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Improvement of peat soil capillary density
A comprehensive approach to solve fire disaster in peatland area

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Abstract: In the last seventeen years, Riau province has suffered from fire disaster and smog despite several efforts taken by the government. These problems have brought damaging impact to the peatland forest where fire is likely to occur especially during dry season. The continuation of fire disaster in peatland has caused the organic compound within peat soil to decompose and oxidize. The physical characteristics of the peatland are also changing, for instance: its ability to restore water. In dry season peat soil is extremely dry due to the depletion of groundwater. This has caused the peatsoil release methane gas which will affect the soil porosity. This condition makes peatland prone to fire. This paper suggests that the improvement of capilary density of the peat soil as a preventive way to stop the fire incident. The method is carried out by replanting endogeneous plants or vegetation on the peatland. A tube of 5 μm diameter is capable of rising the water up to 2.96 m from the surface of table water (groundwater level). It is aproximately equal to radius of xylem tube within plants. The height of a column of water in a single tube with a circular cross-section radius ***r*** is driven by the balance of two forces. They are force of gravity and adhesive force between the walls of the tube.

Key word: *capillary density, moisture content, wetting, replanting, ground waterlevel*

Introduction

Riau's peatland rainforest, which covers 56% of Sumatra's peatland, plays importan role in the hydrological control of Riau coastal region. Before land clearings and the exploitation of land for commercial purposes, fire incident rarely happened. The first fire and smog disaster took place in the beginning of 1997 and it has continued to happen especially during dry season. This problem has brought negative impact not only to the environment but also to people's health.

Smog even caused disruption to the economic sector since the transportation system was paralyzed. Several efforts have been taken to solve the problems caused by fire and smog. However, the previous approach was not comprehensive enough to deal with fire incident in peatland area. This paper suggests a method of science and engineering in order to return peatland area to its origin where it can absorb and hold water. By keeping the peatland wet along the year, the risk of fire could be reduced.

Hydromorphic is characteristic of peatland. High densly vegetation on peatland increase its water retention and capability to restoring hydrological sistem and water supply. This condition makes the peatland capable of keeping ground water level very close to ground surface even in dryseason [1]. Because of this capability, peatland always wet and in high moisture. It restores and conserves the wetland. Mostly, peat land profile in Riau province have been changing within 30 years. The change due to massive convertion of low-land rain forest to industrial planted forest (*Hutan Tanaman Industri*, HTI) and palm oil plantation. This convertion destroyed indegenous vegetation. Furthermore that also change hydrology characteristic and physical properties of peat soil. Most area of the peatland become uncovered area in which climate accelerates weathering process of top peatsoil. It was reported that these changes are function of soil decomposition and consolidation [2]. Indeed, conductivity hydrolic decrease due to those processes [3]. It was also reported that porous size of peat soil, ability restoring water decrease with depth [4].

Organic material decomposition has been happening along with repetitive fired disaster on peat area. Decomposition process of organic materials and steady state weathering process generate acumulation of methan gas in the peatsoil. In situation of decreasing moisture content within the peat, fired disaster possible to happen any time and any where on the area. This condition creates other problem regarding irreversible decomposed prosess. This means that the top soil of land always dry eventhough ground water level is not so deep. During the dry season periods the root zone of various plants are supplied by the action of the capillary rise from the groundwater level. Capillary rise can be characterised by the maximum height and its intensity. To estimate these values in peat soil the steady-state soil moisture flow theory can be applied [1].

Rewetting and improving capillary density

Calculations of steady state capillary rise were performed for observed peat soil at Desa Tanjung Leban. The physical characteristic of the soil is typically burned peat soil of about 2 cm thickness with very low moisture content. Peat thickness is 950 cm in average and considered as deep peat soil. Ground water level is 200 cm depth in average during dry season within time of investigation. In such condition, it is impossible to cultivate baby plant without rewetting the top soil or increasing ground water level to ≤ 30 cm depth.

It is introduced three scenarios rewetting mechanism on that arid peat land area. Firstly, it needs to blocking tributary and canal water way around the observed area for improving moisture content of the topsoil. This way makes the top peat soil less dry and becomes wet in high moisture content. When it has been achieved, it is easier to grow baby plant on that area. A stable water surface rises up after canal and tributary blocking, it starts to expand and restores water within peat soil intermolecullar distance. This process starts to create new capillary structure in burned peat soil layer. However, they capacity of rising tabel water is not strong enough to keep and restore water remain in the soil when tha blocking canal have been released. The last scenario is to increase capillary density at that area by repplanting endegenous trees. This way ensures that peatland area always wet and in high moisture content. In hydrology, capillary action describes the attraction of water molecules to soil particles. Capillary action is responsible for moving groundwater from wet areas of the soil to dry areas. Differences in soil potential γ drive capillary action in soil.

In trees, capillary action alone is not the only mechanism to transport water. First, without evaporation, capillary action would only transport water until mechanical equilibrium is reached and the flow stops. There is also osmotic pressure at the roots drawing the water in from the soil. There are probably osmotic effects throughout the tree itself.

Based on physics theory [5] the height ***h*** of a liquid column is derived here. The height of a column of water in a single tube with a circular cross-section radius ***r*** is driven by the balance of two forces: the force of gravity with pulling down on the column of water and the adhesive force between the walls of the tube and the water column pulling up. The force of gravity is easy, it's simply the weight of a column of water of height ***h*** is :

$$F_{g,1} = \rho g \pi r^2 h \qquad \text{(eq. 1)}$$

where **ρ** is the density of water and **g** is the acceleration due to gravity (and the "1" indicates that this result is for a single tube). The adhesion force is due to the surface tension at the top of the column of water pulling against the walls of the tube. The surface tension, **γ**, is the force per unit length at the interface of two materials. If the surface of the water makes an angle ***θ*** with respect to the normal to the wall, the upward component of the adhesive force is:

$$F_{ad,1} = \gamma 2\pi r \cos\theta \qquad \text{(eq. 2)}$$

Since θ is somewhere between 0 and 90 degrees, let us ignore the *cosθ*. Equating the two forces, we find the height of the water column is:

$$h = \frac{2\gamma \cos\theta}{\rho g r} = \frac{2\gamma}{\rho g r} \qquad \text{(eq. 3)}$$

where **γ** is the liquid-air surface tension (force/unit length), ***θ*** is the contact angle, ***ρ*** is the density of liquid (mass/volume), ***g*** is local acceleration due to gravity (length/square of time), and ***r*** is radius of tube (length). Thus the thinner the space in which the water can travel, the further up it goes.

For a water-filled glass tube in air at standard laboratory conditions, γ = 0.0728 N/m at 20°C, θ = 0° (cos(0) = 1), ρ is 1000 kg/m^3, and g = 9.81 m/s^2. For these values, the height of the water column is

$$h \approx \frac{0,0148\times10^{-3}}{r} m \qquad \text{(eq. 4)}$$

A capillary of xylem tube with r = 5 × 10^{-6} m. Using above equation it is able to rise water about : 2.96 m or 296 cm in cappillary tube from root zone. Therefore moisturing of dry peat is theoritically possible based on capillary density improvement in peat soil to sip up table water from 200 cm depth to ground surface. At the same time, because of plant roots are developping, root plants drive peat layer to expand and to develop that inter-molecular space. This becomes water store chamber during rainy season. New water dome naturally is being crated in that zone. **Fig 1** describes correlation data betwen capillary radius and water height computed based on various radii of capillary .

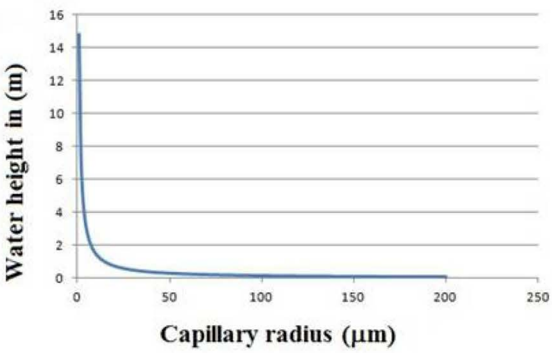

Fig 1. Corelation between capillary radius (µm) and water height (m)

Field observation and discussion

Rewetting and improving capillary density program under considered and monitoring took place at certain area of desa Tanjung Leban. The activities are blocking water canal and replanting endegenous trees to keep the ground water level remain in an appropriate level. Peat soil thickness in this project area is between 8m–9.5m. Ground water level is 2 m depth from ground surface during dry season. Most part of top soil layer (0 cm–20 cm thickness) has been deformed due to fired catastropic in 2010. So this layer is very arid with moisture content less than 10% when there is no rain within one month period.

Fig 2. Water Cannal at a HTI company, it has been burning in March 2014

Although ground water level is not so deep, water molecule is unable to reach top surface due to the absence of capillary at the burned peat.

Fig 3. STBA Team is working together, blocking a tributary, wetting peat land area to avoid fire.

Replanting program

The first replanting program was done in 2012, two years after fired disaster in 2010. In April 2014, the second replanting activities was carried out in order to accelerate reforestration program in Desa Tanjung Leban. As trees are growing, roots plants naturally create porouses in the soil and peat soil capillary therefore is formed. In tree itself however, capillary density increases following its growth.

The older the age of tree, the thicker its xylem tissue layer and the number capillary tube increase. **Fig 5** shows 2 cross section of tree bars. One is two years old tree and the other are less than one year old tree. Tree bark where the xylem tube take place grows significantly by years. It means more water volume can be pump up by the tree and hold it up for reserve. This mechanism makes the soil is always wet even during dry season. So that it is important to keep peat area always wet and high moisture content by replanting trees which is mean increase capillary tube density per unit area.

Fig 4. Project Team, preparing various baby trees to be cultivated

Fig 5. Cross section area of tree bars of 2 years and < 1 year ages

Conclusion

Scientific and engineering approach regarding fired disaster in peatland area is highly possible to be solved. A comprehensive solution by rewetting peatland area and replanting with endegenous trees are capable of improving peat land moisture content, rising ground water level through its capillary density both within the soil and the trees. When the area is always in wet condition, it is prevented that from fired.

Fig 6. A result of first replanting program in 2012. It shows burned area being covered by two years age trees and other wild grass and bush as peat soil going wet.

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