hand, soils with low soil hydraulic conductivity will be relatively easy to inundate (Handayani and Wahyuni, 2016).

Based on the graph of the analysis results presented in (Fig. 3), it shows that in the HA site which has the highest saturated soil hydraulic conductivity (permeability) value, namely at a depth of 0-10 cm was 6.76 cm h^{-1} which is classified as a rather fast, while at the HS site has the lowest soil saturated soil hydraulic conductivity (permeability) at a depth of 20-30 cm was 0.93 cm h^{-1} which is classified as a rather slow. The HS site has the lowest/slowest soil hydraulic conductivity value compared to the other sites. The slower the movement of water in peatlands will cause a decrease in the ability of the land to hold water, so that the humidity of the peatlands will be lower. This condition causes peatlands to experience severe dry conditions during the dry season and difficult to rewet during the rainy season due to the slow movement of water. According to the results of that the more mature of the peat, the smaller of the pore size and distribution, thus making the speed of water movement under the peatland soil is slower.

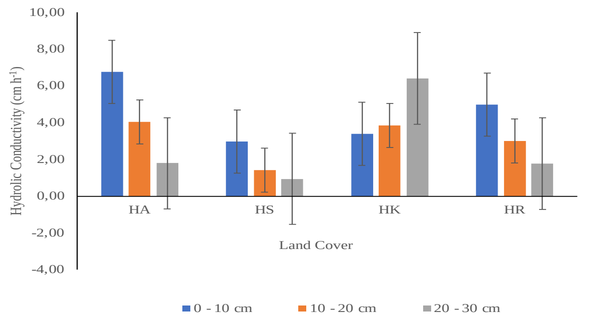

Fig. 3: Saturated soil hydraulic conductivity (permeability) at each depth and land cover

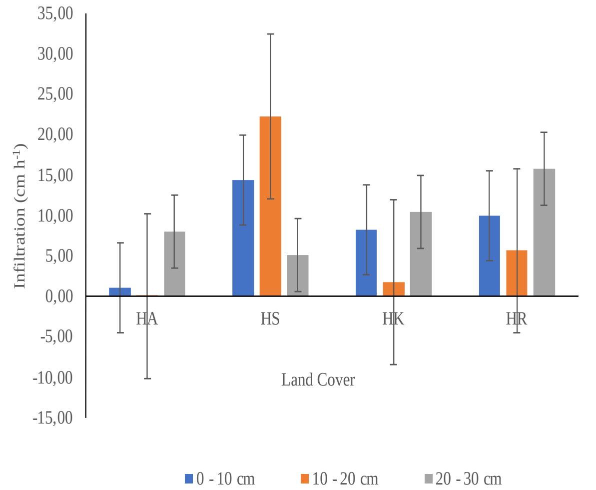

Fig. 4: Unsaturated soil hydraulic conductivity (infiltration) at each depth and land cover

Characteristics of Unsaturated Soil Hydraulic Conductivity (Infiltration) Peat Soil at KHDTK-Tumbang Nusa and LAHG-Sebangau (Dry Season)

Unsaturated soil hydraulic conductivity (infiltration) is a complex interaction between rainfall intensity, characteristics and soil surface conditions. The unsaturated soil hydraulic conductivity class (infiltration) of the soil is determined based on the Kohnke (1968) minimum classification. To determine the value of the unsaturated soil hydraulic conductivity (infiltration) of each land cover with a depth of 0-10, 10-20 and 20-30 cm will be presented in (Fig. 4).

Based on the results, it was found that the HS site has the highest unsaturated soil hydraulic conductivity (infiltration) value at a depth of 10-20 cm was 22.60 cm h^{-1} which was classified as very fast and the lowest was at a depth of 20-30 cm was 5.14 cm h^{-1} classified as moderate criteria based on Kohnke (1968). In the HK site, the highest unsaturated soil hydraulic conductivity (infiltration) at a depth of 20-30 cm was 10.47 cm h^{-1} classified as a rather fast criterion and the lowest at a depth of 10-20 cm was 1.76 cm h^{-1} classified as a bit slow criterion. At the HR site has the highest unsaturated soil hydraulic conductivity (infiltration) at a depth of 0-10 cm was 15.80 cm h^{-1} classified as fast and the most low at a depth of 10-20 cm was 5.68 cm h^{-1} classified as medium criteria. At the HA site, the highest unsaturated soil hydraulic conductivity (infiltration) at a depth of 20-30 cm was 8.26 cm h^{-1} classified as a rather fast criterion and the lowest at a depth of 10-20 cm was 0.05 cm h^{-1} classified as a rather slow criterion.

Based on the results of the analysis presented in (Fig. 4) at all land covers shows that the HS site has the highest unsaturated soil hydraulic conductivity (infiltration), namely at a depth of 10-20 cm was 22.60 cm h^{-1} classified as fast. On the other site the lowest unsaturated soil hydraulic conductivity (infiltration) is at the HA site at a depth of 10-20 cm was 0.05 cm h^{-1} classified as very slow. The results of the analysis show that the infiltration rate is included in the fast criteria, namely HS site, this is presumably because the location is a location where the trees are not too close and when the soil sample is taken it is dry so the soil can absorb water quickly because it has pore space. Based on the results of the analysis carried out, the infiltration rate is included in the slow criteria, namely HA site, this is influenced by cover plants on the land in the form of tall trees growing densely and in groups having deep and many roots so that the soil has high humidity. The soil pores so that water is very difficult to enter and be absorbed into the soil because it is covered by vegetation. The presence of these plant roots can create pores in the soil so that there is a lot of space that can be filled by water when absorption occurs. The infiltration rate will be slower if more water enters and fills the pore space of the soil, if this situation continues, the soil becomes saturated and the speed of water entering the soil is slower (Ramdhan and Siregar, 2018).

Description of the Results of the Analysis of the Physical Properties of Peat Soil at KHDTK-Tumbang Nusa and LAHG-Sebangau (Dry Season)

Soil Water Content

The value of the soil water content of each land cover with a depth of 0-10, 10-20 and 20-30 cm will be presented in (Fig. 5).

The soil water content in the LAHG-Sebangau area tends to have a higher soil water content than that in KHDTK-Tumbang Nusa area. States that the ability to absorb and hold water from peat depends on the level of maturity. This condition is in accordance with the original nature of peat soil which has a porous nature so that it can store large amounts of water. In general, the top of the peat in the study area includes dry peat on burnt land with shrubs because it had been burned in 2015, secondary forest and natural forest with large and dense tree vegetation. However, natural forest land cover has a denser distance between trees than secondary forest. At this location also still has unspoiled forests that have never been touched by humans so that they still have many large trees with close distances between trees. So it has a higher water content value than other types of land cover. The value of water content in HS site is lower due to shrinkage. The forest and peatland fires that occurred in 2015 resulted in the loss of vegetation on the surface of the peat soil, which continued with the shrinkage of the soil surface on the peat soil which was exacerbated by drainage channels, resulting in a decrease in the groundwater level on the land which in turn resulted in compaction or the compaction of soil particles, which at the same time will cause a narrowing of macro pores into micro pores, which results in a decrease in the ability of peat soil to absorb water. Depreciation of peat water content is caused by loss of ground cover vegetation, resulting in reduced function of rainwater inhibitors by vegetation (Purbowaseso, 2004).

Fiber Content

Following are the results of the fiber content for each land cover with a depth of 0-10, 10-20 and 20-30 cm, which are presented in (Fig. 6).

Based on the results of this study, the highest fiber content was found in HA site at a depth of 10-20 cm was 22.67% which was classified as hemic (half ripe peat) and at the HR site at a depth of 10-20 cm has the lowest fiber content of 8.00% which is classified as sapric (ripe peat). The average maturity level of peat at the research site is sapric peat and hemic peat. Sapric peat is peat that has advanced weathering (mature). Hemic peat is peat that has a moderate level of weathering (half-cooked), some of the material has undergone weathering and partly is in the form of fiber. The ability of peat soil to absorb and bind water in fibric peat is greater than hemic and sapric peat, while hemic peat is greater than sapric peat (Sabiham *et al*., 2010).

Each depth has a different fiber content at each depth, but at the same depth at different points it has almost the same fiber content and has the same peat maturity. In general, the decomposition rate of the peat layer above and above the groundwater table is higher or further than that of the peat layer below the water table. Peat found on the surface (top layer) is generally relatively more mature, due to the faster decomposition rate. However, mature peat is often found in the deeper peat layers. This indicates that peat was formed in several stages of time, meaning that the peat that was in the deep layers was once at the surface position.

Bulk Density

The results of the analysis of the bulk density of each land cover with a depth of 0-10, 10-20 and 20-30 cm will be presented in (Fig. 7).

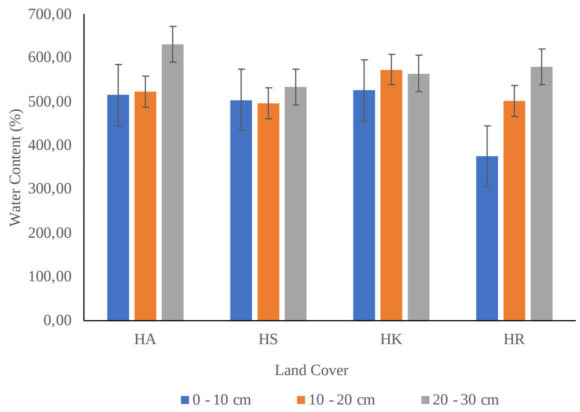

Fig. 5: Soil water content at each depth and land cover

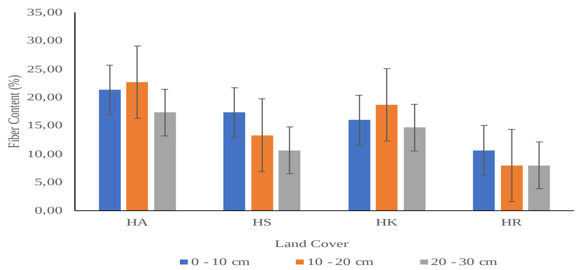

Fig. 6: Fiber content at each depth and land cover

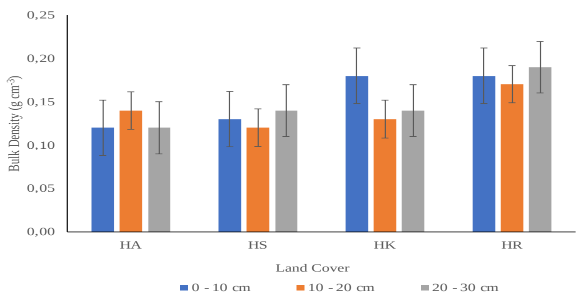

Fig. 7: Bulk densityat each depth and land cover

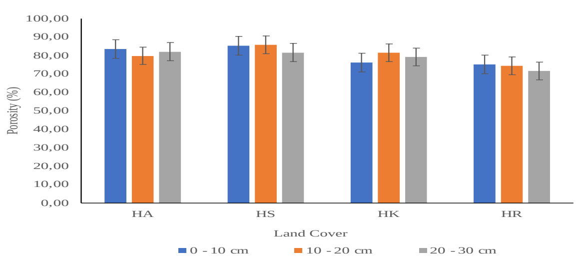

Fig. 8: Soil porosity at each depth and land cover

Based on the results of the graph above, it shows that the highest bulk density is found in HR site at a depth of 20-30 cm was 0.19 g cm^{-3} and the lowest is at the HA site, HS site at a depth of 10-20 cm and HA site at a depth of 0-10 and 20-30 cm by 0.12 g cm^{-3}. The value of the volume weight of HK site and HS site have almost the same value, because the area experienced a fire in 2015 so the value is higher than other types of land cover. The difference is caused by the volume weight in the area of the soil that has been burned has increased the value of the density of the contents. This increase in volume weight is caused by heating caused by combustion which causes the soil to expand and damage the soil pore space and cause the soil to become denser. The denser the soil, the heavier the volume also increases. The size of the value of the weight of the soil volume is influenced by the specific gravity of the particles, the composition of the particles and the organic matter. According to the volume weight value shows the level of soil density, the higher the volume weight value, the denser the soil and vice versa. The higher the volume weight value, the denser a particular soil is, making it more difficult for water to enter it.

Soil Porosity

Following are the results of the soil porosity analysis of each land cover with a depth of 0-10, 10-20 and 20-30 cm, which are presented in (Fig. 8).

Based on the results of the graph (Fig. 8) it shows that the highest porosity was found in the HSsite at a depth of 10-20 cm was 85.83% and the lowest is in the HR site at a depth of 20-30 cm was 71.61%. The porosity values are quite diverse, peat soil has a fairly high porosity range. This is supported by the statement of Agus *et al*. (2016), namely that peat porosity generally has a relatively high value between 70-95%. According to Agung (2012), the higher the porosity value, the higher the infiltration rate. Macro pores have a big influence on the rate of infiltration because macro pores are large pores filled with air or water by gravity and easily allow water to penetrate deeper layers. Macro-sized soil pores are more involved in the process of water and air exchange in the soil compared to micro-sized soil pores. According to its size, soil porosity is grouped into capillary pore spaces that can inhibit the movement of water into capillary movement and non-capillary pore spaces that can provide opportunities for rapid air movement and percolation, so they are often called drainage pores.

Soil Color

From the (Table 1), the results of the analysis of soil color produced by each land cover tend to be dark brown, very dark brown and very dark blackish red. Based on the table, the color of the soil in each land cover shows that the HS site and the HR site has the darkest color compared to the HK site and the HA site. The HK site and the HA site are more reddish in color. The cause of differences in the color of the soil surface is generally influenced by differences in the content of organic matter. The higher the organic matter content, the darker the soil color, so it can be said that the soil is ideal for processing into a growing medium. Dark colored soil indicates high organic matter content, graycolor indicates the dominant influence of water, red color indicates that the soil has undergone advanced weathering. Soil with a higher or more moist to wet water content which causes the soil color to become darker.

The Relationship of Saturated Soil Hydraulic Conductivity to Physical Properties of Inland Peat at the HS Site

Based on the results of regression analysis and multiple linear correlations between soil hydraulic conductivity and other physical properties of the HS site has a relationship, namely bulk density, soil porosity and soil water content. Regression model of bulk density y = -60.059x+9.443. The constant number is 9.443 meaning that if the bulk density variable is zero, then the saturated soil hydraulic conductivity variable is 9.443. Bulk density has a regression coefficient of 60,059, meaning that for every 1% increase in bulk density variable, there will be a 60% decrease in saturated soil hydraulic conductivity. The value of the regression determination coefficient seen from the R^2 value is 0.391. This means that the X variable affects the Y variable, which is 39.1%, while the rest is influenced by other variables. Based on the correlation coefficient value of 0.625 which indicates that the degree of relationship (correlation) between the independent variable (independent variable) and the dependent variable (bound variable) is 62.5%. Based on the results obtained, bulk density has a strong relationship with saturated soil hydraulic conductivity. The negative correlation value means inversely, if the saturated soil hydraulic conductivity increases then the bulk density value will be low and vice versa. This is in accordance with the statement of Lewis *et al*. (2012) that the greater the bulk density value, the smaller the saturated soil hydraulic conductivity value due to the small number of voids in the soil, which will hinder the movement of water.

Regression model of soil porosity y = 0.3669x-2.907. The constant number is 2,907, meaning that if the porosity variable is zero, then the saturated soil hydraulic conductivity variable is 2,907. Soil porosity has a regression coefficient of 0.366, meaning that for every 1% increase in the soil porosity variable, there will be an increase in saturated soil hydraulic conductivity of 36.6%. The value of the regression determination coefficient seen from the R^2 value is 0.465. This means that the variable X affects the Y variable that is equal to 46.5%, while the rest is influenced by other variables. Based on the correlation coefficient value of 0.682 which indicates that the degree of relationship (correlation) between the independent variable and the dependent variable is 68.2%. This means that soil porosity has a strong relationship with saturated soil hydraulic conductivity. The relationship of positive correlation value means undirectional, if the saturated soil hydraulic conductivity increases then the soil porosity value will be high and vice versa. According to Isnawati and Listyarini (2018), the saturated soil hydraulic conductivity of soil and soil porosity has a directly proportional relationship because the empty soil pore space and not filled with mineral or other materials will increase the soil's ability to drain water (permeability).

Regression model of water content y = 0.0107x-3.6342. The constant number is 3.6342, meaning that if the soil water content variable is zero, then the saturated soil hydraulic conductivity variable has decreased by 3.6342. The soil water content has a regression coefficient of 0.175, meaning that for every 1% increase in the soil water content variable, there will be an increase in saturated soil hydraulic conductivity of 17.5%. The value of the regression determination coefficient seen from the R^2 value is 0.175. This means that the X variable affects the Y variable, which is 17.5%, while the rest is influenced by other variables. Based on the correlation coefficient value of 0.418 which indicates that the degree of relationship (correlation) between the independent variable and the dependent variable is 41.8%. The soil water content has a relationship that is >0.25-0.50 the correlation is quite related to the soil hydraulic conductivity. The positive correlation value means that it is in the same direction, if the soil hydraulic conductivity increases, the soil water content will be high and vice versa. Asmaranto *et al*. (2012) stated that the greater the value of the soil water content, the greater the soil hydraulic conductivity. This is because the horizontal movement of water will be faster if the soil is in a saturated state.

The Relationship of Saturated Soil Hydraulic Conductivity to Physical Properties of Inland Peat at the HK Site

Based on the results of regression analysis and multiple linear correlations between saturated soil hydraulic conductivity and other physical properties of the HK site has the strongest relationship, namely porosity. The regression model of soil porosity is y = -0.3145x+27.664. The constant number is 27.664 meaning that if the soil porosity variable is zero, then the soil hydraulic conductivity variable is 27.664. The value of the regression determination coefficient seen from the R^2 value is 0.091. This means that the X variable affects the Y variable, which is 1%, while the rest is influenced by other variables. Soil porosity has a regression coefficient of 0.3145, meaning that for every 1% increase in the soil porosity variable, there will be a decrease in soil hydraulic conductivity of 0.310%. Based on the correlation coefficient value of 0.310 which indicates that the degree of relationship (correlation) between the independent variable and the dependent variable is 31.4%. Soil porosity has a relationship that >0.25-0.50 correlation is quite related to saturated soil hydraulic conductivity. The negative correlation value means inverse, if the saturated soil hydraulic conductivity increases then the soil porosity value will be low and vice versa. This is in accordance with the opinion of (Malau and Utomo, 2017), that the number of pores in the soil will determine the ability of the soil to pass water.

The Relationship of Saturated Soil Hydraulic Conductivity to Physical Properties of Inland Peat at the HR Site

The relationship between soil hydraulic conductivity and other physical properties on the HR site has the strongest relationship, namely infiltration, volume weight and fiber content. The regression model of infiltration is y = -0.227x+6.768. The constant number is 0.227, meaning that if the infiltration variable is zero, then the soil hydraulic conductivity variable has decreased by 0.227. The value of the regression determination coefficient seen from the R^2 value is 0.09. This means that the X variable affects the Y variable, which is 1%, while the rest is influenced by other variables. Infiltration has a regression coefficient of 6.768, meaning that for every 1% increase in the infiltration variable, there will be an increase in soil hydraulic conductivity of 6.78%. The value of the coefficient of regression determination seen from the R^2 value is 0.12. This means that the variable X affects the Y variable, which is 12%, while the rest is influenced by other variables. Based on the correlation coefficient value of 0.30 which indicates that the degree of relationship (correlation) between the independent variable and the dependent variable is 30%. This means that infiltration has a relationship >0.25-0.50, the correlation is quite related to soil hydraulic conductivity. The negative correlation value means inversely, if the soil hydraulic conductivity increases, the infiltration value will be low and vice versa. This indicates an increase in permeability at certain limits, so the infiltration rate increases. The higher the soil permeability value, the higher the infiltration rate will be, this will be more influenced if the amount of soil permeability is in the top layer.

The regression model is volume of weight, namely y = 182.17x-27.972. The constant number is 27.972 meaning that if the volume of weight variable is zero, then the soil hydraulic conductivity variable has decreased by 27.972. Volume of weight has a regression coefficient of 182.17, meaning that for every 1% increase in volume of weight variable, there will be an 18.2% increase in soil hydraulic conductivity. The value of the regression determination coefficient seen from the R^2 value is 0.20. This means that the variable X affects the Y variable by 20%, while the rest is influenced by other variables. Based on the correlation coefficient value of 0.44 which indicates that the degree of relationship (correlation) between the independent variable and the dependent variable is 44%. This means that the volume weight has a relationship that is >0.25-0.50 which is quite correlated with soil hydraulic conductivity. The correlation value is positive, meaning that it is in the same direction, if the soil hydraulic conductivity increases, the volume weight will be high and vice versa. The weight value of peat volume is relatively low and generally has a high porosity, so the potential for absorbing and distributing water is high.

Regression model of fiber content y = 0.7654x-1.948. The constant number is 1.948, meaning that if the 1.948 variable is zero, then the soil hydraulic conductivity variable has decreased by 1.948. The fiber content has a regression coefficient of 0.7654, meaning that for every 1% increase in the fiber content variable, there will be an increase in soil hydraulic conductivity of 0.76%. The value of the regression determination coefficient seen from the R^2 value is 0.12. This means that the X variable affects the Y variable, which is 12%, while the rest is influenced by other variables. Based on the correlation coefficient value of 0.35 which indicates that the degree of relationship (correlation) between the independent variable and the dependent variable is 35%. This means that the fiber content has a relationship that is >0.25-0.50 which is quite correlated with soil hydraulic conductivity. The positive correlation value means that it is in the same direction, if the soil hydraulic conductivity increases, the fiber content will be high and vice versa. The more organic matter in the soil, the higher the water content in the field capacity, as a result of the increase in medium sized pores (meso) and the decrease in macro-pores, so that the soil water holding capacity increases and has an impact on increasing the availability of water for plant growth (Scholes *et al*., 1994).

The Relationship of Soil Hydraulic Conductivity to Physical Properties of Inland Peat Soil in the HA Site

Based on the results of regression analysis and multiple linear correlations between hydraulic conductivity and other physical properties of the HA site has the strongest relationship, namely porosity. The regression model of porosity is y = -0.3388x+24.024. The constant number is 24.024 meaning that if the porosity variable is zero, then the hydraulic conductivity variable is 24.024. Porosity has a regression coefficient of 0.3388, meaning that for every 1% increase in the porosity variable, there will be a decrease in hydraulic conductivity of 0.33%. Based on the correlation coefficient value of 0.30 which indicates that the degree of relationship (correlation) between the independent variable and the dependent variable is 30%. This means that porosity has a relationship that is >0.25-0.50 which is quite correlated with soil hydraulic conductivity. The relationship of positive correlation value means unidirectional, if the soil hydraulic conductivity increases then the soil porosity value will be high and vice versa. Handayani and Wahyuni (2016) also revealed that high soil porosity will make it easier for the soil to pass water, so that the movement of water will be faster.

Research Site Conditions

Previously, the LAHG-Sebangau area was called peat swamp forest with an area of about 50,000 ha of peat forest. LAHG-Sebangau has 3 types of forest class, namely mixed-swamp forest, low-pole forest and tall-interior forest. KHDTK-Tumbang Nusa has an area of about 5,000 ha, with an altitude of 0-5 m above sea level with an elevation of 0-18%, while the peat depth is ≥3 m. Based on the 2007 ALOS image map and the 2008 central Kalimantan RTRWP map. The plant vegetation is dominated by Meranti Bunga (*Shorea teysmanniana*), Jambu-jambuan (*Syzygium* sp.), *Pandanus* sp., Keruing (*Dipterocarpus caudiferus*), Medang Telur (*Stemonurus scorpiodes*), Gencilai (*Elaeocarpus mastersii*), *Calophyllum* sp., *Ilex* sp., *Cyperus* sp., Getah Hangkang (*Palaquilum lelocarpum*), Gutta-percha (*Palaquilum gutta*), *Xanthophyllum eurhynchum*, Bajuku Keput (*Stemonurus scorpiodes*) and *Barringtonia sp*. Then the location of the KHDTK-Tumbang Nusa is grouped into 5 types of successional conditions, namely 80% dense forest, 9% sparse vegetation, 5% shrubs, 4% grasslands and moderate vegetation. Plant vegetation is dominated by ferns, karamunting, epatorium and other types of grasses, include: Meranti Bunga (*Shorea teysmanniana*), Merapat (*Combretocarpus rotundus*), Nyatoh (*Palaquium cochlearia*), Meranti Batu atau Meranti Tembaga (*Shorea parvifolia*), Ramin (*Gonystylus bancanus*), Terantang (*Campnosperma auriculata*), Malam-malam (*Diospyros malam*), Bintangur (*Calophyllum kunstleri*), Keruing (*Dipterocarpus caudiferus*), Mandarah (*Horsfieldia* sp.), Gerunggang (*Cratoxylun arborescens*), Medang Telur (*Stemonurus scorpiodes*), Pantung/Jelutung (*Dyera polyphylla*) and other species other non-commercial. Based on this research results, it was found that there were differences in soil color at various soil depths and land cover (Table 1).

Soil Water Retention

The measured soil water content values are presented in Table 2a-b. The measurement results show that the soil water content values in HS site is higher than HA site, HK site and HR site. The results of the calculation of the calculated soil water content are presented in Table 2a-b, where the measured water content value is input to the SWRC fit program, then the van Genuchten value is obtained. Furthermore, it is calculated using Eq. (2), so that the calculated value of soil water content is obtained.

The pore size distribution was obtained from the determination of the soil water content that had been given various pressures in the laboratory (Table 3). These various pressures have a relationship with the distribution of soil pores and capillaries.

Table 1: Soil color at each depth and land cover

Land cover	Depth	Code	Soil color	Color
HS	0-10 cm	HS-1A	7.5 YR 2.5/2	Very dark brown
	10-20 cm	HS-2A	7.5 YR 3/3	Dark brown
	20-30 cm	HS-3A	7.5 YR 3/4	Dark brown
	0-10 cm	HS-1B	7.5 YR 2,5/1	Black
	10-20 cm	HS-2B	7.5 YR 3/1	Very dark gray
	20-30 cm	HS-3B	7.5 YR 3/3	Dark brown
	0-10 cm	HS-1C	7.5 YR 2.5/3	Very dark brown
	10-20 cm	HS-2C	7.5 YR 3/3	Dark brown
	20-30 cm	HS-3C	7.5 YR 3/3	Dark brown
HK	0-10 cm	HK-1A	7.5 YR 2.5/3	Very dark brown
	10-20 cm	HK-2A	5 YR 3/4	Dark reddish brown
	20-30 cm	HK-3A	2.5 YR 3/4	Dark reddish brown
	0-10 cm	HK-1B	7.5 YR 2.5/2	Very dark brown
	10-20 cm	HK-2B	7.5 YR 3/3	Dark brown
	20-30 cm	HK-3B	2.5 YR 2.5/2	Very dusky red
	0-10 cm	HK-1C	7.5 YR 2.5/1	Black
	10-20 cm	HK-2C	7.5 YR 3/3	Dark brown
	20-30 cm	HK-3C	7.5 YR 3/3	Dark brown
HR	0-10 cm	HR-1A	7.5 YR 3/4	Brown
	10-20 cm	HR-2A	7.5 YR 2.5/3	Very dark brown
	20-30 cm	HR-3A	7.5 YR 3/3	Brown
	0-10 cm	HR-1B	7.5 YR 2.5/2	Very dark brown
	10-20 cm	HR-2B	7.5 YR 2.5/2	Very dark brown
	20-30 cm	HR-3B	7.5 YR 2.5/3	Very dark brown

Table 1: Continue

	0-10 cm	HR-1C	7.5 YR 2.5/1	Black
	10-20 cm	HR-2C	7.5 YR 2.5/3	Very dark brown
	20-30 cm	HR-3C	2.5 YR 3/4	Very dark brown
HA	0-10 cm	HA-1A	7.5 R 3/3	Dusky red
	10-20 cm	HA-2A	7.5 R 3/4	Dusky red
	20-30 cm	HA-3A	7.5 R 3/4	Dusky red
	0-10 cm	HA-1B	7.5 R 3/4	Dusky red
	10-20 cm	HA-2B	7.5 R 2.5/2	Very dusky red
	20-30 cm	HA-3B	7.5 R 3/4	Dusky red
	0-10 cm	HA-1C	7.5 R 3/6	Dark red
	10-20 cm	HA-2C	7.5 R 3/8	Dark red
	20-30 cm	HA-3C	7.5 R 3/8	Dark red

Source: The result of laboratory analysis at the UPT LLG-CIMTROP UPR 2021

Table 2a: Measured value of soil moisture content (θv in %w)

	Water content (%v)											
pF	HA (0-10 cm)	HA (10-20 cm)	HA (20-30 cm)	HS (0-10 cm)	HS (10-20 cm)	HS (20-30 cm)	HK (0-10 cm)	HK (10-20 cm)	HK (20-30 cm)	HR (0-10 cm)	HR (10-20 cm)	HR (20-30 cm)
2	46,750	42,637	57,050	61,504	61,762	61,525	50,732	58,457	56,931	32,526	53,875	46,046
2,5	38,068	38,508	48,594	54,907	60,604	58,006	41,118	52,895	49,931	30,283	50,779	43,316
3	37,600	37,011	46,640	53,398	59,446	56,634	40,118	52,069	47,691	29,009	48,014	39,468
3,5	35,410	36,076	45,975	50,711	59,159	54,962	39,615	51,521	45,783	26,036	43,024	38,478
3,7	34,501	33,223	44,713	48,737	58,142	52,750	39,397	51,036	43,836	22,572	36,618	33,811
4	32,723	32,462	43,809	46,747	57,723	50,340	39,165	50,329	42,740	18,396	33,568	32,444
4,2	30,655	31,897	43,131	45,436	57,402	48,085	38,796	49,869	40,805	12,665	28,813	28,158

Table 2b: Measured value of soil moisture content (θv in %w)

	Water Content (%w)											
pF	HA (0-10 cm)	HA (10-20 cm)	HA (20-30 cm)	HS (0-10 cm)	HS (10-20 cm)	HS (20-30 cm)	HK (0-10 cm)	HK (10-20 cm)	HK (20-30 cm)	HR (0-10 cm)	HR (10-20 cm)	HR (20-30 cm)
2	45,961	42,188	56,849	60,566	61,799	61,101	41,554	58,34	56,35	30,994	51,308	37,574
2,5	40,351	39,455	49,428	56,698	60,614	61,101	41,554	53,464	51,324	30,675	49,319	36,458
3	36,662	36,953	46,189	53,118	59,548	61,101	41,554	51,595	47,501	29,517	45,523	35,239
3,5	34,256	34,697	44,779	49,837	58,621	61,101	41,554	50,88	44,621	25,805	39,062	33,92
3,7	33,549	33,864	44,471	48,608	58,29	61,101	41,554	50,739	43,684	23,025	35,671	33,366
4	32,693	32,688	44,165	46,855	57,836	61,101	41,554	50,607	42,468	17,441	29,93	32,508
4,2	32,235	31,952	44,031	45,744	57,561	61,101	41,554	50,553	41,769	13,303	25,879	31,919

Table 3: Pore size distribution in various land covers

	Pore size distribution (%v)		
Sites	Fast pore drainage	Slow pore drainage	Water holder pore
HA	0,488	0,071	0,065
HS	0,616	0,038	0,075
HK	0,554	0,074	0,048
HR	0,442	0,027	0,183

Conclusion

Based on the results of the study it can be concluded that: The HA site resulted in a higher average saturation soil hydraulic conductivity (permeability) rate of 6.76 cm h^{-1} compared to the HK site of 6.40 cm h^{-1}, HR site of 4.98 cm h^{-1} and the HS site of 2.96 cm h^{-1}. At the HS site resulted in a higher average value of the unsaturated soil hydraulic conductivity (infiltration) of 22.60 cm h^{-1} compared to the HR site of 15.80 cm h^{-1}, HK site of 10.47 cm h^{-1} and at HA site is 8.06 cm h^{-1}. Then, the HA site has a higher soil moisture content and fiber content of 631.364 and 22.67%, the HS site has a higher soil porosity value of 85.83% and the HR site has a higher volume of weight value of 0.19 g cm^{-3}. The color of the soil is dark brown to very dark blackish red.

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Author’s Contributions

All authors equally contributed to this study.

Ethics

All statements related to enriching this scientific journal have been included in the bibliography.

References

Agus, F. Anda, M., & Jamil, A. (2016). *Lahan gambut Indonesia: Pembentukan, karakteristik, dan potensi mendukung ketahanan pangan*. IAARD Press.

Agustina, D., Setyowati, D. L., & Sugiyanto, S. (2012). Analisis kapasitas infiltrasi pada beberapa penggunaan lahan di Kelurahan Sekaran Kecamatan Gunungpati Kota Semarang. *Geo-Image*, *1*(1). https://doi.org/10.15294/geoimage.v1i1.952

Arifin, M. (2010). Kajian sifat fisik tanah dan berbagai penggunaan lahan dalam hubungannya dengan pendugaan erosi tanah. *Mapeta*, *12*(2). http://ejournal.upnjatim.ac.id/index.php/mapeta/article/view/212

Asmaranto, R., Soemitro, R. A. A., & Anwar, N. (2012). Penentuan nilai konduktivitas hidrolik tanah tidak jenuh menggunakan uji resistivitas di laboratorium. *Jurnal Teknik Pengairan: Journal of Water Resources Engineering*, *3*(1), 81-86. https://jurnalpengairan.ub.ac.id/index.php/jtp/article/view/150

Agung, S. D. (2012). Beberapa sifat fisika kimia tanah yang berpengaruh terhadap model kecepatan infiltrasi pada tegakan mahoni, jabon, dan trembesi di Kebun Raya Purwodadi. *Berkala Penelitian Hayati*, *17*(2), 185-191. http://karya.brin.go.id/id/eprint/14789/

Bagarello, V., Iovino, M., & Elrick, D. (2004). A simplified falling-head technique for rapid determination of field-saturated hydraulic conductivity. *Soil Science Society of America Journal*, *68*(1), 66-73. https://doi.org/10.2136/sssaj2004.6600

BBSDLP. (2006). Sifat fisik tanah dan metode analisisnya. Balai Besar Litbang Sumber Daya Lahan Pertanian. Bogor. 282 hal.

BBSDLP. (2013). Atlas arahan pengelolaan lahan gambut terdegradasi, skala 1:250.000. (Balai Besar Litbang Sumber Daya Lahan Pertanian). Badan Penelitian dan Pengembangan Pertanian, Kementerian Pertanian.

BRG. (2017). Rencana Restorasi Ekosistem Gambut 2017. (unpublished). Material Presentasi pada ekspose kegiatan Penyusunan Rencana Teknis Tahunan Restorasi Gambut. Jakarta.

Edwards, W. M., Shipitalo, M. J., Owens, L. B., & Dick, W. A. (1992). Rainfall intensity affects transport of water and chemicals through macropores in no-till soil. *Soil Science Society of America Journal*, *56*(1), 52-58. https://doi.org/10.2136/sssaj1992.03615995005600010008x

Handayani, T., & Wahyuni, D. (2016). Pengaruh sifat fisik tanah terhadap konduktivitas hidrolik jenuh pada lahan pertanian produktif di Desa Arang Limbung Kalimantan Barat. *Prisma Fisika*, *4*(1). http://dx.doi.org/10.26418/pf.v4i1.14840

Indahyani, S., Sumawinata, B., & Darmawan, D. (2017). Pengukuran retensi air tanah gambut menggunakan kombinasi three phase meter dan ceramic plate. *Buletin Tanah Dan Lahan*, *1*(1), 109-114. file:///C:/Users/User/Downloads/17699-Article%20Text-53635-1-10-20170818.pdf

Isnawati, N., & Listyarini, E. (2018). Hubungan antara kemantapan agregat dengan konduktifitas hidraulik jenuh tanah pada berbagai penggunaan lahan di Desa Tawangsari Kecamatan Pujon, Malang. *Jurnal Tanah dan Sumberdaya Lahan*, *5*(1), 785-791. http://orcid.org/0000-0002-3955-1278

Kohnke H. (1968). Soil Physics. McGraw-Hill.

Kurnain, A. (2008). Potensi air tersedia tanah gambut tropika bagi kebutuhan tanaman. *Kalimantan Scientiae*, *71*(2), 39-46.

Larashati, I. (2010). Analisis tumbuhan bawah di hutan rawa gambut Sebangau Kalimantan Tengah. *Berkala Penelitian Hayati*, 19-22. http://berkalahayati.org/files/journals/1/articles/27/submission/27-84-1-SM.pdf

Lewis, C., Albertson, J., Xu, X., & Kiely, G. (2012). Spatial variability of hydraulic conductivity and bulk density along a blanket peatland hillslope. *Hydrological Processes*, *26*(10), 1527-1537. https://doi.org/10.1002/hyp.8252

Malau, R. S., & Utomo, W. H. (2017). Kajian sifat fisik tanah pada berbagai umur tanaman kayu putih (*Melaleuca cajuputi*) di lahan bekas tambang batubara PT Bukit Asam (Persero). *Jurnal Tanah dan Sumberdaya Lahan*, *4*(2), 525-531. e-ISSN: 2549-979.

Mariaty, M., & Santosa, P. B. (2019). Studi Tingkat Keanekaragaman Hayati Lahan Bekas Terbakar di Taman Nasional Sebangau & Kawasan Hutan Dengan Tujuan Khusus (KHDTK) Tumbang Nusa: Study Of Biodiversity Level On Burnt Landa at Sebangau National Park & Forest Area with Spesific Purpose (KHDTK) Tumbang Nusa. *Daun: Jurnal Ilmiah Pertanian dan Kehutanan*, *6*(2), 129-139. https://doi.org/10.33084/daun.v6i2.1259.

Page, S. E., Rieley, J. O., & Banks, C. J. (2011). Global and regional importance of the tropical peatland carbon pool. *Global Change Biology*, *17*(2), 798-818. https://doi.org/10.1111/j.1365-2486.2010.02279.x

Perfect, E. M. C. S., Sukop, M. C., & Haszler, G. R. (2002). Prediction of dispersivity for undisturbed soil columns from water retention parameters. *Soil Science Society of America Journal*, *66*(3), 696-701. https://doi.org/10.2136/sssaj2002.6960

Purbowaseso. (2004). Pengendalian Kebakaran Hutan. Rineka Cipta, Jakarta.

Ramdhan, M., & Siregar, Z. A. (2018). Pengelolaan wilayah gambut melalui pemberdayaan masyarakat desa pesisir di kawasan hidrologis gambut Sungai Katingan dan Sungai Mentaya Provinsi Kalimantan Tengah. *Jurnal Segara*, *14*(3), 145-157. http://dx.doi.org/10.15578/segara.v14i3.6416

Rosyidah, E., & Wirosoedarmo, R. (2013). Pengaruh sifat fisik tanah pada konduktivitas hidrolik jenuh di 5 penggunaan lahan (studi kasus di Kelurahan Sumbersari Malang). *Agritech*, *33*(3), 340-345. https://doi.org/10.22146/agritech.9557

Sampurno, R. M., & Thoriq, A. (2016). Klasifikasi tutupan lahan menggunakan citra landsat 8 Operational Land Imager (OLI) di Kabupaten Sumedang (land cover classification using landsat 8 Operational Land Imager (OLI) data in Sumedang Regency). *Jurnal Teknotan*, *10*(2), 1978-1067. ISSN: 2528-6285.

Scholes, M. C., Swift, M. J., Heal, O. W., Sánchez, P. A., Ingram, J. S. I., & Dalal, R. (1994). *Soil fertility research in response to the demand for sustainability* (pp. 1-14). John Wiley & Sons. ISBN: 9780471950950

Suswati, D., Hendro, B., Shiddieq, S., & Indradewa, D. (2011). Identifikasi sifat fisik lahan gambut Rasau Jaya III Kabupaten Kubu Raya untuk pengembangan jagung. *Perkebunan dan Lahan Tropika*, *1*(2), 31-41. http://dx.doi.org/10.26418/plt.v1i2.408

Sabiham, S., & Pramudya, B. (2010). Analisis lingkungan biofisik lahan gambut pada perkebunan kelapa sawit. *Jurnal Hidrolitan*. https://online-journal.unja.ac.id/hidrolitan/article/view/462

Sajarwan, A. (2022). Retensi air dan derajat kejenuhan tanah gambut dari kawasan das sabangau. *Journal*, *27*(2). https://jurnal.polbangtanyoma.ac.id/index.php/jiip/article/view/551

Torr, G. S., Condron, L. M., Di, H. J., & Cameron, K. C. (2004). Seasonal fluctuations in phosphorus loss by leaching from a grassland soil. *Soil Sci. Soc. Am. J*, *68*, 1429-1436. www.soils.org/publications/sssaj/pdfs/.../1429