# BUKTI KORESPONDENSI
# ARTIKEL INTERNATIONAL SEMINAR TERINDEX SCOPUS

Judul Makalah : **Developing Water Management Objective On Tropical Peatlands Under Oil Palm Cultivation**

Seminar Internasional : 6th International Symposium on Wetlands and Environmental Management. Banjarmasin, 30th November until 1st December 2020

Daftar korespondensi :

| No | Tanggal Korespondensi | Kegiatan korespondensi |
|---|---|---|
| 01 | 26 November 2020 | Surat Penerimaan Abstrak |
| 02 | 28 November 2020 | Penerimaan Makalah |
| 03 | 29 November 2020 | Penyerahan Makalah |
| 04 | 10 Desember 2020 | Mendapat Sertifikat |
| 05 | 26 Maret 2021 | Permintaan Perbaikan Makalah |
| 06 | 28 Maret 2021 | Penyerahan Makalah Hasil Perbaikan |
| 07 | 12 Mei 2021 | Publikasi Online Terbit<br>iopscience.iop.org/article/10.1088/1755-1315/758/1/012002/meta |

## Abstract Acceptance Letter Momon Sodik Imanudin2

Yahoo/Terkirim

**sadanghusain@ulm.ac.id**

**Kepada:**momon_unsri@yahoo.co.id

Kam, 26 Nov 2020 jam 19.19

Here we send an abstract acceptance letter to be presented at the 6th International Symposium on Wetlands and Environmental Management. Please immediately re-register via the link bit.ly/ISWEM6

LoA 6th ISWEM 2020 Momon Sodik Imanudin.pdf

335.9kB

# INTERNATIONAL SYMPOSIUM ON WETLANDS ENVIRONMENTAL MANAGEMENT (6th ISWEM)

Banjarmasin, 30th November until 1st December 2020

## ACCEPTANCE LETTER

**To**

**Momon Sodik Imanudin**
**Sriwijaya University**

We are pleased to inform you that your submission to the International Symposium On Wetlands Environmental Management (6th ISWEM) *titled* ***"DEVELOPING WATER MANAGEMENT OBJECTIVE ON TROPICAL PEATLANDS UNDER OIL PALM CULTIVATION",*** has been accepted for presentation in 6th ISWEM 2020.

You are invited to submit a full-length paper before 29 November 2020 for publication in the indexed conference proceedings (IOP) in http://bit.ly/ISWEMpresenter.

Best Regards,
Chairman of the Committee

Irfan Prasetia
Less talk, write more

**RUNDOWN OF THE 6th ISWEM 2020 (VIRTUAL)**

**The 1st day of Symposium (30 November 2020)**

| No. | Time (WITA/ Central Indonesian Time) | Activities | PIC |
|---|---|---|---|
| 1. | 08.30 - 08.45 | Registration of the participants | Committee |
| 2. | 08.45 - 09.00 | **Opening Ceremony**<br>• Singing the Indonesian National Anthem-Indonesia Raya<br>• Singing March of Lambung Mangkurat University | MC |
| 3. | 09.00 - 09.25 | Welcoming Speeches by:<br>• Chairman of the Committee<br>• Rector of Lambung Mangkurat University | MC |
| 4. | 09.25 - 09.28 | Prayer | MC |
| 5. | 09.28 - 09.30 | Photo Session | MC |
| 6. | 09.30 - 10.30 | **The 1st Keynote Speaker**<br>Dr. Syahrul Yasin Limpo, SH., MH<br>(Minister of Agriculture of the Republic of Indonesia) | Moderator |
| 7. | 10.30 - 11.30 | **The 1st Invited Speaker**<br>Prof. Dr. Ir. H. Yudi Firmanul Arifin, M.Sc.<br>(Head of Center for Wetland Innovation and Technology, Lambung Mangkurat University) | |
| 8. | 11.30 – 11.35 | **Break and photo session** | MC |
| 9. | 11.35 - 12.30 | **Lunch Break** | MC |
| 10. | 12.30 - 13.15 | **The 2nd Invited Speaker**<br>Prof. Weiguo Cheng<br>(Professor in Environmental Science, Yamagata University, Japan) | Moderator |
| 11. | 13.15 - 14.00 | **The 3rd Invited Speaker**<br>Prof. Chien-Kuo Chiu<br>(Professor and Vice Dean of College of Engineering, National Taiwan University of Science and Technology, Taiwan) | Moderator |
| 12 | 14.00 - 14.45 | **The 4th Invited Speaker**<br>Dr. Mohammad Zaman<br>(Senior Researcher, International Atomic Energy Agency, Vienna, Austria) | Moderator |
| 13 | 14. 45 - 15.30 | **The 5th Invited Speaker**<br>Dr. Husnain<br>(The Head of Research and Development Center of Agricultural Resources ) | Moderator |
| 14 | 15.30 - 18.00* | The First Session of the Conference | Committee |

**The 2nd day of Symposium (1 December 2020)**

| No. | Time (WITA/ Central Indonesian Time) | Activities | PIC |
|---|---|---|---|
| 1. | 08.00 - 08.30 | Registration of the participants | Committee |
| 2. | 08.30 - 09.30 | **The 2nd Keynote Speaker**<br>Dr. Aloe Dohong<br>(Vice Minister of Environment and Forestry of the Republic of Indonesia) | Moderator |
| 3. | 09.30 - 10.15 | **The 6th Invited Speaker**<br>Dr. Jay P. Sah<br>(Research Associate Professor, Florida International University, USA) | |
| 4. | 10.15 – 10.30 | **Break and photo session** | MC |
| 5. | 10.30 – 11.15 | **The 7th Invited Speaker**<br>Emeritus Professor Tim Roberts<br>(Emeritus Professor at the University of Newcastle, Australia) | Moderator |
| 6. | 11.15 – 12.00 | **The 8th Invited Speaker**<br>Dr. Yiyi Sulaeman<br>(The Head of Wetlands and Agricultural Research Center) | Moderator |
| 7. | 12.00 – 13.00 | **Lunch Break** | MC |
| 8. | 13.00 – 13.45 | **The 9th Invited Speaker**<br>Prof. Dr. Ahmed Abisaeed<br>(King Saud University, Saudi Arabia) | Moderator |
| 9. | 13.45 - 14.30 | **The 10th Invited Speaker**<br>Prof. Dr. Phil Al Makin, S.Ag., MA<br>(Rector of UIN Sunan Kalijaga, Indonesia) | Moderator |
| 10. | 14.30 - 17.00* | The Second Session of the Conference | Committee |
| 11. | 17.00 - 17.30 | Briefing for the articles<br>Prof. Dr. Ir. H. Abdul Hadi, M.Agr.<br>(Head of The Center for Journal Management and Publication) of Lambung Mangkurat University) | MC |
| 12. | 17.30 - 18.00 | **Closing Ceremony** | MC |

**CODE OF CONDUCT FOR CONFERENCE SESSION**

(ORAL PRESENTATION)

1. The oral presenters are obliged to attend the zoom room for two days.
2. The oral presenters attend the room session conference and fill in the attendance list provided.
3. The time allocation for each oral presenter is fifteen (15) minutes, including a question and answersession.
4. The oral presenters submit PPTs or video presentations on 29 November 2020 at 6.00 pm throughhttp://bit.ly/ISWEMpresenter.
5. All oral presenters submitting PPTs will get the presentation schedule based on the provided time.
6. For oral presenters submitting video presentations, they are required to attend a session. conferencebecause there will be a question and answer session during video presentation in ten (10) minutes.
7. The oral presenters are obliged to use a shirt or *batik* while the program is running.
8. The schedule of the conference session will be informed in the abstract book.*

• **Penyerahan Makalah 29 November 2020**

# DEVELOPING WATER MANAGEMENT OBJECTIVE ON TROPICAL PEATLANDS UNDER OIL PALM CULTIVATION

By
Momon Sodik Imanudin[1/], M. Edi Armanto[1/], Elisa Wildayana[1/], Bakri[1/], and Heri Junedi[2/]
[1/] Faculty of Agriculture, Sriwijaya University, Indonesia
Indralaya Campus Jln Palembang-Prabumulih Km 32 Tel/Fax 62-711-580469
Email: momon_unsri@yahoo.co.id
[2/] Faculty of Agriculture Jambi University, Indonesia

ABSTRACT

Less attention to peatlands for various economic development activities have led to the emergence of serious environmental problems. The problems are floods in the rainy season, fires in the dry season and increased carbon emissions. This paper aimed to examine physical and hydrological characteristics to develop land management plans. The research was conducted on peatlands used for oil palm plantations. The study concluded that the available drainage system generally indicates excess discharge (over drainage). Water retention efforts proved effective in secondary channels and are able to raise the water level of 20-30 cm higher than the uncultivated peatlands (no water retention). Fluctuations in groundwater levels in the period from August to September on the cultivated peatlands showed that the groundwater is deeper than the uncultivated peatlands. It determined greater value of evapotranspiration of oil palm plantation. If the floodgates do not exist, then the groundwater becomes deeper than the cultivated peatlands. In the January-February period of the groundwater in the cultivated peatlands can be increased to 20-30 cm under the soil surface, but on the uncultivated peatlands without controlling the water level drops at the position 40-50 cm below the soil surface. Thus the concept of water retention became the main purpose for water management in peatlands.

**Key words**: hydrological components, tropical peatlands, water management, oil palm

## 1. Introduction

Approximately 20 million ha of peatlands, which is equivalent to half of the tropical peatlands in the world, are located in Indonesia (Sjarkowi *et al.*, 2007). Therefore Indonesia has an important value and strategic views of biodiversity and ecological functions. Peat land is generally located between two rivers, thus it hydrologically formed a unique island-shaped "dome". Depth variability of peats greatly affect the carrying capacity of peats to store water, vegetation and management policies. On the other hand, land clearing for oil palm plantations and industrial plants are still ongoing (Wildayana, 2014).

Approximately 1.4 million ha of peatlands are located in South Sumatra province. Land clearing of peatlands for small scale agriculture has been done by Buginese and Banjarnese as spontaneous migrations especially in South Sumatra (Wildayana *et al.*, 2017; Wildayana, 2016). Large-scale transmigration program was conducted by Indonesian Government and large companies since 1980s. In 2015, about 114 thousand ha of peatlands were totally burnt and others were mostly opened for oil palm plantation (already opened about 48,592 ha) and Industrial Plantation Forest (HTI opened approximately 585,000 ha), especially in District of Ogan Komering Ilir (OKI). These conditions have an impact on the environment, especially the balance of land and forest existence (Armanto *et al.*, 2008), paddy fields (Armanto *et al.*, 2013; Wildayana, 2015) and oil palm plantation. Land and forest fires in South Sumatra were mostly purposely stimulated by human activity (Imanudin and Susanto, 2015; Armanto and Wildayana, 1998; Wildayana and Armanto, 2009). Propagation of fires will start from an area close to settlement and land clearing by burning in *sonor* agricultural system. In addition to physical factors which peatlands in dry conditions have combustible nature? These dry conditions are due to the ground water level in more than 1.5 m. The deeper water levels were mainly found in areas that have been opened by canalization system.

In the long dry conditions (more than 3 months) in the absence of added water containment efforts then drying peat is becoming increasingly widespread, even to areas that have not opened. It is therefore important to do a field study to find peat land management options for the creation of conditions of the ground water level that can meet the needs of plant growth and prevent the danger of forest fires. Approach to land capability should be involved in the preparation of management plans on peatlands (Imanudin *et al.,* 2010; 2011). During this time entrepreneurs just see from the ground surface, the depth of peat is the key factor often overlooked. Often found in the cultivation of plants is done on the peat depth more than 3.0 m deep or even more (Imanudin and Bakri, 2016). The business world should count carefully, because cultivation in peatlands is the high cost. To increase one-two units of pH values required 10-30 tons of dolomite (Armanto *et al.,* 2016).

Cultivating wetlands and peatlands for oil palm plantation and acacia industrial plantation (HTI) in South Sumatra has been started since 1990, which have brought serious impacts to environmental issues, among others degradation peat quality, decreasing water level, increasing decomposition rate of peatlands that leads to carbon emissions, peat subsidence, peat characteristics, losing ability to store water, hydrology, land and forest fires (Liu *et al.,* 2014; Edwin *et al.,* 2014; Sumarga *et al.,* 2016; Armanto, 2014). Several epporst should be done to increase ground water table. Installing the canal bloking canal in the collector and secondary canal has significant effect to increase water table (Sutikno, et al., 2020).

Farmers of Buginese and Banjarnese success as spontaneous migration in South Sumatra gave good examples how to cultivate peatlands by using indigenous technology (Wildayana *et al.,* 2008). They opened the potential land area, the optimum number and make a simple water system with water level control terraced. If no control measures, the impact of oil palm on peat land clearing are land subsidence (land subsidence). Simulation for a period of fewer 50 years, more than 50% acreages of peatlands in South Sumatra will be fully flooded.

Water management in peatlands are very unique compared to mineral soils, this is because the peatlands have high ability to absorb a lot of water (hydrophilic), and if peatlands are over drained their ability to absorb water will dramatically decrease (hydrophobic). The condition occurs because the peats occur irreversible drying process (irreversible drying), especially if peats experience very long (extreme) drying condition. Therefore peat land drainage process is not simply boast drain the excess water or land, but how to create the conditions so that the water level could support evapotranspiration needs of plants, and water movement of capillarity humidity can still maintain that peat soil surface soil from drying out (Ritzema *et al.,* 2016; Runtunuwu *et al.,* 2011). Therefore, the process of peat land drainage is not only to throw excessive water or drain the land, but how to create the conditions where the water level in order to support the needs of crop evapotranspiration, and the movement of capillary water can still maintain soil moisture on the soil surface, so that peats are not experiencing totally dry (Car *et al.,* 2011; Rezanezhad *et al.,* 2016; Mohammadbeigi *et al.,* 2017).

Plants responded different to condition of shallow ground water table. Food crop vegetable group have the optimum water depth of 20-30 cm, around 40-50 cm for corn and for annual plants over 60 cm. For the cultivation of oil palm in accordance with government regulations have to be located at a depth of 40 cm (PP 71, 2014); The depth of the water level so that the plants in question could be fulfilled and does not damage the environment. Taufik *et al.* (2011) stated the critical value of fire danger based Keetch-Byram Drought Index (KBDI) for peatlands in Ogan Ilir is at the level of the water depth of 60 cm. The fuel (biomass) will be difficult to burn when the moisture content of more than 12%. Condition of fuel moisture content on the surface of the location of burnt peat land forests in Riau contains an average moisture content of 12.40-12.68%. These results indicate fuel content belongs in the dry, so it is potentially a fire. Fewer water content of the fuel it is easier for fuel to be burnt (Vembrianto *et al.,* 2015).

Water regulation in peatlands has also to consider the impact on the rate of decomposition of peat. There is a linear relationship between the depth of the ground water level in the channel and the water level in the plot of land. Decreased water level will be followed by an increase in carbon emissions. There is a very strong correlation with less value of regression ($R^2$ = 0.71), which is expressed in $CO^2$ emissions = 0.91 x depth of groundwater (Hooijer *et al.,* 2010).

The depth of drainage for the ideal oil palm is between 50-70 cm and rubber plants ranging from 20-40 cm, while the sago palm plants do not require drainage but still require water circulation as well as rice. In general criteria for good water acacia management (HTI) in peat land among which the depth of soil water at planting about 20 cm, and after the age of 1 year was lowered to 30 cm, for further lowered by 10 cm for each year of the aging of the plant. Finally at the age of 6 to 8 years of ground water depth was maintained at approximately 80 cm below the soil surface. According to Imanudin et al., (2019) Land use for agroforestry systems allows groundwater to be maintained at a depth of 40 cm. Because it aims to meet the needs water requirement.

Saharjo *et al.* (2012) concluded that oil palm plantations in Central Kalimantan produced the highest greenhouse gas emissions (CO2), reaching 801,764 tons in 2005 to 2009. Maswar *et al.* (2011) showed the young oil palm loss carbon amounted to 48 t $CO_2$-eq/ha/year. The distance from the drainage channel effect on the ground water table, subsidence, and the loss of carbon, which is farther away from drainage channels: increasingly shallow groundwater table (near surface), subsidence is getting smaller and smaller carbon loss. This paper aimed to examine physical and hydrological characteristics to develop land management plans.

## 2. Materials and Methods

The study was conducted in peatlands cultivated with oil palm and some areas not been planted. The research was conducted in the beginning of August to December 2016. Tools and materials used included peat driller, ring samples, measuring instruments of soil conductivity (permeameter) and the well to measure groundwater levels. The research work was divided into field and laboratory works. Filed activities were to perform network of water system, land use, measuring peat depths, making the soil profiles and monitoring of water levels and daily rainfall.

The excess water was calculated in the root zone of 30-50 cm. Rated value of 30 cm was determined as the minimum condition of the ground water level, which was received by the crops not to experience water stress in wet condition, while the excess water of more 50 cm in the rooting zone is the tolerable limit for oil palm.

Water status on each plot of farmers can vary due to differences in humidity and depth of the groundwater levels.. The excess amount of water (excess surplus water) at a depth of less than a certain depth SEW-30, for example, gives a measure of the condition of excessive soil moisture deficiency during infancy, which can inhibit plant growth. These conditions indicated when water falls below 30 cm soil, plants will suffer from water stress.

Calculating the excess water in the root zone of 40 cm can be used for the majority of non-rice crops, and also meets the regulatory criteria by the Government, which states that utilizing peatlands has to maintain the water level at a depth of 40 cm below the soil surface. An excess amount of water in the upper 40 cm can be calculated to predict excessive soil moisture for crop growth period. The formula is as follows:

$$SEW-40=\sum_{i=1}^{n}(40-x_i) \qquad [1]$$

where xi is the groundwater table on day i, where i is the first day and n is the number of days during plant growth. Model Drainmod actually calculate the value of SEW-30 cm per hour, rather than calculate the daily value, therefore the calculation of the value of SEW-30 is more accurate and defined by the following equation:

$$SEW-40=\sum_{j=1}^{m}(40-x_j)/24 \qquad [2]$$

where xj is the ground water level by the end of each hour and m is the total hours during the period of plant growth.

The position of the water table to the critical limit of 30 cm is done with consideration of the figure of 30 cm below the soil surface taken as not most crops will suffer physiological disorders when the ground water level drops at a point 30 cm or otherwise increase from the figure of 30 cm of the soil surface. This means that when the ground water getting away from the boundary figure of 30 cm or closer to the ground, there will be excess water (excess water). Prediction of excess or shortage of water in an area was following the rules of the conservation period. The rule describes the state of the soil moisture balance for a certain period of time. The formula is follows:

Incoming water - water out = change in loose soil

It is systematically expressed as the following formula:

$$(I + PLT)\,n - (P + E + T)n = (\Delta LTN)n \qquad [3]$$

With:

I = Water infiltration (mm)

PLT = Contributions status of ground water (rainfall, irrigation tide, shallow ground water level through kopilator)

P = Percolation (mm)

E = Evaporation (mm)

T = Transpiration (mm)

ΔLTN = Changes in groundwater levels (mm)

n = an interval of observation (day)

The water flow was towards the ground by a layer of unsaturated expressed by Darcy in the form of the equation:

$$Q=K\left(\frac{dW}{dz}-1\right) \qquad [4]$$

Q = Flux capillary (cm/day)

K = Hydraulic conductivity (cm/day)

W = Soil matric section (cm)

Z = High above the ground water level (cm)

By way of integration, equation (4) yields the value of Z:

$$\int_{20}^{2} dz = \int_{w_0}^{w} \frac{K}{K+Q} DW \qquad [5]$$

With the boundary conditions;
W = W0 = 0 at Z = Z0 = 0; position parallel to the ground water level,
W = Wr = 0 at Z = Zr = 0; position below the root zone.

Equation (4) also generated the relationship between K and (W), K and (ø) of less value histerisc soil than K (W), then that is used is the value of K (ø), equation (5) also states that the high-rise capillary is the height above the shallow ground water level by adjusting the height of matric suction. Soil capillarity values can also be predicted from the soil hydraulic conductivity (Liu *et al.,* 2014). It was calculated in this study using a computer model of the up flow (Mohammadbeigi *et al.,* 2017).

## 3. Results and Discussions

### 3.1. Climate Conditions

Climate characteristics in the study site belonged to the agro-climatic zone C1 according to the Oldeman classification with a monthly average temperature of 27.5°C. The lowest temperature 26°C was found in January and the highest temperature of 28.7°C in October, relative humidity 80%. The mean average annual rainfall of 2,553 mm with the characteristics of the tropical rainy climate where hot and humid conditions occur throughout the year, 5-6 months in a row to get rainfall of more than 200 mm per month. The number of rainy days ranged between 15-22 days per month and 1-2 months of drought, with rainfall less than 100 mm per month, with the number of rainy days ranged from 8-14 days per month.

Solar radiation is required for plant growth and especially to the process of photosynthesis. Total rainfall and distribution in a region will determine the magnitude of the intensity of solar radiation. The maximum solar radiation occurs in June by 49%, to an average of 38% of solar radiation. Air humidity has little impact on rice growth as long as enough moisture available in the soil, optimum less than 80%. Low humidity (73%) was in September and the highest humidity in January (87%). The air temperature is affected by the altitude above sea level, the distance from the beach and can also be affected by rainfall distribution contained in an area.

Meanwhile, to see rainy conditions in the study area, used rainfall data from the nearest station Kayu Agung. To see the effects of climate anomalies compared to the rainfall the last two years 2014, 2015 and 2016 (Figure 1). In 2014, the condition is classified normal rainfall conditions, where extreme dry conditions only occur within a month, while in 2015 there was the influence of Elnino, where rainfall is less 50 mm, experienced during the four months from July, August, September, and October. This period is very critical and causes of land have a very big fire. The opposite condition in 2016 was influenced by climatic conditions Lanina, where more than normal rainfall in August is still no rain. Even recently the city Palembang on 12 September 2016 experienced flooded. Yet in the same month, last year was very dry condition. In 2016 the study area did not have a fire because of precipitation fairly evenly throughout the month. The water deficit in May-June can be controlled by retaining water in the channel. The movement could capillary water to meet the needs of crop evapotranspiration.

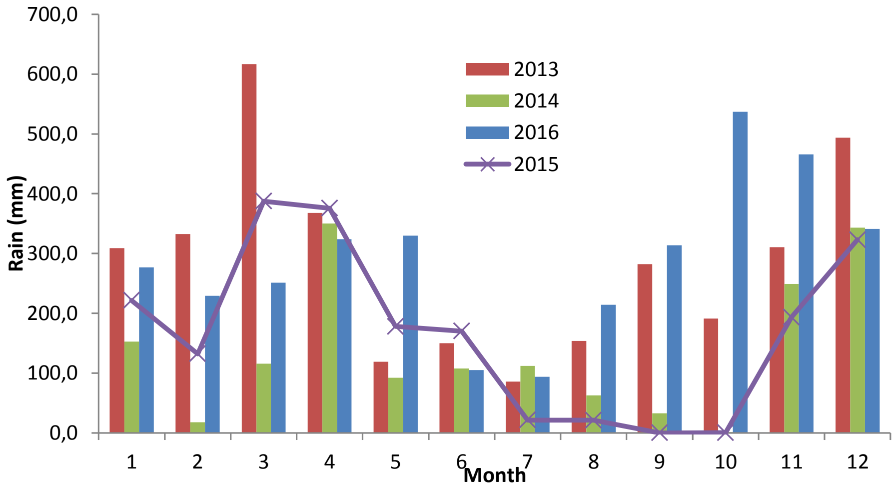


Figure 1. Distribution of monthly rainfall in 2014, 2015 and 2016

### 3.2. Soil Physical Conditions

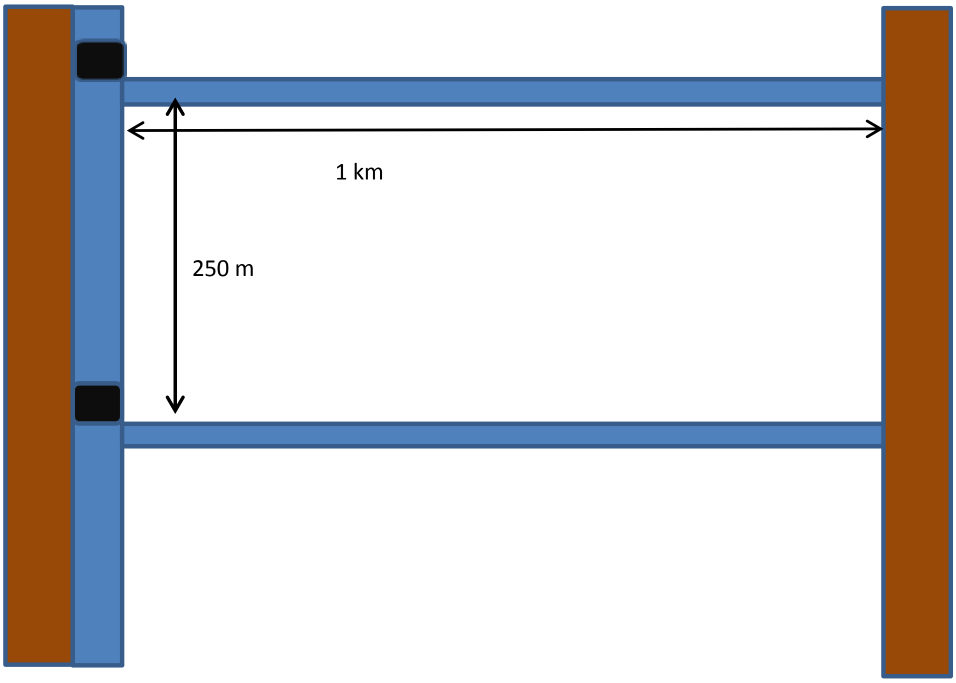
Ability of peat land drainage is dependent upon the soil physical characters, decomposition rate and soil compaction. The soil physical characters played the greatest role in water planning, which is the value of soil hydraulic conductivity. Hydraulic conductivity value experienced a significant decrease in depth of more than 50 cm. The field research showed the level of decomposition of organic material is sapric at a depth of 0-20 cm and hemic at the depth of 30-100 cm (Table 1). Generally the average soil hydraulic conductivity value was around 2.87 m/day, around $2.88\times10^{-8}$ m/s to $3.29\times10^{-5}$ m/s for the drained peatlands, and about $8.49\times10^{-8}$ m/s for the peatland forest. Values of Kh estimates ranged from $10^{-9}$ to $10^{-6}$ m/s. The results of calculation of water level rise on average by adding water from the rain showed the value of drainable porosity is 0.56. This means that the soil has the ability to store water for 56% of total volume. The soil porosity ranged from 0.90 to 0.93.

Table 1. The value of soil hydraulic conductivity in the research area

| Sampling codes | The value of soil hydraulic conductivity (m/day) | Criteria |
|---|---|---|
| 01 | 1.58 | rather quickly |
| 02 | 2.91 | quickly |
| 03 | 3.95 | quickly |
| 04 | 2.46 | quickly |
| 05 | 4.05 | quickly |

### 3.3. Existing Condition of Water System Network

Figure 1 shows the arrangement of the network system in the research area. Secondary channel (2) also serves to open access roads, because this channel is parallel to the road. Perpendicular to the secondary channel in the wake of the tertiary channels, these channels have a surface width dimension of 2.5-3.0 m, on bottom width of 1.5-2.0 m. This channel is only connected next to the secondary channel, while the other part (closed end). Tertiary channel length is approximately 1000 m (Figure 2).




Note : (1) Secondary channel; (2) tertiary channel; and (3) main road

Figure 2. The network system of water management in peat land areas

Oil palm cultivation especially for large plantation in peatlands is mainly restricted by intensive inundation (poor drainage). Oil palm requires ground water level of 60-70 cm below the soil surface. Thus, land reclamation efforts were carried out by making primary channels, secondary and tertiary channels to remove excess water. The research area is classified as peatlands with average peat depth of 5 m. Oil palm has been cultivated by establishing an open channel water system (open channel) for the initial phase, and then developed with a closed folder system where there is an effort to make water retention (water containment).

Water level setting in the secondary canals is done by making containment dikes and to flow water in the pipe connecting with 3 pieces. The pipe has a diameter of 30 cm. This method aims for the water distribution system in the tertiary channel for each secondary plot. Each tertiary channel has a height difference of water surface. Thus the water in the drainage channel has the potential gravity. If the water in the plot is full, it will overflow drain next to the next plots, so that all plots are expected to obtain the same water. Water distribution system refers to the principle of connecting vessel (Figure 3). Pipe was buried embankment near the surface (10 cm below the soil surface), it is intended to make the water in the channel to remain the lowest in the 10-20 cm from the canal banks. Swath end is usually connected with the main drain, i.e., the area or river swamp in nature (Figure 4). The water system is using the concept of excess water disposal, where the door at the main drainage valve was installed at a height above the bottom line, more or less be in a depth of 1 m above the bottom line. Therefore, the water disposal will run when the water level in the main channel of the numbers exceed 1 m. Furthermore, when the rains come where overflow water from the river or swamp the outside of the area will go to the land, the valve door closes automatically by the encouragement of water. This condition causes the water from the outside cannot enter into the land.

(a)

(b)

Figure 3. A water-retaining embankments in the secondary channels; in downstream (a) and in the upstream (b)

(a)

(b)

Figure 4. The main drainage systems including valve door; (a) the inside; (b) the outer lead toward to free waters or disposed region (swamp)

### 3.4. Hydrological Parameters in the Fields

The groundwater dynamics in the field was mainly affected by the rainfall amount. Field conditions with *lebak* physiographic peatlands were not much influenced by both tides of the river and especially from the sea. This is due to the peatlands being away from the sea and not be passed by a large river. Overview of water level in the channel can be seen in Figure 5. The water level in the channel from 23 August until 3 September continued to decline, although there is only three times the rainfall event. The rain fell still lower intensity of only 10 mm and was unable to raise the water level in the channel. The water level continues to decline indicating the peatlands are not influenced by tides. This condition requires water management aiming at maximizing rainfall retention system.

The variation of the groundwater table is shown in Figure 6. The groundwater level with their location near the channel showed a shallower depth compared to the much of the channel. Groundwater is also likely to continue to decline, from August to September. This decline is in line with the drop in water level in the tertiary canals. The water level dropped -55 cm tertiary canals making the groundwater level dropped -54 cm in the area close to the channel and -82 cm in the middle area of the channel. These data indicate that the groundwater level in dry conditions tends to follow a pattern elliptic. If the groundwater is getting closer to the channel, meaning the groundwater level is closer to the water level in the channel. If the groundwater is getting away to the channel, then the groundwater condition is getting deeper. Even the differences in ground water level can reach 30 cm lower than the water in the channel.

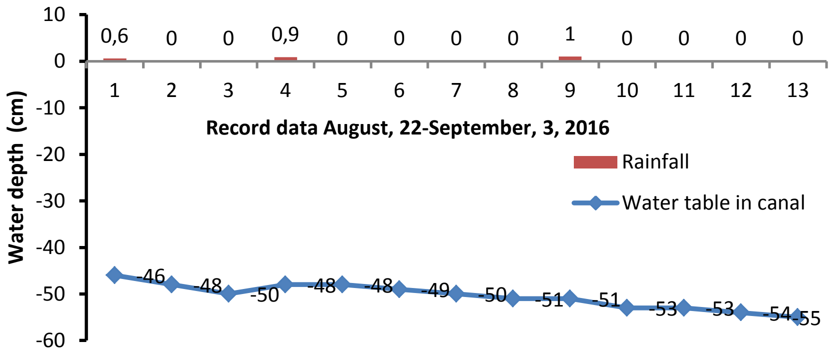



Figure 5. The relationships between water depths in the channel with rainfall

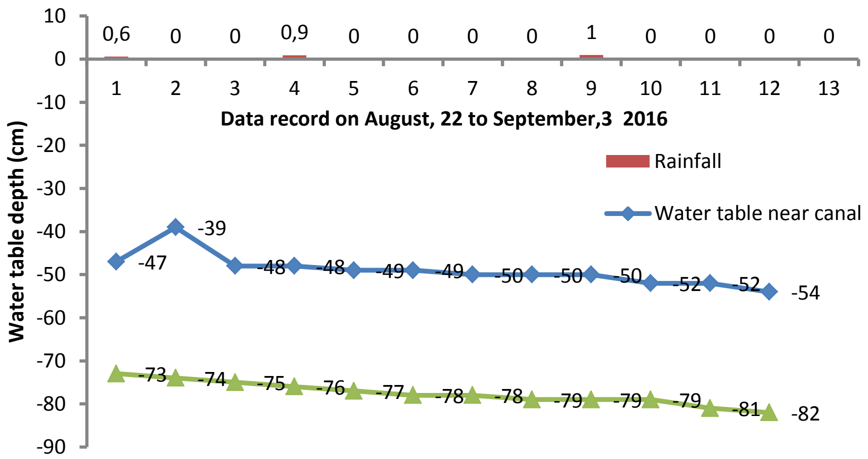



Figure 6. The condition of the groundwater in the area near the channel and away from the channel (middle)

Observations on the maximum drained area (there are palm trees) and the unplanted areas showed a very real difference. The depth of ground water on unplanted areas was relatively stable at around 35-39 cm below the soil surface, which were in the safe zone of fires. While on drained areas for oil palm showed groundwater level reached a critical zone, which was located at a depth of 80 cm below the ground surface. It can be concluded to overcome land and forest fires, it is necessary to build a green belt (conservation zone) around the plantation area bordering to the protected areas. Green belt has not to be opened and conditioned in still wet, so if there is fire movement from outside the plantation, then the fires can firstly be minimized or controlled by a green belt area. Green belt zone should be made at least 50 m from the outer limits of oil palm plantations (Figure 7).

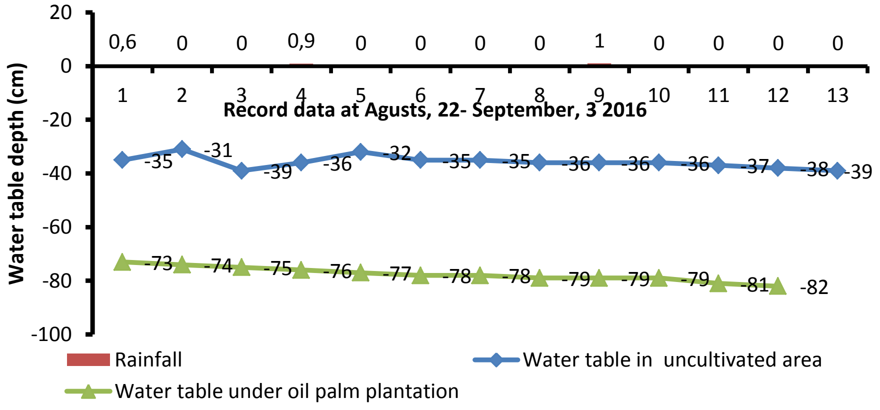



Figure 7. Comparison of the ground water conditions in planted and unplanted areas

### 1. The Influence of Rainfall on Water Dynamics

The dynamics of groundwater were greatly influenced by rainfall amount both on cultivated peatlands (with drainage channel) and uncultivated peatlands. Rainfall event of 2-3 mm has been able to raise the water level in the land plots of 2-3 cm (Figure 8). The conditions caused by loss of water out of the area can be minimized by closing the floodgates on tertiary canals. Therefore the trend of rising groundwater levels in uncultivated peatlands can be followed by the cultivated peatlands if the uncultivated peatlands are equipped with floodgates and detention in tertiary channels. Figure 8 showed the dynamics of the water level in the tertiary canals and land plots. Rainfall events are also able to raise the water level of 1-2 cm tertiary canals when detention (retention).

The pattern of the water dynamics in the tertiary canals and groundwater showed the same trend. The increase in water level in tertiary channel has been followed by rising water levels in tertiary channels. The rise of water in the tertiary canals in the study area occurred because no rain events, not because of the influence of the tide. Therefore, the best option to control water levels in the study area is the increase in water retention. Water containment efforts by closing the channel (dam) were only able to maintain the groundwater at a depth of -50 to -60 cm from the canal banks.

This condition is not optimal because the ground water level in the oil palm fields down to the nearest 100 cm below the ground surface. The increase in water level in the channel to number -36 cm and followed by the rise -78 cm soil water. This means that the water level rise of 20 cm in a channel will also be followed by increase in the ground water level approximately 20 cm in the peatlands. This condition occurred due to peatlands have high hydraulic conductivity value as the impact of high porosity.

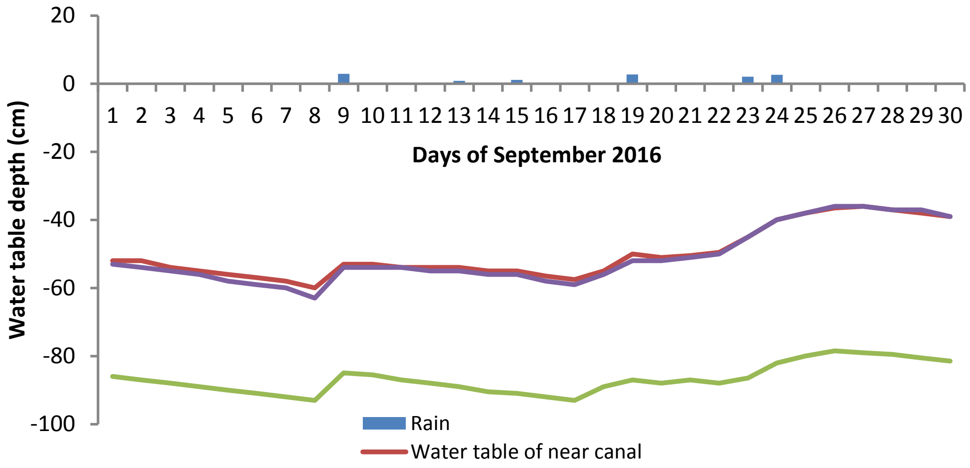



Figure 8. Water table fluctuations in the research area

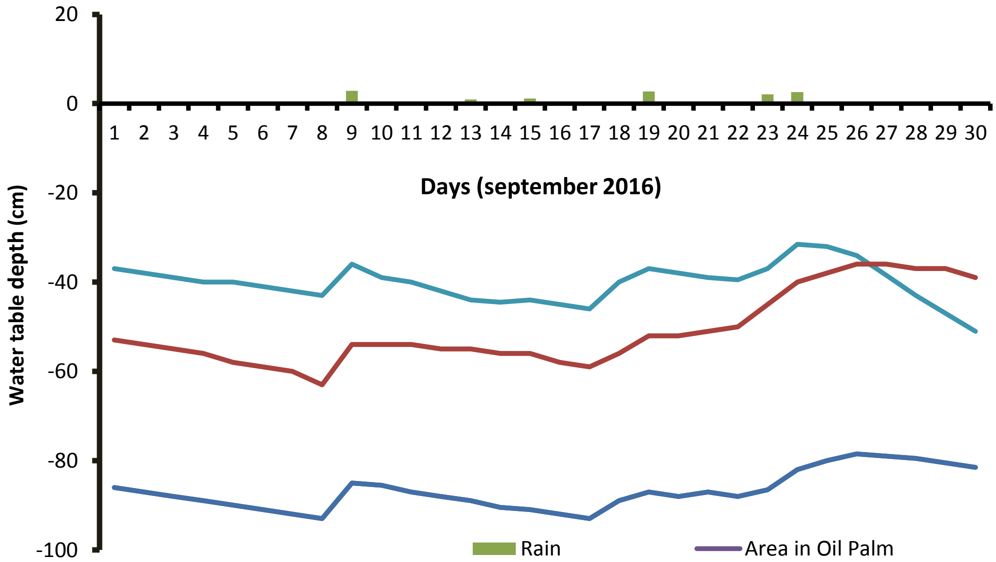



Figure 9. The dynamics of groundwater and water in the canal during the dry season

Periods of wet months were commonly found in months of December, January, February and March. In the four months the oil palm is be able to adapt to the wet conditions and so far oil palm has a high tolerance to saturated soil conditions. The oil palm can tolerate fairly high on inundation if the oil palm entered its second year. On the inundation condition during 4 months, the oil palm can still survive. Thus the company efforts were to implement a retention system (canal blocking), which were true to support government policy and to restore the peatlands. The initial step of the peat land ecosystem restoration is through rewetting. Channel blocking is one of the efforts to raise the groundwater level, and can reduce the rate of peat subsidence.

Water loss in the peatlands is still high despite the condition of the rainy season. Data of groundwater table in January 2017 on cultivated peatlands and without the water level control indicates that the average groundwater stands at 45-58 cm below the soil surface. This showed that the danger of the land clearing by building canals and without being followed by water control (door operation). Even in the wet season conditions, the water level in the research area was approaching the critical zone. But instead on the oil palm land where to control the operation of tertiary entrance is retention, the water level in the channel can be increased and the impact on groundwater levels in the area are in the safe zone, which is located at a depth of 15-30 cm below the soil surface (Figure 10).

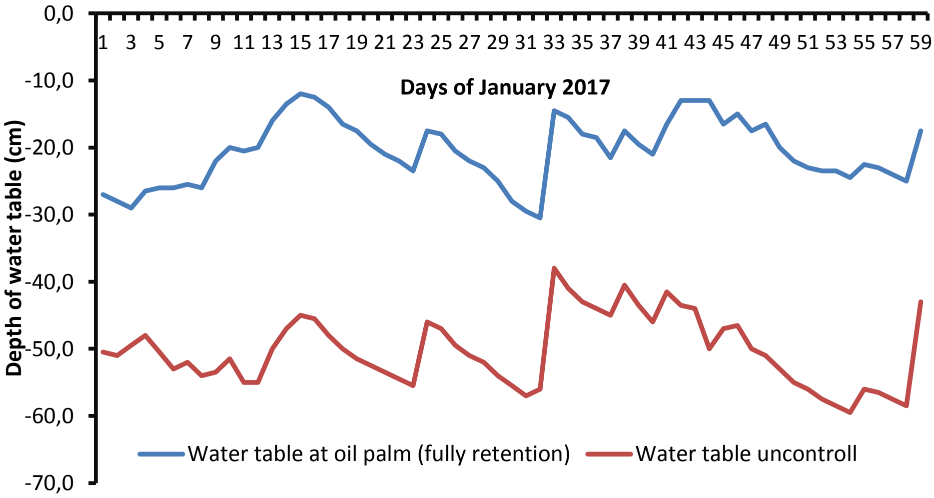



Figure 10. Dynamics of the ground water level during the rainy season in January 2017

**2. Analysis of Excess Water Surplus above 30 and 40 cm (SEW-30 and SEW-40)**

Analysis of the excess water 30 cm above the root zone was carried out to analyze whether food crops can be potentially planted in intercropping systems with oil palm. If the water level is still in the fields, food crops are still expected to grow. The analysis was carried out in the dry season and rain season (January). In relevance to guidelines for peat land ecosystems recovery issued by the ministry of the environment, then it was analyzed the dynamics of groundwater at a depth of 40 cm below the soil surface to see the land potential against fires. Excess water analysis was only done in the area of cultivated peatlands with oil palm.

The analysis showed that in September showed the water for 30 days under the root zone of 30 cm and 40 cm. It means that potential of food crops was sensitive to drought and needs watering in this month. Similarly an analysis of the potential for fire showed all day under the figure of 40 cm of the soil surface, so the area is also susceptible to fires. The lowest water depth is at a value of 90 cm, this showed the total water deficit (40-90) cm = -50 cm. The research area was dominated by peatlands with the maturity level of hemic, which have porosity values of 83%, then to be able to meet the land area of 1 ha with water until peatlands are saturated with water, thus we require water around 830 $m^3$/ha. Figure 11 shows the condition of the ground water level is relatively constant, there is no sharp decline, this is because the period in 2016 was no rain and no effort to control the water level with the water in the channel tertiary containment.

The average depth of the peat layer burning was around 21.99 cm (variation between 0-41.97 cm), but at a certain point peat layers can be burnt up to 90 cm. This condition was clearly influenced by the depth of the ground water level during the dry season, which falls below 50 cm from the soil surface (Figure 10). Therefore fire extinguishing on the peatlands is very difficult and requires a lot of water. Experience of fire-fighting effort since 2000, the need of fire extinguishing on a total area of 1 $m^2$ of peatlands needed 150-350 liters of water. This situation clearly requires the availability of water storage. In the long dry seasons it is so hard to get water in the research area. Therefore the fire prevention is more important in management of peatlands.

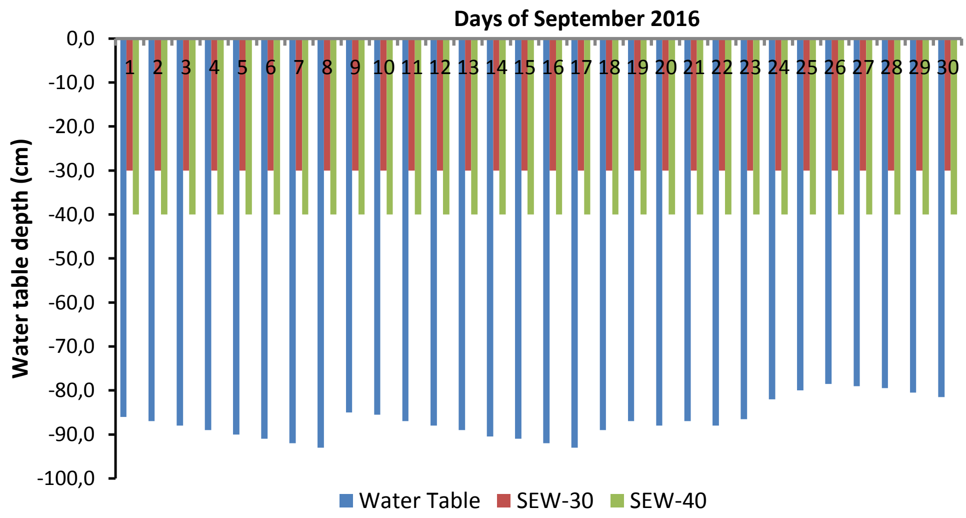



Figure 11. Analysis of excess surplus water 30 and 40 cm on the condition of groundwater levels in dry season

Analysis of SEW-30 and SEW-40 values on the rainy season (January) has been an increase of water level and ground water especially at the root zone. The average ground water level is at a depth of 20 cm from the ground. Excess water is above 40 cm and 30 cm in the rainy season goes positive, it means the water is always above the value of 30 cm and 40 cm, so the excess water was found in the root zone. In this period the land was categorized as safe from fire hazards. This condition is created because the water system is operated as retention, thus maximize the rainfall that is not lost to the outside plantations. Taufik et al., (2011) found that the unit index of forest fires in peat land areas around Ogan Ilir was at the level of 60 cm below the ground surface. This condition is still said to be in a safe zone, which means that the value of the land capillarity is still able to keep the ground from potential fires (Figure 12).

Oil palm has evapotranspiration rate (ETc) of 4-5 mm/day with the distribution of plant roots at a depth of 0-60 cm below the soil surface. Flooding 5-10 days turned out to significantly affect the growth of palm oil. Oil palm growth was restricted and morphological adaptation was the addition of adventitious roots by oil palm.

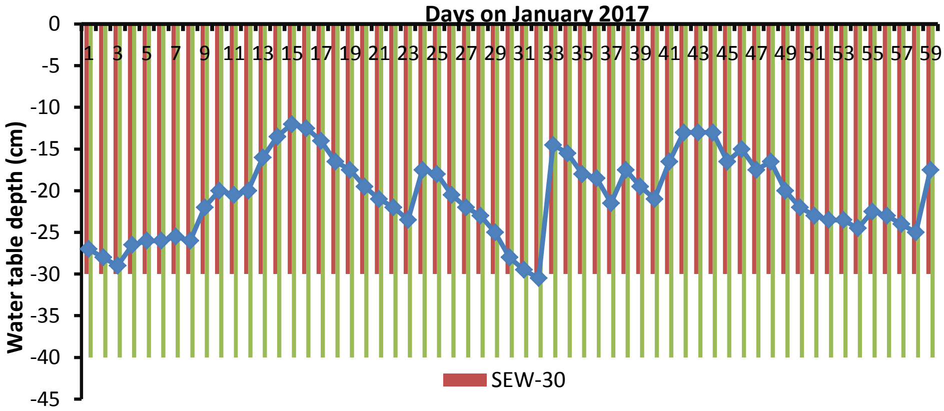



Figure 12. Groundwater level in the fields relative to the surplus of excess water 30 cm and 40 cm in the rainy season

Looking at the critical value of fire hazard in the zone of 60 cm, then in January or during the rainy season the research area is relatively safe from fire hazards. Beside that the land is also very suitable for planting oil palm and food crops.

### 3. Dynamics of Soil Water and Capillarity Power

The water availability in the root zone of plants or critical zone of ground fire in swamp area is highly dependent on the water volume moving in the capillaries. Capillary water movement is strongly influenced by the position of the groundwater depth, texture, and soil hydraulic conductivity values. On soils with clay or clayey texture, the depth of ground water 1.5 m is able to meet the needs of the plant evapotranspiration, but the sand or sandy texture, soil maximum water depth of only 0.5-1 m. Our research areas are peatlands, thus determination of soil texture is very difficult to do because of the high soil organic matter that would interfere with the determination of soil texture, which is likely to do is, to determine the soil water dynamics by maturity peat. Figure 12 shows the soil profile on peat soil-hemic sapric where groundwater at a depth of 40-50 cm is able to create conditions in the root zone moist conditions and moisture content of field capacity, so the land is relatively safe against fires (Figure 13).

(a) Soil profile under oil palm

(b) Soil profile in uncultivated peatlands (bush)

Figure 13. Condition of peat soil profile at a depth of 40-50 cm soil water condition

The depth of the ground water greatly affected the value of water capillary and soil moisture status. Computer calculations up flow models for soil hydraulic conductivity value of 8 m/day water show capillary 5 mm/day are at a fixed value ranging in groundwater found at a depth of -120 cm to -60 cm. This means the plant has not requiring irrigation for the purposes of evapotranspiration 5 mm/day until the position of ground water in the depths of -120 cm of the soil surface. Avoiding the danger of fires, the ground water should be at the level of 40-50 cm below the soil surface. The water content in these conditions is above the field capacity and is close to saturation. Water saturated condition is usually achieved when the depth of the groundwater was 30-20 cm below the ground surface. This condition is caused by the movement of water capillary in the peats, which is relatively small compared to the mineral soil even with the sandy soils.

Conditions and fuel moisture content affects the behavior of fires, especially in terms of ease of the fuel to ignite, the speed of combustion, flame propagation speed, and ease of firefighting efforts. Fuel moisture (high water content) will require more heat energy to burn, therefore the heat energy is used to evaporate the water vapor contained in the fuel. Fuel becomes difficult to burn by fires when the water content contained by the fuel exceeds 12%. Weather factors such as rainfall, humidity, and temperature are factors influencing climate (Table 2).

Table 2. Water table contribution for soil water status in peatlands

| Depth of groundwater (cm) | Contributions to water capillary (mm/day) | The water content of peats (%) |
|---|---|---|
| -200 | 1.6 | 14.8 |
| -190 | 1.8 | 15.2 |
| -180 | 2.1 | 15.1 |
| -170 | 2.5 | 15.5 |
| -160 | 2.9 | 16.4 |
| -150 | 3.5 | 16.5 |
| -140 | 4.1 | 17.5 |
| -130 | 4.9 | 18.3 |
| -120 | 5 | 18.2 |
| -110 | 5 | 19.1 |
| -100 | 5 | 19.9 |
| -90 | 5 | 20.8 |
| -80 | 5 | 22.2 |
| -70 | 5 | 23 |
| -60 | 5 | 25.7 |
| -50 | 5 | 28.8 |
| -40 | 4.7 | 31.5 |
| -30 | 2.6 | 33.6 |
| -20 | 0.3 | 34.7 |
| -10 | 0 | 35.6 |

### 3.5. Smart Water Management for Sustainable Peatlands

The horizontal movement of water in the peatlands is more dominant than the vertical movement, so that the depth of the groundwater on the condition of no input when the rain showed deeper the closer the channel, and the more shallow when it is away from channel. Field data indicates the difference between the land located close to the channel and away from the channel is only 6 cm in the dry season and 2 cm in the rainy season. Effect of water retention in the channel is very strong, so there is not sharp decline (only 6 cm) and the sharp differences occur until over 10 cm, i.e. the difference between the middle and end of the line (Figure 14).

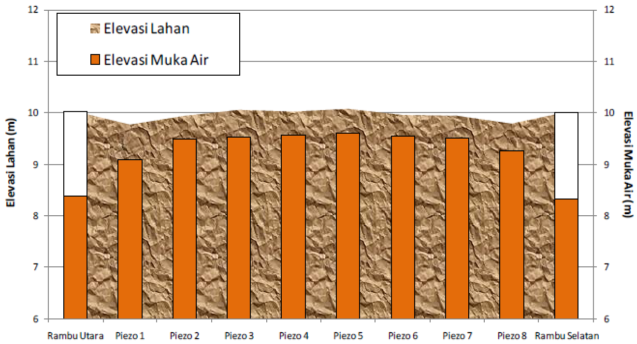



Figure 14. Profile of soil water level between the two channels (Runtunuwu, et al., 2011)

Imanudin and Susanto (2015) showed the water level control for the cultivation of food crops in peatlands was able to raise the groundwater level from an average of -46 cm to -23 cm. This means that through the water control in the tertiary channels can reduce carbon emissions of 41.72-20.53 tones $CO_2$/ha/year, which was to reduce 50% of the total carbon emissions. Changes in peat subsidence ranged from 1.15 to 9.21 cm/year.

In certain circumstances the concept of charging water (rewetting), difficulty is to apply because of limited availability of water resources and rewetting efforts require a high cost. Agronomy approach by using paludiculture cropping systems is capable of creating conditions that secure the ground water level to maintain the ecological functions of peats. These plants are relatively tolerant of shallow ground water table. Rewetting concept has also been applied in the research area on the condition of a long dry periods, has built a well with a depth of 40-50 m, and operated well pump with the discharge capacity of 18 liters/sec for 12 hours, which was able to raise the water level in the secondary channel 2 cm. Paludiculture concept has been applied to the local community by planting pineapple in the oil palm plantation. Pineapple can grow well and produce 30-40 tons/ha in between oil palm trees.

General figure shows the dynamics of daily water on peatlands in different soil conditions. Pretreatment blocking the canal system applied to the dry season starts since August 22 through September 28 either on cultivated peat land and uncultivated peatlands. The results showed an effective ground water level can be held at a depth of 40-50 cm below the soil surface. In the area of uncultivated peatlands water level is relatively higher than cultivated peatlands. The second treatment continued with the opening of the channel-blocking (uncontrolled) on uncultivated peatlands, while the cultivated peatlands are still closed. Results indicated that there was a real change in the dynamics of the water where the ground water level in the area of cultivated peatlands rises and is above the groundwater level dynamics in uncultivated peatlands.

This proved that the uncultivated peatlands due to the influence of drainage is decreasing ground water level if no immediate action water retention (canal blocking). While cultivated peatlands when managed and detention water, ground water can be controlled according to the desired depth. Water detention was beginning in September until February 2017 showed tangible results, where the water table is at a depth of 20-30 cm safety zone below the ground surface. In high rain conditions the ground water level a few days closer to the ground and even flooded 1-2 weeks. However, because of oil tolerant, puddle, then the condition is not a constraint to oil palm.

No real change depth of the groundwater in the area around the open palm replanting. Ground water level in the cultivated peatlands fluctuated according to the season. The depth of the ground water is strongly influenced by rainfall, evapotranspiration as well as control at the channel level. A real change of decreased water level occurred at the time of building water channel and water retention efforts were not made. If peatlands have not been planted with oil palm, then decreasing water level was steeper compared with those with cultivated peatlands with water retention. Thus, the main key to manage peatlands is how to control the water level through water conservation principles. In other word that peatlands should always be in wet condition. Drainage system is not just how to provide optimal condition for plant growth, but the most important parameter should be considered, that how ecological functions of peatlands are not totally disturbed (Imanudin et al., 2018)

In the operational activities of fire prevention in the fields should be combined with the water level control operations plan in tertiary-secondary level with the integrated management of land fire monitoring team. Two of these divisions should be integrated into a single unit, so that mutual support can be achieved. Division of water management should firstly work to prepare for the water level at a safe level, so that the water retention efforts are carried out since 3 months before arriving the dry season and when the year is predicted there will be a dry climate (Elnino). In the years 2016-2017 show the condition of water detention was effectively able to raise the water level at 20-30 below the ground surface during the rainy season (Figure 15).

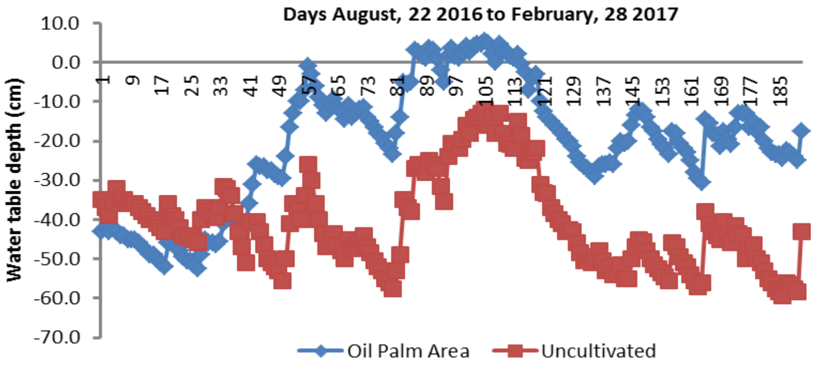



Figure 15. Dynamics of groundwater in peatlands planted with oil palm by controlling the water gates

Control of water levels in cultivated peatlands should be integrated also with land utilization plans. Experience in European countries (Ritzema *et al.,* 2016) showed land used for grazing cattle. In the dry season the water of detention, so that the ground water is maintained not fall below 40 cm, and the wet season, the floodgates were opened and the water level can be controlled below 10 cm below the soil surface. However, in some areas, in trying to conservation, then the area of stagnant water left. This condition should be adopted in the exploitation of peatlands. Often companies (both acacia timber and oil palm) to maximize all land cleared and planted with oil palm or acacia. They have to allocate for the conservation of at least 20%. The areas that should be conserved are peatlands. The areas will also be balancing the ecosystem and to replenish the groundwater in the dry season.

Local wisdom in managing water in the peatlands is also an important think to be applied. In West and South Kalimantan, farmers control water level with multi-store block technique, meaning that farmers have done water conservation efforts. Multi-store block technique was done along the tertiary channels. Figure 15 shows multi-store block technique in tertiary canal level. With this technique, the ground water level in the plot of land can be maintained (not easy to drop), so that the soil moisture content is safe from fire hazards. This system inspired canal blocking technique in the research area with the upper dam system is equipped with a discharge pipe or overflow (Figure 16).



Imanudin et al (2018)

1 2 3

Figure 16. The multi-store block technique (photos 1 and 2: Silvius 2008); (3) the secondary channel blocking in an oil palm plantation and control overflow

## 3. **Conclusions**

Based on results and discussion of research data, thus it can be taken some conclusions as follows:

1) The drainage system is open system with the primary channel (4 m wide and 2m deep), perpendicular to the primary channel is secondary channels (2 m wide and 2 m deep) and distance between the secondary channels is 250 m. The channel dimensions are too wide and deep, so that when there is no water retention, excess discharge will occur in the dry season
2) Water control with a multi-store block system shows the evident influence in increasing water level in the land plots. Detention in the dry season is able to raise the water level at a safe level (40-50 cm). In the uncultivated land there is no water, thus water level down to the level of 70-80 cm. Water control in the rainy season is able to raise the water level at the level of 20-30 cm, while without the water control the water level down to the level of 40-50 cm. For the safety, the water detention policy since the rainy season is the right step to keep track so that the water is at a safe zone.
3) The horizontal water movement is more dominant than vertical movement, which was shown by the water level tends to be deeper when getting closer to the channel. However, the difference is not so noticeable only 6 cm in the dry season and 2 cm in the rainy season. This is because the effects of water retention in the secondary channel.
4) Excess water analysis in zones 30 cm and 40 cm at a time of water retention in the channel, show that in the period from August to September groundwater conditions at the level below normal (-), but due to the movement of water capillarity then when the ground water at depths up to the limit 50-60 cm, they can create soil conditions valleys on the surface, making it safe against fire.
5) The availability of surface water reserves in the oil palm plantation is also very dependent on the conservation of forest area, however forest area was already burnt, so it must be done immediately peat forest restoration around the plantation area
6) The model of peat management should integrate ecological and economic objective, rewetting efforts have to be followed by food crops, which can increase the income of

farmers. Intercropping patterns with pineapple, watermelon and others will help create environmental conditions remain moist area, and free land of fires.

7) The control model to water level should be integrated with local raw material and local knowledge technology, so that socially and technically acceptable to the farmers. Making the block with board materials, soil dam, and in combination with the pipe as overflow into effect at the water system peatlands. Valve door applied to the mouth of the main drainage directly adjacent to a water body (river).

**Acknowledgments**

This article belongs to a part of our research project activities funded through "Penelitian Unggulan Profesi Dosen" Sriwijaya University with the research contract of Nr. 1023/UN9.3.1/LPPM/2016 dated July 18, 2016. On this occasion the authors would like to say thank you to the staffs of the Faculty of Agriculture, Sriwijaya University and local people who have helped in the conduct of research in the field.

**REFERENCES**

Armanto, M.E. 2014. Spatial Mapping for Managing Oxidized Pyrite ($FeS_2$) in South Sumatra Wetlands, Indonesia. Journal of Wetlands Environmental Managements. Vol 2(2); 6-12, October 2014. Indexed in DOAJ. Web-link: http://ijwem.unlam.ac.id/index.php/ijwem

Armanto, M.E. dan E. Wildayana. 1998. Analisis Permasalahan Kebakaran Hutan dan Lahan dalam Pembangunan Pertanian dalam Arti Luas. Jurnal Lingkungan dan Pembangunan, Vol.18(4):304-318. ISSN. 0216-2717. *Accredited.*

Armanto, M.E., E. Wildayana dan N. Rahmawati. 2008. Keterkaitan Kesesuaian Lahan dengan Keputusan Investasi Perkebunan Kelapa Sawit di Lahan Pasang Surut. Jurnal Habitat Vol. XIX (3): 193-206, Desember 2008.

Armanto, M.E., M.A. Adzemi, E. Wildayana and M.S. Imanudin. 2013. Land Evaluation for Paddy Cultivation in the Reclaimed Tidal Lowland in Delta Saleh, South Sumatra, Indonesia. Journal of Sustainability Science and Management. Vol 8(1): 32-42. June 2013. (SCOPUS, Google Scholar and DOAJ indexes). Web-link: http://jssm.umt.edu.my/files/2013/07/4w.pdf

Armanto, M.E., M.S. Imanudin, E. Wildayana, H. Junedi and M. Zuhdi. 2016. Managing Actual Problems of Peatsoils Associated with Soil Acidity. Sriwijaya Journal of Environment, Vol 1(3); 58-63, December 2016. http://dx.doi.org/10.22135/sje.2016.1.3.53-58

Carr, M.K.V. 2011. The Water Relations and Irigation Requirement of Oil Palm (*Elaeis Guineensis* L.): A Review Expl Agric. Vol 47(4); 629-652. Doi:10.1017/S0014479711000494

Edwin, M.S., I. Lubis, Y. Harahap, C. Taufigh, Y.H. Pangaribuan, E.S. Sutarta, A. Zaharah, B.S. Rahman, C. Teh and M.M. Hanafi. 2014. Changes in Water Table Depth in an Oil Palm Plantation and its Surrounding Regions in Sumatra, Indonesia. Journal of Agronomy 13(3); 140-146.

Hooijer, A., S. Page, J.G. Canadell, M. Silvius, J. Kwadijk, H. Wosten, and J. Jauhiainen. 2010. Current and Future $CO_2$ Emissions from Drained Peatlands in Southeast Asia. Biogeoscience. Vol 7:1505-1514.

Imanudin, M.S., Satria, J.P., M.Said, and Rahmat, R. 2019. Land And Water Management In Pineapple And Albizia Chinensis Agroforestry Systems In Peatland. Sriwijaya Journal of Environment. 4(2): 52-58 http://dx.doi.org/10.22135/sje.2019.4.2.52-58

Imanudin, M. S., Eliza, W, and Armanto,M.E. 2018. Option for Land and Water Management to Prevent Fire in Peat Land Areas of Sumatera Indonesia. Journal of Wetlands Environmental Management. 6(1): 12 – 26. http://dx.doi.org/10.20527/jwem.v5i2.108

Imanudin, M.S. and R.H. Susanto. 2015. Intensive Agriculture on Peatlands Areas to Reduce Carbon Emission and Fire Prevention (A Case Study in Tanjung Jabung Timur Tidal Lowland Reclamation Jambi). Proceeding the First Young Scientist International Conference of Water Resources Development and Environmental Protection, Malang Indonesia, 5-7 June 2015.

Imanudin, M.S., M.E. Armanto and R.H. Susanto. 2011. Developing Seasonal Operation for Water Table Management in Tidal Lowland Reclamations Areas at South Sumatra Indonesia. Journal of Tropical Soils. Vol. 16(3): 233-244. Web-link: http://journal.unila.ac.id/index.php/tropicalsoil DOI: 10.5400/jts.2011.16.3.233

Imanudin, M.S., M.E. Armanto, R.H. Susanto and S.M. Bernas. 2010. Water Table Fluctuation in Tidal Lowland for Developing Agricultural Water Management Strategies. Journal of Tropical Soils. Vol. 15(3): 277-282. Web-link: http://journal.unila.ac.id/index.php/tropicalsoil DOI: 10.5400/jts.2010.15.3.277

Liu, Q., N. Yasufuku, J. Miao, and J. Ren. 2014. An Approach for Quick Estimation of Maximum Height of Capillary Rise. Soils and Foundations. Vol 54(6); 1241-1245.

Maswar, O. Haridjaja, S. Sabiham, and M. van Noordwijk. 2011. Cadangan, Kehilangan, dan Akumulasi Karbon pada Perkebunan Kelapa Sawit di Lahan Gambut Tropika. J. Solum. Vol 8(1); 1-9.

Mohammadbeigi, A.A., F. Mirzaei and N. Ashraf. 2017. A Study on Capillary Rise in Controlled Drainage System and Its Comparison Eigth UPFLOW model. Proceeding of the 13th International Drainage Workshop of ICID Ahwaz, Iran 4-7 March 2017

Rezanezhad, F., J.S. Price, W.L. Quinton, B. Lennartz, B.T. Milojevic, and V.P. Cappellen. 2016. Structure of Peat Soils and Implications for Water Storage, Flow and Solute Transport: A review Update for Geochemists. Chemical Geology. Vol 429; 75-84.

Ritzema, H., H. Kirkpatrick, J. Stibinger, H. Heinhuis, H. Belting, R. Schrijver, and H. Diemont. 2016. Water Management Supporting the Delivery of Ecosystem Services for Grassland, Heath and Moorland. Sustainability, Vol 8(5), 440-450. Doi:10.3390/su8050440

Runtunuwu, E., B. Kartiwa, Kharmilasari, K. Sudarman, W.T. Nugroho, dan A.A. Firmansyah. 2011. Dinamika Elevasi Muka Air pada Lahan dan Saluran di Lahan Gambut. Riset. Geo. Tam. Vol 21(2); 65-73.

Sutikno, S.. R Rinaldi1 , E Saputra., M Kusairi., B H Saharjo., E I Putra. 2020. Water management for hydrological restoration and fire prevention in tropical peatland. The 2nd Aceh International Symposium on Civil Engineering (AISCE)IOP Conf. Series: Materials Science and Engineering 933 (2020) 012053doi:10.1088/1757-899X/933/1/012053

Saharjo, B.H., E.I. Putra, and U. Atik. 2012. Pendugaan Emisi $CO_2$ sebagai Gas Rumah Kaca akibat Kebakaran Hutan dan Lahan pada Berbagai Tipe Penutupan Lahan di Kalimantan Tengah Tahun 2000-2009. Jurnal Silvikultur Tropika: 3(3); 143-148.

Sjarkowi, F., A. Arbain, M.E. Armanto, U. Santoso, J. Arjuna, Rifardi, A. Setiawan, J. Syahrul, Khairijon dan Azizah. 2007. Kualitas Lingkungan Hidup Sumatera 2007. PPLH Regional Sumatera, Kementerian Lingkungan Hidup RI, Pekanbaru, Riau, ISBN. 978-602-8107-00-6. 393 hal.

Sumarga, E., L. Hein, A. Hooijer, and R. Vernimmen. 2016. Hydrological and Economic Effects of Oil Palm Cultivation in Indonesian Peatlands. Ecology and Society. Vol 21(2); 52-61. Doi.org/10.5751/ES-08490-210252

Taufik, M., Setiawan, B.I, Prasetyo, L.B, Pandjaitan, dan N.H. Soewarso. 2011. Pengembangan Indeks Bahaya Kebakaran di HTI SBA Wilayah Sumatera Selatan. Jurnal Penelitian Hutan Tanaman, Vol 8(4); 215-223.

Vembrianto, N., D. Yoza, and E. Sribudiani. 2015. Karakteristik Ekologi Lokasi Kebakaran Hutan dan Lahan di Desa Rantau Bais Kecamatan Tanah Putih Kabupaten Roan Ilir. Jom Faperta. Vol 2(1) Februari 2015.

Wildayana, E. 2014. Formulating Oil Palm Investment Decision in Tidal Wetlands of South Sumatra, Indonesia. Journal of Wetlands Environmental Managements. Vol 2(2); 30-36, October 2014, Indexed in DOAJ. Web-link: http://ijwem.unlam.ac.id/index.php/ijwem

Wildayana, E. 2015. Formulating Rice Fields Conversion Control to Oil Palm Plantations in Tidal Wetlands of South Sumatra, Indonesia. Journal of Wetlands Environmental Managements. Vol 3(2); 72-78, October 2015. Indexed in DOAJ. Web-link: http://ijwem.unlam.ac.id/index.php/ijwem

Wildayana, E. 2016. Income Increase of Farmers through Utilization of Acacia Logging Residues for Wood Chips. Jurnal Habitat, Vol 27(1); 48-54, April 2016. DOI: 10.21776/ub.habitat.2016.027.1.6. Web-link: http://habitat.ub.ac.id/index.php/habitat/article/view/222/241

Wildayana, E. dan M.E. Armanto. 2009. Dampak Financial Kehilangan Hara ke Atmosfir Akibat Kebakaran Hutan dan Lahan. Jurnal Habitat Vol. XX (2): 81-88, Agustus 2009.

Wildayana, E., D. Adriani and M.E. Armanto. 2017. Livelihoods, Household Income and Indigenous Technology in South Sumatra Wetlands, Vol. 2(1); 23-28, February 2017. http://dx.doi.org/10.22135/sje.2017.2.1.23-28

Wildayana, E., M.E. Armanto dan N. Rahmawati. 2008. Dampak Pembangunan Perkebunan Kelapa Sawit terhadap Peningkatan Ekonomi Masyarakat di Lahan Pasang Surut (Pendekatan Multiplier Effect). Jurnal Habitat Vol. XIX (2): 159-168, Agustus 2008.

Wildayana, E., M.E. Armanto dan N. Rahmawati. 2008. Pengembangan Program Pola Usahatani Agribisnis Spesifik Lokasi di Lahan Pasang Surut. Jurnal Habitat Vol. XIX (3): 223-236, Desember 2008.

Wildayana, E., M.S. Imanudin, H. Junedi, M. Zuhdi and M.E. Armanto. 2016. Parameters Affecting Household Income Diversity of Farmer's Tribes in South Sumatra Tidal Wetland. Sriwijaya Journal of Environment, Vol 1(3); 47-52, December 2016. http://dx.doi.org/10.22135/sje.2016.1.3.47-52

# 6th ISWEM Certificate

Yahoo/Email Masuk

- **sadanghusain@ulm.ac.id**

  **Kepada:**momon_unsri@yahoo.co.id

  ## Kam, 10 Des 2020 jam 07.15

  This is your 6th ISWEM 2020 Certificate Momon Sodik Imanudin

  - 6th ISWEM CERTIFICATE.pdf

    439.9kB

  Dikirim dari ponsel cerdas Samsung Galaxy saya.

  - 6th ISWEM CERTIFICATE a.n. Momon Sodik.pdf

    439.9kB

# CERTIFICATE

Number: 201/UN8.1/PPJP/2020

MINISTRY OF EDUCATION AND CULTURE
LAMBUNG MANGKURAT UNIVERSITY
CENTER OF JOURNAL MANAGEMENT AND PUBLICATION

Given to:

**Momon Sodik Imanudin**

as

**Oral Presenter**

6th International Symposium Of Wetlands Environmental Management

The Center Of Journal Management and Publication (CJMP) Lambung Mangkurat University

Banjarmasin, 30 November – 1 December 2020

*"Covid-19 Pandemic reflection on Wetlands Environmental Management"*

| Rector, | Head of CJMP, | Chief of Organizer, |
|---|---|---|
| Prof. Dr. H. Sutarto Hadi, M.Si., M.Sc. | Prof. Dr. Ir. H. Abdul Hadi, M.Agr. | Dr. Eng. Irfan Prasetia |
| NIP. 19660331 199102 1 001 | NIP. 19680207 199303 1 004 | NIP. 19851026 200812 1 001 |

[ISWEM] Manuscript Revise Required

**Perbaikan Makalah Untuk di Publikasi**

Eksternal

Kotak Masuk

**Nukhak Nufita Sari** **<nukhak.sari@ulm.ac.id>**

Jum, 26 Mar 2021 18.08

kepada saya

Terjemahkan pesan

Nonaktifkan untuk: Inggris

The following message is being delivered on behalf of The International Symposium on Wetlands Environmental Management (ISWEM).

---

Dear Author,

We have reached your submission to International Symposium on Wetlands Environmental Management

Our decision is: Revisions Required

Your article should be corrected according to reviewers' comments. Please find the file attached below.

Please revise the article within 2 days from the date of sending off. We kindly ask you to resubmit revised article to this email address.

If you have any questions, please contact me. Thank you for considering this journal as a venue for your work.

Yours sincerely,
Nukhak Nufita Sari

Jurusan Agroekoteknologi, Fakultas Pertanian

Universitas Lambung Mangkurat

Jl. A. Yani Km. 36 Kotak Pos 1028 Banjarbaru, Kalimantan Selatan 70714

# Developing water management objective on tropical peatlands under oil palm cultivation

**M S Imanudin[1], M E Armanto[1], E Wildayana[1], Bakri[1] and H Junedi[2]**

[1] Faculty of Agriculture, Sriwijaya University, Indonesia.
[2] Faculty of Agriculture Jambi University, Indonesia.

E-mail: momonsodikimanudin@fp.unsri.ac.id

**Abstract**. Less attention to peatlands for various economic development activities have led to the emergence of serious environmental problems. The problems are floods in the rainy season, fires in the dry season and increased carbon emissions. This paper aimed to examine physical and hydrological characteristics to develop land management plans. The research was conducted on peatlands used for oil palm plantations. The study concluded that the available drainage system generally indicates excess discharge (over drainage). Water retention efforts proved effective in secondary channels and are able to raise the water level of 20-30 cm higher than the uncultivated peatlands (no water retention). Fluctuations in groundwater levels in the period from August to September on the cultivated peatlands showed that the groundwater is deeper than the uncultivated peatlands. It determined greater value of evapotranspiration of oil palm plantation. If the floodgates do not exist, then the groundwater becomes deeper than the cultivated peatlands. In the January-February period of the groundwater in the cultivated peatlands can be increased to 20-30 cm under the soil surface, but on the uncultivated peatlands without controlling the water level drops at the position 40-50 cm below the soil surface. Thus the concept of water retention became the main purpose for water management in peatlands.

## 1. Introduction

Approximately 20 million ha of peatlands, which is equivalent to half of the tropical peatlands in the world, are in Indonesia [1]. Therefore, Indonesia has an important value and strategic views of biodiversity and ecological functions. Peatland is generally located between two rivers; thus, it hydrologically formed a unique island-shaped "dome". Depth variability of peats greatly affect the carrying capacity of peats to store water, vegetation, and management policies. On the other hand, land clearing for oil palm plantations and industrial plants are still ongoing [2].

In the long dry conditions (more than three months) in the absence of added water containment efforts then drying peat is becoming increasingly widespread, even to areas that have not been opened. It is therefore important to do a field study to find peatland management options for the creation of conditions of the ground water level that meet the needs for plant growth and prevent forest fires. Approach to land capability should be involved in the preparation of management plans on peatlands [3]. During this time, many companies only see from the ground surface; the depth of peat is the key factor often overlooked. Often found in the cultivation of plants is done on the peat depth more than 3.0 m deep or even more [4]. The business world should count carefully because cultivation in peatlands is costly. To increase one-two units of pH values required 10-30 tons of dolomite [5].

Cultivating wetlands and peatlands for oil palm plantation and acacia industrial plantation (HTI) in South Sumatra has been started since 1990, which have brought serious impacts to environmental issues such as among others degradation of peat quality, decreasing water level, increasing decomposition rate of peat leading to carbon emissions, peat subsidence, changing of peat characteristics, losing ability to store water, hydrology, land and forest fires [6]. Several efforts should be done to increase ground water table. Installing the canal blocking has significant effect to increase water table [7].

Water management in peatlands are unique compared to that of mineral soils, since the peatlands have high ability to absorb a lot of water (hydrophilic), and if peatlands are over drained their ability to absorb water will dramatically decrease (hydrophobic). The condition occurs because the peats occur irreversible drying process (irreversible drying), especially if peats experience very long (extreme drying condition. Therefore peat land drainage process is not simply boast drain the excess water or land, but how to create the conditions so that the water level could support evapotranspiration needs of plants, and water movement of capillarity humidity can still maintain that peat soil surface soil from drying out [8]. Therefore, the process of peat land drainage is not only to throw excessive water or drain the land, but how to create the conditions where the water level in order to support the needs of crop evapotranspiration, and the movement of capillary water can still maintain soil moisture on the soil surface, so that peats are not experiencing totally dry [9].

Water regulation in peatlands has also to consider the impact on the rate of decomposition of peat. There is a linear relationship between the depth of the ground water level in the channel and the water level in the plot of land. Decreased water level will be followed by an increase in carbon emissions. There is a very strong correlation with less value of regression ($R^2 = 0.71$), which is expressed in $CO_2$ emissions = 0.91 x depth of groundwater [10].

The depth of drainage for the ideal oil palm is between 50-70 cm and rubber plants ranging from 20-40 cm, while the sago palm plants do not require drainage but still require water circulation as well as rice. In general criteria for good water acacia management (HTI) in peat land among which the depth of soil water at planting about 20 cm, and after the age of 1 year was lowered to 30 cm, for further lowered by 10 cm for each year of the aging of the plant. Finally, at the age of 6-8 years of ground water depth was maintained at approximately 80 cm below the soil surface. According to [11] land use for agroforestry systems allows groundwater to be maintained at a depth of 40 cm. Because it aims to meet the needs water requirement. This paper aimed to examine physical and hydrological characteristics to develop land management plans.

## 2. Materials and methods

The study was conducted in peatlands cultivated with oil palm and some areas not been planted. The research was conducted in the beginning of August to December 2016. Tools and materials used included peat driller, ring samples, measuring instruments of soil conductivity (permeameter) and the well to measure groundwater levels. The research work was divided into field and laboratory works. Filed activities were to perform network of water system, land use, measuring peat depths, making the soil profiles, and monitoring of water levels and daily rainfall.

The excess water was calculated in the root zone of 30-50 cm. Rated value of 30 cm was determined as the minimum condition of the ground water level, which was received by the crops not to experience water stress in wet condition, while the excess water of more 50 cm in the rooting zone is the tolerable limit for oil palm.

Water status on each plot of farmers can vary due to differences in humidity and depth of the groundwater levels. The excess amount of water (excess surplus water) at a depth of less than a certain depth SEW-30, for example, gives a measure of the condition of excessive soil moisture deficiency during infancy, which can inhibit plant growth. These conditions indicated when water falls below 30 cm soil, plants will suffer from water stress.

Calculating the excess water in the root zone of 40 cm can be used for the majority of non-rice crops, and also meets the regulatory criteria by the government, which states that utilizing peatlands has to maintain the water level at a depth of 40 cm below the soil surface. An excess amount of water in the upper 40 cm can be calculated to predict excessive soil moisture for crop growth period. The formula is as follows:

$$SEW - 40 = \sum_{i=1}^{n}(40 - x_i) \tag{1}$$

where xi is the groundwater table on day i, where i is the first day and n is the number of days during plant growth. Model Drainmod calculate the value of SEW-30 cm per hour, rather than calculate the daily value, therefore the calculation of the value of SEW-30 is more accurate and defined by the following equation:

$$SEW - 40 = \sum_{j=1}^{m}(40 - x_j)/24 \tag{2}$$

where xj is the ground water level by the end of each hour and m is the total hours during the period of plant growth.

The position of the water table to the critical limit of 30 cm is done with consideration of the figure of 30 cm below the soil surface taken as not most crops will suffer physiological disorders when the ground water level drops at a point 30 cm or otherwise increase from the figure of 30 cm of the soil surface. This means that when the ground water getting away from the boundary figure of 30 cm or closer to the ground, there will be excess water (excess water).

## 4. Results and discussions

### *4.1. Existing condition of water system network*

Figure 1 shows the arrangement of the network system in the research area. Secondary channel (2) also serves to open access roads, because this channel is parallel to the road. Perpendicular to the secondary channel in the wake of the tertiary channels, these channels have a surface width dimension of 2.5-3.0 m, on bottom width of 1.5-2.0 m. This channel is only connected next to the secondary channel, while the other part (closed end). Tertiary channel length is approximately 1000 m (Figure 1).



**Figure 1.** The network system of water management in peat land areas. (1) Secondary channel; (2) tertiary channel; and (3) main road.

Oil palm cultivation especially for large plantation in peatlands is mainly restricted by intensive inundation (poor drainage). Oil palm requires ground water level of 60-70 cm below the soil surface. Thus, land reclamation efforts were carried out by making primary channels, secondary and tertiary channels to remove excess water. The research area is classified as peatlands with average peat depth of 5 m. Oil palm has been cultivated by establishing an open channel water system (open channel) for the initial phase, and then developed with a closed folder system where there is an effort to make water retention (water containment).

Water level setting in the secondary canals is done by making containment dikes and to flow water in the pipe connecting with three pieces. The pipe has a diameter of 30 cm. This method aims for the water distribution system in the tertiary channel for each secondary plot. Each tertiary channel has a height difference of water surface. Thus, the water in the drainage channel has the potential gravity. If the water in the plot is full, it will overflow drain next to the next plots, so that all plots are expected to obtain the same water. Water distribution system refers to the principle of connecting vessel (Figure 2). Pipe was buried embankment near the surface (10 cm below the soil surface), it is intended to make the water in the channel to remain the lowest in the 10-20 cm from the canal banks. Swath end is usually connected with the main drain, i.e., the area or river swamp in nature (Figure 3). The water system is using the concept of excess water disposal, where the door at the main drainage valve was installed at a height above the bottom line, be in a depth of 1 m above the bottom line. Therefore, the water disposal will run when the water level in the main channel of the numbers exceed 1 m. Furthermore, when the rains come where overflow water from the river or swamp the outside of the area will go to the land, the valve door closes automatically by the encouragement of water. This condition causes the water from the outside cannot enter the land.


(a)


(b)

**Figure 2.** A water-retaining embankment in the secondary channels; in downstream (a) and in the upstream (b) [12].


(a)


(b)

**Figure 3.** The main drainage systems including valve door; (a) the inside; (b) the outer lead toward to free waters or disposed region (swamp).

*4.2. Water status evaluation*

Periods of wet months were commonly found in months of December, January, February, and March. In the four months the oil palm is be able to adapt to the wet conditions and so far, oil palm has a high tolerance to saturated soil conditions. The oil palm can tolerate fairly high on inundation if the oil palm entered its second year. On the inundation condition during four months, the oil palm can still survive. Thus, the company efforts were to implement a retention system (canal blocking), which were true to support government policy and to restore the peatlands. The initial step of the peat land ecosystem restoration is through rewetting. Channel blocking is one of the efforts to raise the groundwater level and can reduce the rate of peat subsidence.

Water loss in the peatlands is still high despite the condition of the rainy season. Data of groundwater table in January 2017 on cultivated peatlands and without the water level control indicates that the average groundwater stands at 45-58 cm below the soil surface. This showed that the danger of the land clearing by building canals and without being followed by water control (door operation). Even in the wet season conditions, the water level in the research area was approaching the critical zone (under 40 cm). But instead on the oil palm land where to control the operation of tertiary entrance is retention, the water level in the channel can be increased and the impact on groundwater levels in the area are in the safe zone, which is located at a depth of 15-30 cm below the soil surface (Figure 4). The period of water table level below 40 cm is from mid-October to Mid June. Under full retention system in the field at wet condition when the annual rainfall is above 4000 mm, ther there will be a water surplus period of 8-9 month.

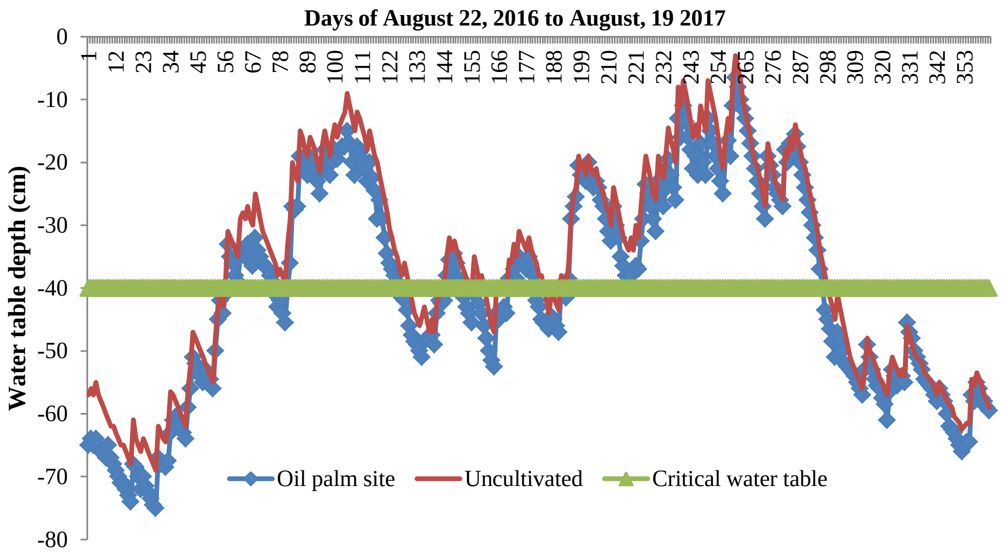
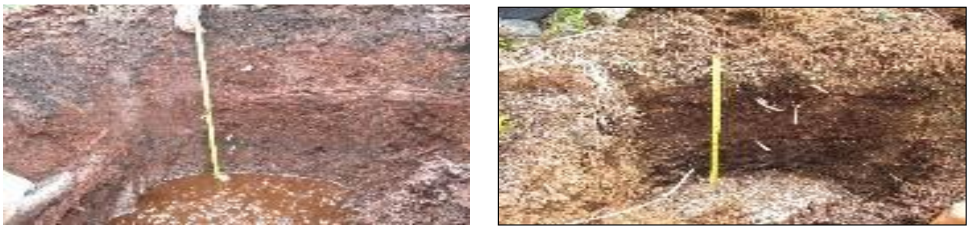



**Figure 4.** Dynamics of the ground water level at 2016-2017 period.

Looking at the critical value of fire hazard in the zone of 60 cm, then in January or during the rainy season the research area is relatively safe from fire hazards. Beside that the land is also very suitable for planting oil palm and food crops.

The water availability in the root zone of plants or critical zone of ground fire in swamp area is highly dependent on the water volume moving in the capillaries. Capillary water movement is strongly influenced by the position of the groundwater depth, texture, and soil hydraulic conductivity values. On soils with clay or clayey texture, the depth of ground water 1.5 m can meet the needs of the plant evapotranspiration, but the sand or sandy texture, soil maximum water depth of only 0.5-1 m. Our research areas are peatlands, thus determination of soil texture is very difficult to do because of the high soil organic matter that would interfere with the determination of soil texture, which is likely to do is, to determine the soil water dynamics by maturity peat. Figure 5 shows the soil profile on peat soil-hemic sapric where groundwater at a depth of 40-50 cm is able to create conditions in the root zone moist conditions and moisture content of field capacity, so the land is relatively safe against fires.



(a) Soil profile under oil palm

(b) Soil profile in uncultivated peatlands (bush)

**Figure 5.** Condition of peat soil profile at a depth of 40-50 cm soil water condition.

The depth of the ground water greatly affected the value of water capillary and soil moisture status. Computer calculations up flow models for soil hydraulic conductivity value of 8 m day$^{-1}$ water show capillary 5 mm day$^{-1}$ are at a fixed value ranging in groundwater found at a depth of -120 cm to -60 cm. This means the plant has not requiring irrigation for the purposes of evapotranspiration 5 mm day$^{-1}$ until the position of ground water in the depths of -120 cm of the soil surface. Avoiding the danger of fires, the ground water should be at the level of 40-50 cm below the soil surface. The water content in these conditions is above the field capacity and is close to saturation. Water saturated condition is usually achieved when the depth of the groundwater was 30-20 cm below the ground surface. This condition is caused by the movement of water capillary in the peats, which is relatively small compared to the mineral soil even with the sandy soils.

*4.3. Water management objecitves in field level*

Control of water levels in cultivated peatlands should be integrated also with land utilization plans. Experience in European countries [8] showed land used for grazing cattle. In the dry season the water of detention, so that the ground water is maintained not fall below 40 cm, and the wet season, the floodgates were opened and the water level can be controlled below 10 cm below the soil surface. However, in some areas, in trying to conservation, then the area of stagnant water left. This condition should be adopted in the exploitation of peatlands. Often companies (both acacia timber and oil palm) to maximize all land cleared and planted with oil palm or acacia. They must allocate for the conservation of at least 20%. The areas that should be conserved are peatlands. The areas will also be balancing the ecosystem and to replenish the groundwater in the dry season.

1 2 3

**Figure 6.** The multi-store block technique (photos 1 and 2: [12]); (3) the secondary channel blocking in an oil palm plantation and control overflow.

Local wisdom in managing water in the peatlands is also an important think to be applied. In West and South Kalimantan, farmers control water level with multi-store block technique, meaning that farmers have done water conservation efforts. Multi-store block technique was done along the tertiary channels. Figure 6 shows multi-store block technique in tertiary canal level. With this technique, the ground water level in the plot of land can be maintained (not easy to drop), so that the soil moisture content is safe from fire hazards. This system inspired canal blocking technique in the research area with the upper dam system is equipped with a discharge pipe or overflow.

In the field operations, a montly operation schedule is required. Table 4 shows the montly canal blocking operations based on climatic condition. The experience of cases in South Sumatra in 2015 and 2019, the annual rainfall is in the range of 4000 mm, and this condition has resulted in severe fires. Meanwhile in 2016 and 2020 whre the rainfall was above 4500 mm, there were no land fires. Therefore based on differences in rainfall conditions, a canal blocking operation model can be prepared in the field (Table 1).

**Comment [U1]:** There is not found The Table 4 in this manuscript. Please correct it.

**Table 1.** Montly operation model in the field for blocking canal

| Blocking canal operation | Operation period | |
|---|---|---|
| | Rainfall <4000 mm $year^{-1}$ | Rainfall >4000 mm $year^{-1}$ |
| Over flow 10 cm | January-March | January-May |
| Permanently closed | April-December | June-December |

## 5. Conclusions

Based on results and discussion of research data, thus it can be taken some conclusions as follows:

8) The drainage system is open system with the primary channel (4 m wide and 2 m deep), perpendicular to the primary channel is secondary channels (2 m wide and 2 m deep) and distance between the secondary channels is 250 m. The channel dimensions are too wide and deep, so that when there is no water retention, excess discharge will occur in the dry season
9) Water control with a multi-store block system shows the evident influence in increasing water level in the land plots. Detention in the dry season can raise the water level at a safe level (40-50 cm). In the uncultivated land there is no water, thus water level down to the level of 70-80 cm. Water control in the rainy season is able to raise the water level at the level of 20-30 cm, while without the water control the water level down to the level of 40-50 cm. For the safety, the water detention policy since the rainy season is the right step to keep track so that the water is at a safe zone.
10) Excess water analysis in zones 30 cm and 40 cm at a time of water retention in the channel, show that in the period from August to September groundwater conditions at the level below normal (-), but due to the movement of water capillarity then when the ground water at depths up to the limit 50-60 cm, they can create soil conditions valleys on the surface, making it safe against fire.
11) The availability of surface water reserves in the oil palm plantation is also very dependent on the conservation of forest area, however forest area was already burnt, so it must be done immediately peat forest restoration around the plantation area
12) The model of peat management should integrate ecological and economic objective, rewetting efforts must be followed by food crops, which can increase the income of farmers. Intercropping patterns with pineapple, watermelon and others will help create environmental conditions remain moist area, and free land of fires.

## 6. Acknowledgments

This article belongs to a part of our research project activities funded through *higher research competiotion of lecture profession* in Sriwijaya University with the research contract of No. 1023/UN9.3.1/LPPM/2016 dated July 18, 2016. The authors would like to say thank you to the staffs of the Faculty of Agriculture, Sriwijaya University and local people who have helped in the conduct of research in the field.

## 7. References


[1] Sjarkowi F, Arbain A, Armanto M E, Santoso U, Arjuna J, Rifardi, Setiawan A, Syahrul J, Khairijon and Azizah 2007 *Kualitas lingkungan hidup Sumatera 2007* PPLH Regional Sumatera, Kementerian Lingkungan Hidup RI, Pekanbaru, Riau ISBN 978-602-8107-00-6 p 393

[2] Wildayana E 2014 *Journal of Wetlands Environmental Managements* **2(2)** 30-6

[3] Imanudin M S, Armanto M E, Susanto R H and Bernas S M 2010 *Journal of Tropical Soils* **15(3)** 277-82

[4] Imanudin M S, Bakri and Karimuddin Y 2017 *Paper Presented at Seminar of Suboptimal Land PUR-PLSO, Sriwijaya University 19-20 October 2017*

[5] Armanto M E, Imanudin M S, Wildayana E, Junedi H and Zuhdi M 2016 *Sriwijaya Journal of Environment* **1(3)** 58-63

[6] Liu Q, Yasufuku N, Miao J and Ren J 2014 *Soils and Foundations* **54(6)** 1241-45

[7] Sutikno S, Rinaldi1 R, Saputra E, Kusairi M, Saharjo B H and Putra E I 2020 *The 2nd Aceh International Symposium on Civil Engineering (AISCE) IOP Conf. Series: Materials Science and Engineering 933*

[8] Ritzema H, Kirkpatrick H, Stibinger J, Heinhuis H, Belting H, Schrijver R and Diemont H 2016 *Sustainability* **8(5)** 440-50

[9] Carr M K V 2011 *Expl. Agric.* **47(4)** 629-52

[10] Hooijer A, Page S, Canadell J G, Silvius M, Kwadijk J, Wosten H and Jauhiainen J 2010 *Biogeoscience* **7** 1505-14

[11] Imanudin M S, Satria J P, Said M and Rahmat R 2019 *Sriwijaya Journal of Environment* **4(2)** 52-8

[12] Imanudin M S, Elisa W and Armanto M E 2018 *Journal of Wetlands Environmental Management* **6(1)** 12 – 26

## Penyerahan Makalah Perbaikan

**28 Maret 2021**

# Developing Water Management Objective on Tropical Peatlands under Oil Palm Cultivation

**Momon Sodik Imanudin[1], M Edi Armanto[1], Elisa Wildayana[1], Bakri[1], and Heri Junedi[2]**

[1]Faculty of Agriculture, Sriwijaya University, Indonesia.
[2]Faculty of Agriculture Jambi University, Indonesia.

E-mail: momonsodikimanudin@fp.unsri.ac.id

**Abstract**. Less attention to peatlands for various economic development activities have led to the emergence of serious environmental problems. The problems are floods in the rainy season, fires in the dry season and increased carbon emissions. This paper aimed to examine physical and hydrological characteristics to develop land management plans. The research was conducted on peatlands used for oil palm plantations. The study concluded that the available drainage system generally indicates excess discharge (over drainage). Water retention efforts proved effective in secondary channels and are able to raise the water level of 20-30 cm higher than the uncultivated peatlands (no water retention). Fluctuations in groundwater levels in the period from August to September on the cultivated peatlands showed that the groundwater is deeper than the uncultivated peatlands. It determined greater value of evapotranspiration of oil palm plantation. If the floodgates do not exist, then the groundwater becomes deeper than the cultivated peatlands. In the January-February period of the groundwater in the cultivated peatlands can be increased to 20-30 cm under the soil surface, but on the uncultivated peatlands without controlling the water level drops at the position 40-50 cm below the soil surface. Thus the concept of water retention became the main purpose for water management in peatlands.

### 3. Introduction

Approximately 20 million ha of peatlands, which is equivalent to half of the tropical peatlands in the world, are in Indonesia [1]. Therefore, Indonesia has an important value and strategic views of biodiversity and ecological functions. Peatland is generally located between two rivers; thus, it hydrologically formed a unique island-shaped "dome". Depth variability of peats greatly affect the carrying capacity of peats to store water, vegetation, and management policies. On the other hand, land clearing for oil palm plantations and industrial plants are still ongoing [2].

In the long dry conditions (more than three months) in the absence of added water containment efforts then drying peat is becoming increasingly widespread, even to areas that have not been opened. It is therefore important to do a field study to find peatland management options for the creation of conditions of the ground water level that meet the needs for plant growth and prevent forest fires. Approach to land capability should be involved in the preparation of management plans on peatlands [3]. During this time, many companies only see from the ground surface; the depth of peat is the key factor often overlooked. Often found in the cultivation of plants is done on the peat depth more than 3.0 m deep or even more [4]. The business world should count carefully because cultivation in peatlands is  costly. To increase one-two units of pH values required 10-30 tons of dolomite [5].

Cultivating wetlands and peatlands for oil palm plantation and acacia industrial plantation (HTI) in South Sumatra has been started since 1990, which have brought serious impacts to environmental issues such as among others degradation of peat quality, decreasing water level, increasing decomposition rate of peat leading to carbon emissions, peat subsidence, changing of peat characteristics, losing ability to store water, hydrology, land and forest fires [6]. Several efforts should be done to increase ground water table. Installing the canal blocking  has significant effect to increase water table [7].

Water management in peatlands are unique compared to that of mineral soils, since the peatlands have high ability to absorb a lot of water (hydrophilic), and if peatlands are over drained their ability to absorb water will dramatically decrease (hydrophobic). The condition occurs because the peats occur irreversible drying process (irreversible drying), especially if peats experience very long (extreme drying condition. Therefore peat land drainage process is not simply boast drain the excess water or land, but how to create the conditions so that the water level could support evapotranspiration needs of plants, and water movement of capillarity humidity can still maintain that peat soil surface soil from drying out [8]. Therefore, the process of peat land drainage is not only to throw excessive water or drain the land, but how to create the conditions where the water level in order to support the needs of crop evapotranspiration, and the movement of capillary water can still maintain soil moisture on the soil surface, so that peats are not experiencing totally dry [9].

Water regulation in peatlands has also to consider the impact on the rate of decomposition of peat. There is a linear relationship between the depth of the ground water level in the channel and the water level in the plot of land. Decreased water level will be followed by an increase in carbon emissions. There is a very strong correlation with less value of regression ($R^2 = 0.71$), which is expressed in $CO_2$ emissions = 0.91 x depth of groundwater [10].

The depth of drainage for the ideal oil palm is between 50-70 cm and rubber plants ranging from 20-40 cm, while the sago palm plants do not require drainage but still require water circulation as well as rice. In general criteria for good water acacia management (HTI) in peat land among which the depth of soil water at planting about 20 cm, and after the age of 1 year was lowered to 30 cm, for further lowered by 10 cm for each year of the aging of the plant. Finally, at the age of 6-8 years of ground water depth was maintained at approximately 80 cm below the soil surface. According to [11] land use for agroforestry systems allows groundwater to be maintained at a depth of 40 cm. Because it aims to meet the needs water requirement. This paper aimed to examine physical and hydrological characteristics to develop land management plans.

.

## 4. Materials and Methods

The study was conducted in peatlands cultivated with oil palm and some areas not been planted. The research was conducted in the beginning of August to December 2016.  Tools and materials used included peat driller, ring samples, measuring instruments of soil conductivity (permeameter) and the well to measure groundwater levels. The research work was divided into field and laboratory works. Filed activities were to perform network of water system, land use, measuring peat depths, making the soil profiles, and monitoring of water levels and daily rainfall.

The excess water was calculated in the root zone of 30-50 cm. Rated value of 30 cm was determined as the minimum condition of the ground water level, which was received by the crops not to experience water stress in wet condition, while the excess water of more 50 cm in the rooting zone is the tolerable limit for oil palm.

Water status on each plot of farmers can vary due to differences in humidity and depth of the groundwater levels. The excess amount of water (excess surplus water) at a depth of less than a certain depth SEW-30, for example, gives a measure of the condition of excessive soil moisture deficiency during infancy, which can inhibit plant growth. These conditions indicated when water falls below 30 cm soil, plants will suffer from water stress.

Calculating the excess water in the root zone of 40 cm can be used for the majority of non-rice crops, and also meets the regulatory criteria by the government, which states that utilizing peatlands has to maintain the water level at a depth of 40 cm below the soil surface. An excess amount of water in the upper 40 cm can be calculated to predict excessive soil moisture for crop growth period. The formula is as follows:

$$SEW-40=\sum_{i=1}^{n}(40-x_i) \qquad [1]$$

where xi is the groundwater table on day i, where i is the first day and n is the number of days during plant growth. Model Drainmod calculate the value of SEW-30 cm per hour, rather than calculate the daily value, therefore the calculation of the value of SEW-30 is more accurate and defined by the following equation:

$$SEW-40=\sum_{j=1}^{m}(40-x_j)/24 \qquad [2]$$

where xj is the ground water level by the end of each hour and m is the total hours during the period of plant growth.

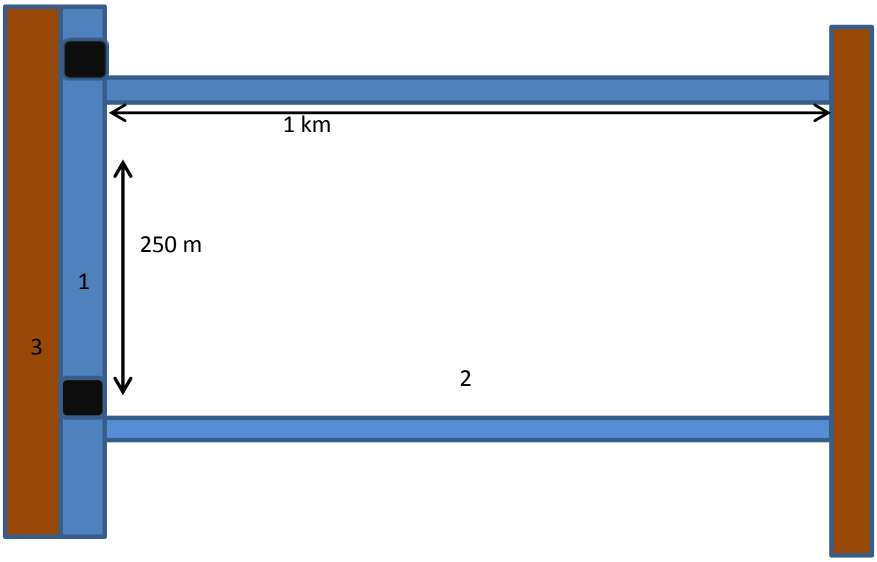
The position of the water table to the critical limit of 30 cm is done with consideration of the figure of 30 cm below the soil surface taken as not most crops will suffer physiological disorders when the ground water level drops at a point 30 cm or otherwise increase from the figure of 30 cm of the soil surface. This means that when the ground water getting away from the boundary figure of 30 cm or closer to the ground, there will be excess water (excess water).

## 8. Results and Discussions

### 8.1. Existing Condition of Water System Network

Figure 1 shows the arrangement of the network system in the research area. Secondary channel (2) also serves to open access roads, because this channel is parallel to the road. Perpendicular to the secondary channel in the wake of the tertiary channels, these channels have a surface width dimension of 2.5-3.0 m, on bottom width of 1.5-2.0 m. This channel is only connected next to the secondary channel, while the other part (closed end). Tertiary channel length is approximately 1000 m (Figure 1).

Oil palm cultivation especially for large plantation in peatlands is mainly restricted by intensive inundation (poor drainage). Oil palm requires ground water level of 60-70 cm below the soil surface. Thus, land reclamation efforts were carried out by making primary channels, secondary and tertiary channels to remove excess water. The research area is classified as peatlands with average peat depth of 5 m. Oil palm has been cultivated by establishing an open channel water system (open channel) for the initial phase, and then developed with a closed folder system where there is an effort to make water retention (water containment).




Note : (1) Secondary channel; (2) tertiary channel; and (3) main road

Figure 1. The network system of water management in peat land areas

Water level setting in the secondary canals is done by making containment dikes and to flow water in the pipe connecting with three pieces. The pipe has a diameter of 30 cm. This method aims for the water distribution system in the tertiary channel for each secondary plot. Each tertiary channel has a height difference of water surface. Thus, the water in the drainage channel has the potential gravity. If the water in the plot is full, it will overflow drain next to the next plots, so that all plots are expected to obtain the same water. Water distribution system refers to the principle of connecting vessel (Figure 2).

(a)

(b)

gure 2. A water-retaining embankment in the secondary channels; in downstream (a) and in the upstream (b) [13]

(a)

(b)

Figure 3. The main drainage systems including valve door; (a) the inside; (b) the outer lead toward to free waters or disposed region (swamp)

Pipe was buried embankment near the surface (10 cm below the soil surface), it is intended to make the water in the channel to remain the lowest in the 10-20 cm from the canal banks. Swath end is usually connected with the main drain, i.e., the area or river swamp in nature (Figure 3). The water system is using the concept of excess water disposal, where the door at the main drainage valve was installed at a height above the bottom line, be in a depth of 1 m above the bottom line. Therefore, the water disposal will run when the water level in the main channel of the numbers exceed 1 m. Furthermore, when the rains come where overflow water from the river or swamp the outside of the area will go to the land, the valve door closes automatically by the encouragement of water. This condition causes the water from the outside cannot enter the land.

### 8.2. Water status evaluation

Periods of wet months were commonly found in months of December, January, February, and March. In the four months the oil palm is be able to adapt to the wet conditions and so far, oil palm has a high tolerance to saturated soil conditions. The oil palm can tolerate fairly high on inundation if the oil palm entered its second year. On the inundation condition during four months, the oil palm can still survive. Thus, the company efforts were to implement a retention system (canal blocking), which were true to support government policy and to restore the peatlands. The initial step of the peat land ecosystem restoration is through rewetting. Channel blocking is one of the efforts to raise the groundwater level and can reduce the rate of peat subsidence.

Water loss in the peatlands is still high despite the condition of the rainy season. Data of groundwater table in January 2017 on cultivated peatlands and without the water level control indicates that the average groundwater stands at 45-58 cm below the soil surface. This showed that the danger of the land clearing by building canals and without being followed by water control (door operation). Even in the wet season conditions, the water level in the research area was approaching the critical zone (under 40 cm). But instead on the oil palm land where to control the operation of tertiary entrance is retention, the water level in the channel can be increased and the impact on groundwater levels in the area are in the safe zone, which is located at a depth of 15-30 cm below the soil surface (Figure 4). The period of water table level below 40 cm is from mid-October to Mid June. Under full retention system in the field at wet condition when the annual rainfall is above 4000 mm, ther there will be a water surplus period of 8-9 month.

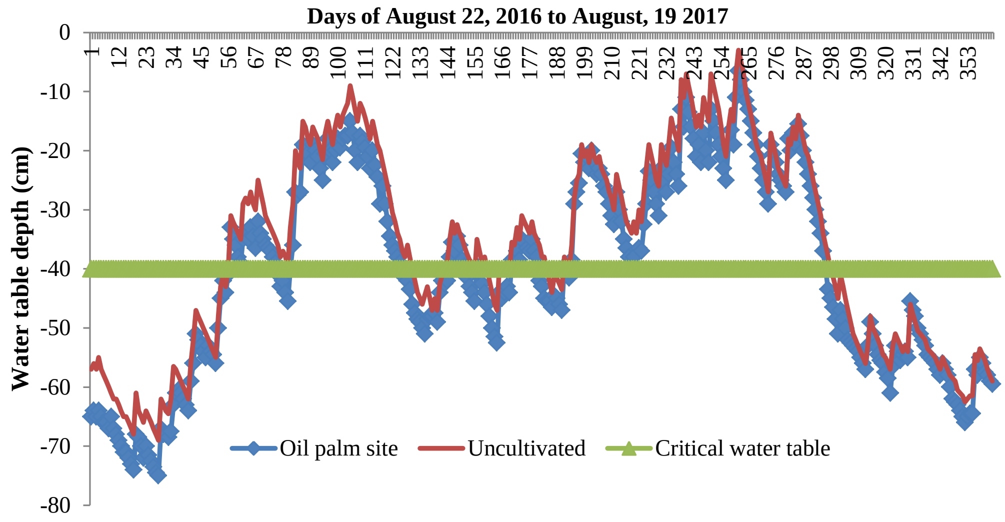



Figure 4. Dynamics of the ground water level at 2016-2017 period.

Looking at the critical value of fire hazard in the zone of 60 cm, then in January or during the rainy season the research area is relatively safe from fire hazards. Beside that the land is also very suitable for planting oil palm and food crops.

The water availability in the root zone of plants or critical zone of ground fire in swamp area is highly dependent on the water volume moving in the capillaries. Capillary water movement is strongly influenced by the position of the groundwater depth, texture, and soil hydraulic conductivity values. On soils with clay or clayey texture, the depth of ground water 1.5 m can meet the needs of the plant evapotranspiration, but the sand or sandy texture, soil maximum water depth of only 0.5-1 m. Our research areas are peatlands, thus determination of soil texture is very difficult to do because of the high soil organic matter that would interfere with the determination of soil texture, which is likely to do is, to determine the soil water dynamics by maturity peat. Figure 5 shows the soil profile on peat soil-hemic sapric where groundwater at a depth of 40-50 cm is able to create conditions in the root zone moist conditions and moisture content of field capacity, so the land is relatively safe against fires.

(a)

Soil profile under oil palm

(b)

Soil profile in uncultivated peatlands (bush)

Figure 5. Condition of peat soil profile at a depth of 40-50 cm soil water condition.

The depth of the ground water greatly affected the value of water capillary and soil moisture status. Computer calculations up flow models for soil hydraulic conductivity value of 8 m/day water show capillary 5 mm day$^{-1}$ are at a fixed value ranging in groundwater found at a depth of -120 cm to -60 cm. This means the plant has not requiring irrigation for the purposes of evapotranspiration 5 mm day$^{-1}$ until the position of ground water in the depths of -120 cm of the soil surface. Avoiding the danger of fires, the ground water should be at the level of 40-50 cm below the soil surface. The water content in these conditions is above the field capacity and is close to saturation. Water saturated condition is usually achieved when the depth of the groundwater was 30-20 cm below the ground surface. This condition is caused by the movement of water capillary in the peats, which is relatively small compared to the mineral soil even with the sandy soils.

### 3.6. Water Management Objecitves in field level

Control of water levels in cultivated peatlands should be integrated also with land utilization plans. Experience in European countries [12] showed land used for grazing cattle. In the dry season the water of detention, so that the ground water is maintained not fall below 40 cm, and the wet season, the floodgates were opened and the water level can be controlled below 10 cm below the soil surface. However, in some areas, in trying to conservation, then the area of stagnant water left. This condition should be adopted in the exploitation of peatlands. Often companies (both acacia timber and oil palm) to maximize all land cleared and planted with oil palm or acacia. They must allocate for the conservation of at least 20%. The areas that should be conserved are peatlands. The areas will also be balancing the ecosystem and to replenish the groundwater in the dry season.

Local wisdom in managing water in the peatlands is also an important think to be applied. In West and South Kalimantan, farmers control water level with multi-store block technique, meaning that farmers have done water conservation efforts. Multi-store block technique was done along the tertiary channels. Figure 6 shows multi-store block technique in tertiary canal level. With this technique, the ground water level in the plot of land can be maintained (not easy to drop), so that the soil moisture content is safe from fire hazards. This system inspired canal blocking technique in the research area with the upper dam system is equipped with a discharge pipe or overflow.

Source [13]

1 2 3

Figure 6. The multi-store block technique (photos 1 and 2: [13]); (3) the secondary channel blocking in an oil palm plantation and control overflow

In the field operations, a montly operation schedule is required. Table 4 shows the montly canal blocking operations based on climatic condition. The experience of cases in South Sumatra in 2015 and 2019, the annual rainfall is in the range of 4000 mm, and this condition has resulted in severe fires. Meanwhile in 2016 and 2020 whre the rainfall was above 4500 mm, there were no land fires. Therefore based on differences in rainfall conditions, a canal blocking operation model can be prepared in the field (Table 1).

Table 1. Montly operation model in the field for blocking canal

| Blocking canal operation | Operation period | |
|---|---|---|
| | rainfall <4000 mm/year | rainfall >4000 mm/year |
| Over flow 10 cm | January-March | January-May |
| Permanently closed | April-December | June-December |

## 4. **Conclusions**

Based on results and discussion of research data, thus it can be taken some conclusions as follows:

13) The drainage system is open system with the primary channel (4 m wide and 2 m deep), perpendicular to the primary channel is secondary channels (2 m wide and 2 m deep) and distance between the secondary channels is 250 m. The channel dimensions are too wide and deep, so that when there is no water retention, excess discharge will occur in the dry season
14) Water control with a multi-store block system shows the evident influence in increasing water level in the land plots. Detention in the dry season can raise the water level at a safe level (40-50 cm). In the uncultivated land there is no water, thus water level down to the level of 70-80 cm. Water control in the rainy season is able to raise the water level at the level of 20-30 cm, while without the water control the water level down to the level of 40-50 cm. For the safety, the water detention policy since the rainy season is the right step to keep track so that the water is at a safe zone.
15) Excess water analysis in zones 30 cm and 40 cm at a time of water retention in the channel, show that in the period from August to September groundwater conditions at the level below normal (-), but due to the movement of water capillarity then when the ground water at depths up to the limit 50-60 cm, they can create soil conditions valleys on the surface, making it safe against fire.
16) The availability of surface water reserves in the oil palm plantation is also very dependent on the conservation of forest area, however forest area was already burnt, so it must be done immediately peat forest restoration around the plantation area
17) The model of peat management should integrate ecological and economic objective, rewetting efforts must be followed by food crops, which can increase the income of farmers. Intercropping patterns with pineapple, watermelon and others will help create environmental conditions remain moist area, and free land of fires.

## Acknowledgments

This article belongs to a part of our research project activities funded through *higher research competiotion of lecture profession* in Sriwijaya University with the research contract of No. 1023/UN9.3.1/LPPM/2016 dated July 18, 2016. The authors would like to say thank you to the staffs of the Faculty of Agriculture, Sriwijaya University and local people who have helped in the conduct of research in the field.

## References

[1] Sjarkowi, F., A. Arbain, M.E. Armanto, U. Santoso, J. Arjuna, Rifardi, A. Setiawan, J. Syahrul, Khairijon dan Azizah. 2007. Kualitas Lingkungan Hidup Sumatera 2007. PPLH Regional Sumatera, Kementerian Lingkungan Hidup RI, Pekanbaru, Riau, ISBN. 978-602-8107-00-6. 393 hal.

[2] Wildayana, E. 2014. Formulating Oil Palm Investment Decision in Tidal Wetlands of South Sumatra, Indonesia. Journal of Wetlands Environmental Managements. **2(2)**; 30-36, October 2014, Indexed in DOAJ. Web-link: http://ijwem.unlam.ac.id/index.php/ijwem

[3] Imanudin, M.S., M.E. Armanto, R.H. Susanto and S.M. Bernas. 2010. Water Table Fluctuation in Tidal Lowland for Developing Agricultural Water Management Strategies. Journal of Tropical Soils. **15(3)**: 277-282. Web-link: http://journal.unila.ac.id/index.php/tropicalsoil DOI: 10.5400/jts.2010.15.3.277

[4] Imanudin, M.S., Bakri and Karimuddin Y., 2017. Rainfall Harvesting Maximalization for Clean Water Supply at Rice Cultivation in First Planting Season (November-February) at Tidal

Lowland of B/C Typhology, Sugihan Kanan Area. Paper Presented at Seminar of Suboptimal Land PUR-PLSO, Sriwijaya University. 19-20 October 2017

[5] Armanto, M.E., M.S. Imanudin, E. Wildayana, H. Junedi and M. Zuhdi. 2016. Managing Actual Problems of Peatsoils Associated with Soil Acidity. Sriwijaya Journal of Environment, **1(3)**; 58-63, December 2016. http://dx.doi.org/10.22135/sje.2016.1.3.53-58

[6] Liu, Q., N. Yasufuku, J. Miao, and J. Ren. 2014. An Approach for Quick Estimation of Maximum Height of Capillary Rise. Soils and Foundations. **54**(6); 1241-1245.

[7] Sutikno, S.. R Rinaldi1 , E Saputra., M Kusairi., B H Saharjo., E I Putra. 2020. Water management for hydrological restoration and fire prevention in tropical peatland. The 2nd Aceh International Symposium on Civil Engineering (AISCE)IOP Conf. Series: Materials Science and Engineering 933 (2020) 012053doi:10.1088/1757-899X/933/1/012053

[8] Ritzema, H., H. Kirkpatrick, J. Stibinger, H. Heinhuis, H. Belting, R. Schrijver, and H. Diemont. 2016. Water Management Supporting the Delivery of Ecosystem Services for Grassland, Heath and Moorland. Sustainability, **8(5)**, 440-450. Doi:10.3390/su8050440

[9] Carr, M.K.V. 2011. The Water Relations and Irigation Requirement of Oil Palm (Elaeis Guineensis L.): A Review Expl Agric. **47**(4); 629-652. Doi:10.1017/S0014479711000494

[10] Hooijer, A., S. Page, J.G. Canadell, M. Silvius, J. Kwadijk, H. Wosten, and J. Jauhiainen. 2010. Current and Future CO2 Emissions from Drained Peatlands in Southeast Asia. Biogeoscience. **7**:1505-1514.

[11] Imanudin, M.S., Satria, J.P., M.Said, and Rahmat, R. 2019. Land And Water Management In Pineapple And Albizia Chinensis Agroforestry Systems In Peatland. Sriwijaya Journal of Environment**. 4(2)**: 52-58 http://dx.doi.org/10.22135/sje.2019.4.2.52-58

[12] Ritzema, H., H. Kirkpatrick, J. Stibinger, H. Heinhuis, H. Belting, R. Schrijver, and H. Diemont. 2016. Water Management Supporting the Delivery of Ecosystem Services for Grassland, Heath and Moorland. Sustainability, **8(5)**, 440-450. Doi:10.3390/su8050440

[13] Imanudin, M.S., Elisa, W., M. Edi. A., 2018. Option for land and water management to prevent fire in peat land areas of sumatera indonesia. Journal of Wetlands Environmental Management Vol 6, No 1 (2018) 12 – 26

# PUBLIKASI ONLINE

Published online: 12 May 2021

Developing water management ⨯

iopscience.iop.org/article/10.1088/1755-1315/758/1/012002/meta

IOPscience | Journals | Books | Publishing Support | Login

IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

## Developing water management objective on tropical peatlands under oil palm cultivation

M S Imanudin[1], M E Armanto[1], E Wildayana[1], Bakri[1] and H Junedi[2]



IOP Conference Series: Earth and Environmental Science, Volume 758, The Sixth International Symposium on Wetlands Environmental Management 30th November - 1st December 2020, Banjarmasin, South Kalimantan, Indonesia

**Citation** M S Imanudin *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **758** 012002

**DOI** 10.1088/1755-1315/758/1/012002

Article PDF

# LAMPIRAN MAKALAH

IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

# Developing water management objective on tropical peatlands under oil palm cultivation

To cite this article: M S Imanudin *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **758** 012002



IOP Conf. Series: Earth and Environmental Science **758** (2021) 012002 doi:10.1088/1755-1315/758/1/012002

# Developing water management objective on tropical peatlands under oil palm cultivation

**M S Imanudin[1], M E Armanto[1], E Wildayana[1], Bakri[1] and H Junedi[2]**

[1] Faculty of Agriculture, Sriwijaya University, Indonesia.
[2] Faculty of Agriculture Jambi University, Indonesia.

E-mail: momonsodikimanudin@fp.unsri.ac.id

**Abstract**. Less attention to peatlands for various economic development activities have led to the emergence of serious environmental problems. The problems are floods in the rainy season, fires in the dry season and increased carbon emissions. This paper aimed to examine physical and hydrological characteristics to develop land management plans. The research was conducted on peatlands used for oil palm plantations. The study concluded that the available drainage system generally indicates excess discharge (over drainage). Water retention efforts proved effective in secondary channels and are able to raise the water level of 20-30 cm higher than the uncultivated peatlands (no water retention). Fluctuations in groundwater levels in the period from August to September on the cultivated peatlands showed that the groundwater is deeper than the uncultivated peatlands. It determined greater value of evapotranspiration of oil palm plantation. If the floodgates do not exist, then the groundwater becomes deeper than the cultivated peatlands. In the January-February period of the groundwater in the cultivated peatlands can be increased to 20-30 cm under the soil surface, but on the uncultivated peatlands without controlling the water level drops at the position 40-50 cm below the soil surface. Thus the concept of water retention became the main purpose for water management in peatlands.

## 1. Introduction

Approximately 20 million ha of peatlands, which is equivalent to half of the tropical peatlands in the world, are in Indonesia [1]. Therefore, Indonesia has an important value and strategic views of biodiversity and ecological functions. Peatland is generally located between two rivers; thus, it hydrologically formed a unique island-shaped "dome". Depth variability of peats greatly affect the carrying capacity of peats to store water, vegetation, and management policies. On the other hand, land clearing for oil palm plantations and industrial plants are still ongoing [2].

In the long dry conditions (more than three months) in the absence of added water containment efforts then drying peat is becoming increasingly widespread, even to areas that have not been opened. It is therefore important to do a field study to find peatland management options for the creation of conditions of the ground water level that meet the needs for plant growth and prevent forest fires. Approach to land capability should be involved in the preparation of management plans on peatlands [3]. During this time, many companies only see from the ground surface; the depth of peat is the key factor often overlooked. Often found in the cultivation of plants is done on the peat depth more than 3.0 m deep or even more [4]. The business world should count carefully because cultivation in peatlands is costly. To increase one-two units of pH values required 10-30 tons of dolomite [5].

Cultivating wetlands and peatlands for oil palm plantation and acacia industrial plantation (HTI) in South Sumatra has been started since 1990, which have brought serious impacts to environmental issues such as among others degradation of peat quality, decreasing water level, increasing decomposition rate of peat leading to carbon emissions, peat subsidence, changing of peat characteristics, losing ability to store water, hydrology, land and forest fires [6]. Several efforts should be done to increase ground water table. Installing the canal blocking has significant effect to increase water table [7].

Water management in peatlands are unique compared to that of mineral soils, since the peatlands have high ability to absorb a lot of water (hydrophilic), and if peatlands are over drained their ability to absorb water will dramatically decrease (hydrophobic). The condition occurs because the peats occur irreversible drying process (irreversible drying), especially if peats experience very long (extreme drying condition. Therefore peat land drainage process is not simply boast drain the excess water or land, but how to create the conditions so that the water level could support evapotranspiration needs of plants, and water movement of capillarity humidity can still maintain that peat soil surface soil from drying out [8]. Therefore, the process of peat land drainage is not only to throw excessive water or drain the land, but how to create the conditions where the water level in order to support the needs of crop evapotranspiration, and the movement of capillary water can still maintain soil moisture on the soil surface, so that peats are not experiencing totally dry [9].

Water regulation in peatlands has also to consider the impact on the rate of decomposition of peat. There is a linear relationship between the depth of the ground water level in the channel and the water level in the plot of land. Decreased water level will be followed by an increase in carbon emissions. There is a very strong correlation with less value of regression ($R^2$ = 0.71), which is expressed in $CO_2$ emissions = 0.91 x depth of groundwater [10].

The depth of drainage for the ideal oil palm is between 50-70 cm and rubber plants ranging from 20-40 cm, while the sago palm plants do not require drainage but still require water circulation as well as rice. In general criteria for good water acacia management (HTI) in peat land among which the depth of soil water at planting about 20 cm, and after the age of 1 year was lowered to 30 cm, for further lowered by 10 cm for each year of the aging of the plant. Finally, at the age of 6-8 years of ground water depth was maintained at approximately 80 cm below the soil surface. According to [11] land use for agroforestry systems allows groundwater to be maintained at a depth of 40 cm. Because it aims to meet the needs water requirement. This paper aimed to examine physical and hydrological characteristics to develop land management plans.

## 2. Materials and methods

The study was conducted in peatlands cultivated with oil palm and some areas not been planted. The research was conducted in the beginning of August to December 2016. Tools and materials used included peat driller, ring samples, measuring instruments of soil conductivity (permeameter) and the well to measure groundwater levels. The research work was divided into field and laboratory works. Filed activities were to perform network of water system, land use, measuring peat depths, making the soil profiles, and monitoring of water levels and daily rainfall.

The excess water was calculated in the root zone of 30-50 cm. Rated value of 30 cm was determined as the minimum condition of the ground water level, which was received by the crops not to experience water stress in wet condition, while the excess water of more 50 cm in the rooting zone is the tolerable limit for oil palm.

Water status on each plot of farmers can vary due to differences in humidity and depth of the groundwater levels. The excess amount of water (excess surplus water) at a depth of less than a certain depth SEW-30, for example, gives a measure of the condition of excessive soil moisture deficiency during infancy, which can inhibit plant growth. These conditions indicated when water falls below 30 cm soil, plants will suffer from water stress.

Calculating the excess water in the root zone of 40 cm can be used for the majority of non-rice crops, and also meets the regulatory criteria by the government, which states that utilizing peatlands has to maintain the water level at a depth of 40 cm below the soil surface. An excess amount of water in the upper 40 cm can be calculated to predict excessive soil moisture for crop growth period. The formula is as follows:

$$\text{SEW - 40} = \sum_{i=1}^{n} (40\text{-}x_i) \quad (1)$$

where xi is the groundwater table on day i, where i is the first day and n is the number of days during plant growth. Model Drainmod calculate the value of SEW-30 cm per hour, rather than calculate the daily value, therefore the calculation of the value of SEW-30 is more accurate and defined by the following equation:

$$\text{SEW - 40} = \sum_{j=1}^{m} (40\text{-}x_j)/24 \quad (2)$$

where xj is the ground water level by the end of each hour and m is the total hours during the period of plant growth.

The position of the water table to the critical limit of 30 cm is done with consideration of the figure of 30 cm below the soil surface taken as not most crops will suffer physiological disorders when the ground water level drops at a point 30 cm or otherwise increase from the figure of 30 cm of the soil surface. This means that when the ground water getting away from the boundary figure of 30 cm or closer to the ground, there will be excess water (excess water).

## 3. Results and discussions

### *3.1. Existing condition of water system network*

Figure 1 shows the arrangement of the network system in the research area. Secondary channel (2) also serves to open access roads, because this channel is parallel to the road. Perpendicular to the secondary channel in the wake of the tertiary channels, these channels have a surface width dimension of 2.5-3.0 m, on bottom width of 1.5-2.0 m. This channel is only connected next to the secondary channel, while the other part (closed end). Tertiary channel length is approximately 1000 m (Figure 1).

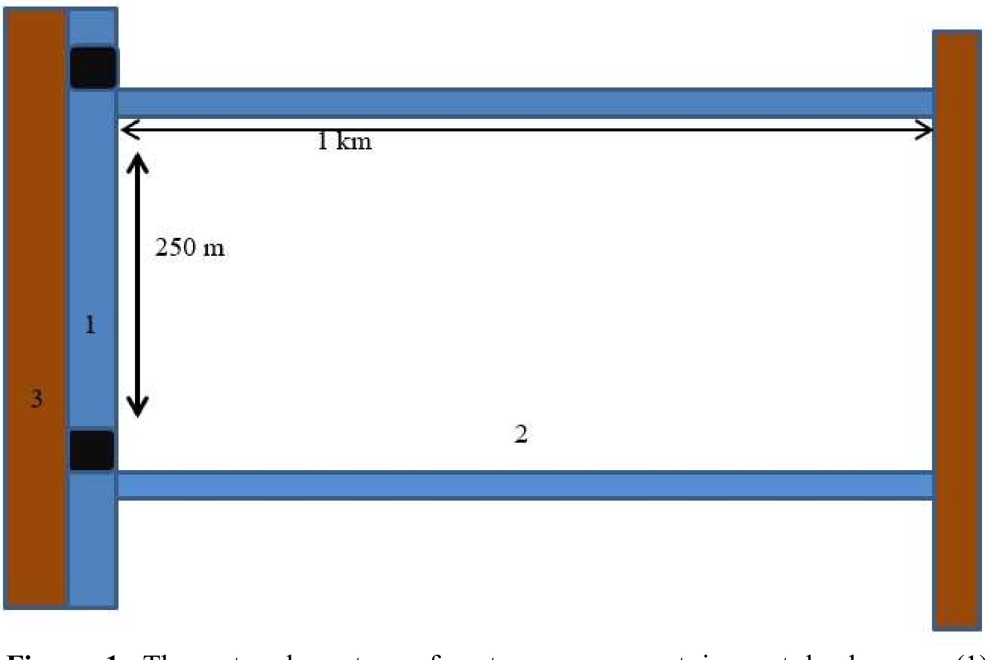



**Figure 1.** The network system of water management in peat land areas. (1) Secondary channel; (2) tertiary channel; and (3) main road.

Oil palm cultivation especially for large plantation in peatlands is mainly restricted by intensive inundation (poor drainage). Oil palm requires ground water level of 60-70 cm below the soil surface. Thus, land reclamation efforts were carried out by making primary channels, secondary and tertiary channels to remove excess water. The research area is classified as peatlands with average peat depth of 5 m. Oil palm has been cultivated by establishing an open channel water system (open channel) for the initial phase, and then developed with a closed folder system where there is an effort to make water retention (water containment).

Water level setting in the secondary canals is done by making containment dikes and to flow water in the pipe connecting with three pieces. The pipe has a diameter of 30 cm. This method aims for the water distribution system in the tertiary channel for each secondary plot. Each tertiary channel has a height difference of water surface. Thus, the water in the drainage channel has the potential gravity. If the water in the plot is full, it will overflow drain next to the next plots, so that all plots are expected to obtain the same water. Water distribution system refers to the principle of connecting vessel (Figure 2). Pipe was buried embankment near the surface (10 cm below the soil surface), it is intended to make the water in the channel to remain the lowest in the 10-20 cm from the canal banks. Swath end is usually connected with the main drain, i.e., the area or river swamp in nature (Figure 3). The water system is using the concept of excess water disposal, where the door at the main drainage valve was installed at a height above the bottom line, be in a depth of 1 m above the bottom line. Therefore, the water disposal will run when the water level in the main channel of the numbers exceed 1 m. Furthermore, when the rains come where overflow water from the river or swamp the outside of the area will go to the land, the valve door closes automatically by the encouragement of water. This condition causes the water from the outside cannot enter the land.


(a)


(b)

**Figure 2.** A water-retaining embankment in the secondary channels; in downstream (a) and in the upstream (b) [12].


(a)


(b)

**Figure 3.** The main drainage systems including valve door; (a) the inside; (b) the outer lead toward to free waters or disposed region (swamp).

### 3.2. *Water status evaluation*

Periods of wet months were commonly found in months of December, January, February, and March. In the four months the oil palm is be able to adapt to the wet conditions and so far, oil palm has a high tolerance to saturated soil conditions. The oil palm can tolerate fairly high on inundation if the oil palm entered its second year. On the inundation condition during four months, the oil palm can still survive. Thus, the company efforts were to implement a retention system (canal blocking), which were true to support government policy and to restore the peatlands. The initial step of the peat land ecosystem restoration is through rewetting. Channel blocking is one of the efforts to raise the groundwater level and can reduce the rate of peat subsidence.

Water loss in the peatlands is still high despite the condition of the rainy season. Data of groundwater table in January 2017 on cultivated peatlands and without the water level control indicates that the average groundwater stands at 45-58 cm below the soil surface. This showed that the danger of the land clearing by building canals and without being followed by water control (door operation). Even in the wet season conditions, the water level in the research area was approaching the critical zone (under 40 cm). But instead on the oil palm land where to control the operation of tertiary entrance is retention, the water level in the channel can be increased and the impact on groundwater levels in the area are in the safe zone, which is located at a depth of 15-30 cm below the soil surface (Figure 4). The period of water table level below 40 cm is from mid-October to Mid June. Under full retention system in the field at wet condition when the annual rainfall is above 4000 mm, ther there will be a water surplus period of 8-9 month.

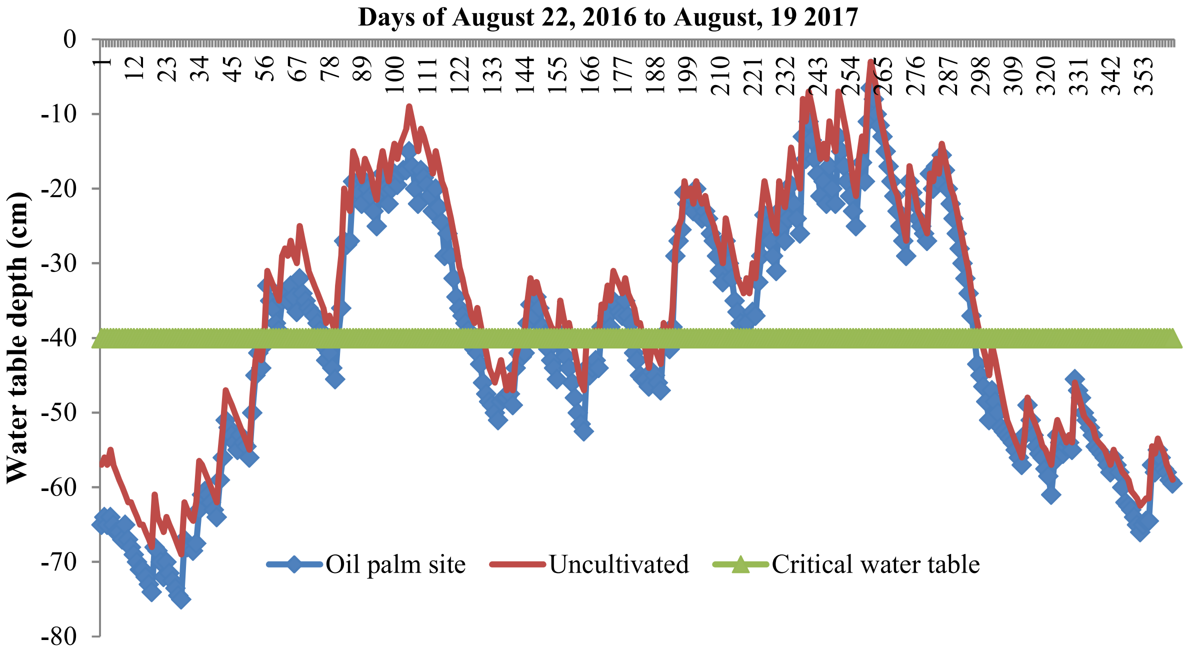



**Figure 4.** Dynamics of the ground water level at 2016-2017 period.

Looking at the critical value of fire hazard in the zone of 60 cm, then in January or during the rainy season the research area is relatively safe from fire hazards. Beside that the land is also very suitable for planting oil palm and food crops.

The water availability in the root zone of plants or critical zone of ground fire in swamp area is highly dependent on the water volume moving in the capillaries. Capillary water movement is strongly influenced by the position of the groundwater depth, texture, and soil hydraulic conductivity values. On soils with clay or clayey texture, the depth of ground water 1.5 m can meet the needs of the plant evapotranspiration, but the sand or sandy texture, soil maximum water depth of only 0.5-1 m. Our research areas are peatlands, thus determination of soil texture is very difficult to do because of the high soil organic matter that would interfere with the determination of soil texture, which is likely to do is, to determine the soil water dynamics by maturity peat. Figure 5 shows the soil profile on peat soil-hemic sapric where groundwater at a depth of 40-50 cm is able to create conditions in the root zone moist conditions and moisture content of field capacity, so the land is relatively safe against fires.

(a) Soil profile under oil palm (b) Soil profile in uncultivated peatlands (bush)

**Figure 5.** Condition of peat soil profile at a depth of 40-50 cm soil water condition.

The depth of the ground water greatly affected the value of water capillary and soil moisture status. Computer calculations up flow models for soil hydraulic conductivity value of 8 m day$^{-1}$ water show capillary 5 mm day$^{-1}$ are at a fixed value ranging in groundwater found at a depth of -120 cm to -60 cm. This means the plant has not requiring irrigation for the purposes of evapotranspiration 5 mm day$^{-1}$ until the position of ground water in the depths of -120 cm of the soil surface. Avoiding the danger of fires, the ground water should be at the level of 40-50 cm below the soil surface. The water content in these conditions is above the field capacity and is close to saturation. Water saturated condition is usually achieved when the depth of the groundwater was 30-20 cm below the ground surface. This condition is caused by the movement of water capillary in the peats, which is relatively small compared to the mineral soil even with the sandy soils.

### *3.3. Water management objecitves in field level*

Control of water levels in cultivated peatlands should be integrated also with land utilization plans. Experience in European countries [8] showed land used for grazing cattle. In the dry season the water of detention, so that the ground water is maintained not fall below 40 cm, and the wet season, the floodgates were opened and the water level can be controlled below 10 cm below the soil surface. However, in some areas, in trying to conservation, then the area of stagnant water left. This condition should be adopted in the exploitation of peatlands. Often companies (both acacia timber and oil palm) to maximize all land cleared and planted with oil palm or acacia. They must allocate for the conservation of at least 20%. The areas that should be conserved are peatlands. The areas will also be balancing the ecosystem and to replenish the groundwater in the dry season.

1 2 3

**Figure 6.** The multi-store block technique (photos 1 and 2: [12]); (3) the secondary channel blocking in an oil palm plantation and control overflow.

Local wisdom in managing water in the peatlands is also an important think to be applied. In West and South Kalimantan, farmers control water level with multi-store block technique, meaning that farmers have done water conservation efforts. Multi-store block technique was done along the tertiary channels. Figure 6 shows multi-store block technique in tertiary canal level. With this technique, the ground water level in the plot of land can be maintained (not easy to drop), so that the soil moisture content is safe from fire hazards. This system inspired canal blocking technique in the research area with the upper dam system is equipped with a discharge pipe or overflow.

In the field operations, a montly operation schedule is required. Table 4 shows the montly canal blocking operations based on climatic condition. The experience of cases in South Sumatra in 2015 and 2019, the annual rainfall is in the range of 4000 mm, and this condition has resulted in severe fires. Meanwhile in 2016 and 2020 whre the rainfall was above 4500 mm, there were no land fires. Therefore based on differences in rainfall conditions, a canal blocking operation model can be prepared in the field (Table 1).

**Table 1.** Montly operation model in the field for blocking canal

| Blocking canal operation | Operation period | |
|---|---|---|
| | Rainfall <4000 mm year$^{-1}$ | Rainfall >4000 mm year$^{-1}$ |
| Over flow 10 cm | January-March | January-May |
| Permanently closed | April-December | June-December |

## 4. Conclusions

Based on results and discussion of research data, thus it can be taken some conclusions as follows:

1) The drainage system is open system with the primary channel (4 m wide and 2 m deep), perpendicular to the primary channel is secondary channels (2 m wide and 2 m deep) and distance between the secondary channels is 250 m. The channel dimensions are too wide and deep, so that when there is no water retention, excess discharge will occur in the dry season
2) Water control with a multi-store block system shows the evident influence in increasing water level in the land plots. Detention in the dry season can raise the water level at a safe level (40-50 cm). In the uncultivated land there is no water, thus water level down to the level of 70-80 cm. Water control in the rainy season is able to raise the water level at the level of 20-30 cm, while without the water control the water level down to the level of 40-50 cm. For the safety, the water detention policy since the rainy season is the right step to keep track so that the water is at a safe zone.
3) Excess water analysis in zones 30 cm and 40 cm at a time of water retention in the channel, show that in the period from August to September groundwater conditions at the level below normal (-), but due to the movement of water capillarity then when the ground water at depths up to the limit 50-60 cm, they can create soil conditions valleys on the surface, making it safe against fire.
4) The availability of surface water reserves in the oil palm plantation is also very dependent on the conservation of forest area, however forest area was already burnt, so it must be done immediately peat forest restoration around the plantation area
5) The model of peat management should integrate ecological and economic objective, rewetting efforts must be followed by food crops, which can increase the income of farmers. Intercropping patterns with pineapple, watermelon and others will help create environmental conditions remain moist area, and free land of fires.

## 5. Acknowledgments

This article belongs to a part of our research project activities funded through *higher research competiotion of lecture profession* in Sriwijaya University with the research contract of No. 1023/UN9.3.1/LPPM/2016 dated July 18, 2016. The authors would like to say thank you to the staffs of the Faculty of Agriculture, Sriwijaya University and local people who have helped in the conduct of research in the field.

## 6. References

[1] Sjarkowi F, Arbain A, Armanto M E, Santoso U, Arjuna J, Rifardi, Setiawan A, Syahrul J, Khairijon and Azizah 2007 *Kualitas lingkungan hidup Sumatera 2007* PPLH Regional Sumatera, Kementerian Lingkungan Hidup RI, Pekanbaru, Riau ISBN 978-602-8107-00-6 p 393

[2] Wildayana E 2014 *Journal of Wetlands Environmental Managements* **2(2)** 30-6

[3] Imanudin M S, Armanto M E, Susanto R H and Bernas S M 2010 *Journal of Tropical Soils* **15(3)** 277-82

[4] Imanudin M S, Bakri and Karimuddin Y 2017 *Paper Presented at Seminar of Suboptimal Land PUR-PLSO, Sriwijaya University 19-20 October 2017*

[5] Armanto M E, Imanudin M S, Wildayana E, Junedi H and Zuhdi M 2016 *Sriwijaya Journal of Environment* **1(3)** 58-63

[6] Liu Q, Yasufuku N, Miao J and Ren J 2014 *Soils and Foundations* **54(6)** 1241-45

[7] Sutikno S, Rinaldi1 R, Saputra E, Kusairi M, Saharjo B H and Putra E I 2020 *The 2nd Aceh International Symposium on Civil Engineering (AISCE) IOP Conf. Series: Materials Science and Engineering 933*

[8] Ritzema H, Kirkpatrick H, Stibinger J, Heinhuis H, Belting H, Schrijver R and Diemont H 2016 *Sustainability* **8(5)** 440-50

[9] Carr M K V 2011 *Expl. Agric.* **47(4)** 629-52

[10] Hooijer A, Page S, Canadell J G, Silvius M, Kwadijk J, Wosten H and Jauhiainen J 2010 *Biogeoscience* **7** 1505-14

[11] Imanudin M S, Satria J P, Said M and Rahmat R 2019 *Sriwijaya Journal of Environment* **4(2)** 52-8

[12] Imanudin M S, Elisa W and Armanto M E 2018 *Journal of Wetlands Environmental Management* **6(1)** 12 – 26