Journal of Wetlands Environmental Management Vol 9, No 1 (2021) 1 - 21 http://dx.doi.org/10.20527/jwem.v8i2.228 -----Accredited by Directorate General of Higher Education Indonesia, No. 21/E/KPT/2018,

by Bakri Bakri

Available on line at:
http://ijwem.ulm.ac.id/index.php/ijwem
ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

Development of Control Drainage Operation Model and Utilization Planning of Post-Fire Peatlands

MOMON SODIK IMANUDIN[1*], BAKRI[1], M.E. ARMANTO[1], E. WILDAYANA[1] AND S. AL RASYID[2]

[1]The Faculty of Agriculture, Sriwijaya University, Indonesia
[2] Researcher of Lowland and Coastal Data Information Center of South Sumatra
Email: momon_unsri@yahoo.co.id

ABSTRACT

The research aimed to determine the monthly operational groundwater control and land use patterns in fire prevention efforts on peatlands. The research method was carried out using a detailed survey scale method in the representative sample area of 20-30 ha. Observations in the field included measuring the physical properties of soils and observing hydrological components. Group discussions with the community were conducted to explore information on the causes of fires, compilation of plans for operational activities in the field, and land use models. The research results showed that in the soil depth of 0-20 cm the level of peat maturity classified as Sapric (mature), at a depth of 20-50 cm is classified as hemic and at a depth of 50-100 cm belongs to fibric (immature). The effects of blocking canal construction were very significant in raising the water level in the channel and groundwater table. However, due to the low rainfall until December 2019, the groundwater level was not yet able to raise to the point of arrangement 40 cm. Till the end of December 2019, the groundwater level was at 70 cm, however there has been an increase in groundwater level of 30 cm since the beginning of December 2019. In the rainfall conditions < 2500 mm/year, blocking canal operations with a retention system have to begin in April. Agroforestry is the best model and *Albizia chinensis* (Osbeck) Merr. (sengon) in combination with pineapple plants are the best land use pattern. In addition, some short-term proposals are to provide infrastructure for firefighting, the construction of a road embankment, normalization of main rivers and canals, providing boring wells, making security control posts, training, monitoring, and providing some incentives for farmers to clear land and firefighting teams at the village level.

Keywords: *operating model; groundwater level control; peat, land fires*

INTRODUCTION

Population growth is increasing from year to year, of course, it will be accompanied by an increase in agricultural areas for food supply. Food in a broad sense is not separated from agriculture alone, but to human efforts to use land resources to make money and subsequently to fulfill the basic needs of the population (Wildayana *et al.,* 2016; 2017). Therefore, the use of land on peat in a large scale is more for oil palm and industrial plantation.

Problems arising from land management in swamps, especially peatlands are clearly greater than in dry mineral lands. Agroecosystem in various peatlands are strongly influenced by biophysical and environmental conditions (Imanudin *et al.,* 2018; 2019a; 2019b). Opening of peatlands is always done by making channels to lower the water level. Land clearing of peatlands for plantations had an impact on 58% of global carbon emissions. In addition, a decrease in groundwater level of more than 1.00 m and in the dry season makes the land vulnerable to fire (Wösten *et al.,* 2006a; 2006b). Clearly the

**Correspondence*: Momon Sodik Imanudin; Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indonesia; Email: momon_unsri@yahoo.co.id.

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

effect of channel construction is very real on peatlands in a decrease in water level. Peatlands with canals have three times deeper water levels than before channels (Astiani *et al.,* 2017; Armanto *et al.,* 2016). On the other hand, social problems also often arise from land clearing, especially the number of lost land use rights for local residents (Sumarga *et al.,* 2016; Wildayana *et al.,* 2018a; 2018b; 2018c).

Some main problems often arising in agriculture or plantations in peatlands are flooding in rainy season and drought in the dry season. In addition, problems with the presence of shallow layers (pyrite) which will occur when oxidation decreases in the groundwater level (dry season) causes the soil to become acidic due to pyrite oxidation, and finally increasing the solubility of aluminum and iron which is toxic to plants (Imanudin and Armanto, 2013-2015; 2016-2017). This condition is also followed by an increase in soil acidity. When the groundwater level is too deep, it will cause the soil capillarity to be low, so the upper soil surface becomes dry. This condition makes the land vulnerable to fire (Imanudin *et al,* 2017a; 2017b). Within a period of 50 years, land clearing for oil palm led to a decline in land subsidence of 3.00-4.00 m and continuous land fires will cause the land to be flooded in the rainy season, and will be a limiting factor in restoring land. An integrated approach has to be taken especially to stimulate economy of local people in peatlands, so that the community can play an active role from planning to implementation and it is hoped that they can help protect the environment (Uda *et al.,* 2017; Surahman *et al.,* 2019).In connection with these conditions, water level control efforts are needed aiming to optimize the water level which does not cause the plants to die and also if it does not cause land to be burnt easily. In the condition of a depth of 40 cm in groundwater with land on the condition of having biomass above, it is able to create soil water content in the root zone of the plant in saturated conditions. Even in peat conditions that are in the sapric class (mature) the depth of 50 cm of groundwater can create soil conditions at the top of the valley. A value of 40 cm is considered a critical limit for land fires (Imanudin *et al.,* 2015; 2018; Taufik *et al.,* 2019). Putra *et al.* (2018) added that land fires occur when groundwater level drops below 30 cm. It is very important to maintain water levels above 30 cm to avoid fire and peatlands degradation. However, the condition of micro-climate change is very influential on environmental conditions that cause widespread land fires.

Some efforts to restore and to conserve peatlands are carried out in an integrated, technical and non-technical manners. Technically, of course through efforts to fulfill water (rewetting) and also water conservation (rain harvest). A field study of the ability of the network system and the operation of canal blocking on water levels has not been carried out. Non-technical approach, namely increasing the participation of the community in the preparation of the fire prevention program needs to be done in a participatory manner and has a beneficial value for the addition of local income. Community participation is expected to grow when the surrounding peatlands can generate direct benefits to household income. If it is only limited to indirect benefits (conservation of environmental services), thus they will not care, because the surrounding population is still poor.

RESEARCH METHOD

This research was carried out in September to December 2019. The research site is located in Kedaton Village, Kayu Agung, Ogan Komering Ilir District, South

-----Accredited by Directorate General of Higher Education Indonesia, No. 21/E/KPT/2018, Valid until 9 July 2023-----

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

Sumatra Indonesia. The study site has an area of ± 20 ha having flat topography and is

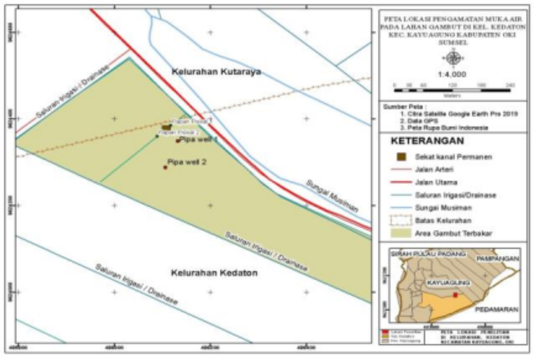

Figure 1. Research location for peat hydological monitoring in Kedaton Ogan Komering Ilir South Sumatra Indonesia

located at an altitude of 4 m above sea level. In general, the research area consists of three parts, namely settlements, plantations, rivers and swamps.

The materials used in this study were peatlands taken from burnt peatlands and natural forests. The tools used were ring samples, hoes, peat drills, ovens, analytical scales, porcelain cups, measuring cups, plastics, isolates, GPS (Global Positioning System), cameras, meters, stationery and laboratory tools for soil analysis. The research was carried out using field trial methods by taking some examples of peatlands area bounded by two canals. Field work includes soil sampling, peat depth drilling, measurement of groundwater level, channel water level, hydraulic discharge value, and collecting rainfall data. Laboratory analyses include total pore space, content weights and level of soil maturity.

Sampling was carried out in secondary peatlands using a proportional random sampling method consisting of 6 sample points with a depth of 0-50 cm, 50-100 cm, and 100-150 cm. Depth analyses of groundwater level (cm) and peat depth (cm) were done by direct drilling in the field. Peat maturity was carried out in the field based on the ratio of the amount of fiber, while the weight content (gram/cm^3) and water content (%) using the gravimetric method.

To obtain socio-economic data of the population, interviews and focus group discussion methods were conducted in the Kedaton Village. Secondary data was obtained from the village head's office. Rainfall measurements are carried out directly in the field using an ombrometer.

The water level was measured using a piezometer mounted near the channel (50 m) and in the middle of the 100 m block. Piezometer reading was done every day. Piezometers were made from 2.5-inch PVC pipes that are installed in holes in peatlands. Measurement of soil hydraulic conductivity was carried out directly in the fields using the Auger hole method. The general principle of the Auger hole method is that a hole is prepared using a drill to a certain depth below the groundwater level. If the water balance with the environment has been reached, some water in the hole is removed. The water will seep back into the hole, and the rate of rise of groundwater level in the hole over time is recorded. By using appropriate graphs and

-----Accredited by Directorate General of Higher Education Indonesia, No. 21/E/KPT/2018, Valid until 9 July 2023-----

formulas, the ground hydraulic conductivity (K) can be calculated from these observational data. K values are calculated using the equation 1 (Van Beers, 1983).

$$K = \frac{4000 r^2 \, dY}{(H + 20r)\left(2 - \frac{Y}{H}\right) Y \, dt} \quad (1)$$

where

K is the ground hydraulic conductivity (m.day^{-1});

H is the depth of the auger hole below groundwater level (cm);

Y is the distance between the groundwater level and the average water level below the auger hole at dt (cm) time intervals;

r is the radius of the auger hole (cm); and

t is the measurement time (seconds).

Analysis of drainage capability or rewetting was carried out by observing groundwater level between the two channels. Analysis of the advantages and disadvantages of groundwater in the plant root area was carried out for one year. The groundwater status analysis method was carried out using the concept of SEW-40 (surplus excess water under 40 cm). This SEW-40 calculation was based on Government Regulation (PP) Number 71 year of 2014. This concept is used to show the condition of excess groundwater (cm-days) during the land tenure period. At groundwater depth of 40 cm, the land is relatively safe from fire hazards (Kettridge *et al.*, 2015; Junedi *et al.*, 2017). The value of excess water above 40 cm can be calculated to predict excess groundwater under during the period of plant growth. The formula (equation 2) is as follows:

$$SEW - 40 = \sum_{i=1}^{n} (40 - x_i) \quad (2)$$

Where:

xj is the groundwater level at the end of each hour and,

n is the total hours during the plant growth period.

The water management strategy that will be built in the adaptation of operating models in the field is the concept of containment and control of water levels (control drainage). The drainage system is controlled by providing drain control at a depth of 40 cm. Canals are built in the secondary channel. The preparation of fire prevention and control programs is carried out using a participatory approach through group discussions and interviews.

RESULTS AND DISCUSSIONS

Profile of the community around the peatlands area

The Kedaton village has various kinds of people, namely contractors, entrepreneurs, cracker sellers, brick building owners, drivers, motorcycle drivers, public servants, traders and farmers. Most communities reside relatively far from the peatlands. This is because their homes and workplaces are mostly located near to Kayuagung city. While the profession of farmers is only occupied by a small portion of the Kedaton community, this is due to the insufficient availability of land to be managed

-----Accredited by Directorate General of Higher Education Indonesia, No. 21/E/KPT/2018, Valid until 9 July 2023-----

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

by the community, farmers in this region include farmers in the oil palm, rubber, pineapple and vegetable plantations sectors. For the agricultural sector, namely rice farming. The results of interviews with several community members were found that the working hours of the whole community were from 08.00-16.00 pm and other time were used by the community for rest. Only for the profession of rubber farmers who have free time during the day at 13.00-18.00 pm because rubber farmers only actively tap at 07.00-11.00 am.

The land fire in the research area has been in a severe category since 2015 and another severe fire occurred in 2019. According to the local community, this fire occurred due to drought, low rainfall intensity and surface water sources are limited. So far, the land has been tried to plant oil palm, but it failed because the peat was too deep. The status of land ownership is also unclear, because it includes a conservation area. However, because it is near the access road and the population, the community tries to own the land, some even sell to outsiders. The failure of agricultural business in the area caused the land to be abandoned, which eventually became a source of fire every year. Figure 2 The area conditions of peat land in Sepucuk Kedaton OKI that has experienced a fire in November 2015.

Figure 2. Fire in process (lefth) and burnt peats in research area (right)

In the event of a large peat fire, the surrounding community immediately reports to the government to send assistance, such as assistance from the land route, namely a fire engine along with the National Disaster Management Authority (BNPB) crew and helicopter assistance carrying water booms. However, this effort cannot run effectively because if a fire has occurred on peatlands, it will be difficult to extinguish.

Climatic and Hydrological Conditions

The climate of the research area belongs to tropical climate having two seasons, namely the rainy season and dry season. The temperature ranges between 24-38 °C, the lowest temperature ranges at 02.00-04.00 in the morning, while the highest temperature is in the afternoon ranging between 01.30-03.00 pm. Humidity ranges between 80-88% with wind speeds of 3-8 km/hour and the highest rainfall of 2,849 mm/year. Serious fires that occurred in 2019 are reasonable because the rainfall is relatively low. The dry period is longer because the value of precipitating is lower than the need for evapotranspiration (deficit) that occurs from June to November (Figure 3). Therefore, the peak of fires began in August, September and October.

Rainfall is one of the determinants of water availability in peatlands. The addition of water from rainfall will cause the water level of the channel and groundwater level in the

-----Accredited by Directorate General of Higher Education Indonesia, No. 21/E/KPT/2018, Valid until 9 July 2023-----

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

land to increase. This is one of the factors in the availability of water on land to prevent drought and keep away from land forest fires on peat. Measurement of daily rainfall in the morning was done to see the effect on the rise in groundwater level. Daily rain picture from November to December 2019.

Peatlands get rain on 19 November 2019 at 4.8 mm/day. The value < 5 mm/day is classified as very mild and does not make significant changes to the peatlands area. The rainfall occurring on 22 November 2019 obtained by 1 mm.day^{-1} was still in very light criteria. The next rain occurred on 24 November 2019 with moderate criteria of 28 mm/day. The peatlands received the highest rainfall on 17 December 2019 at 47 mm/day, but according to BMKG Class I Palembang (2019), it is still in the medium criteria. Figure 4 shows that the rain in November was not enough to raise groundwater levels. So that in November there was still a water deficit and some areas of land were still experiencing land fires. Groundwater has markedly increased by about 30 cm into December rain where daily rainfall reaches 47 mm. Besides the increase in groundwater level is also followed by an increase in water level in the channel. The channel water that was initially installed was at 100 cm, after the rain in December showed an increase to 118 cm. The research of Putri *et al.* (2019) and Imanudin *et al*. (2020) stated that the effect of canal blocking is very real in raising the groundwater level. The range of wet soil can reach 240 m perpendicular to the channel. However, in this study there was an average difference of 15 cm in the decrease in groundwater level at changes in the distance from 50 and 100 m to the channel.

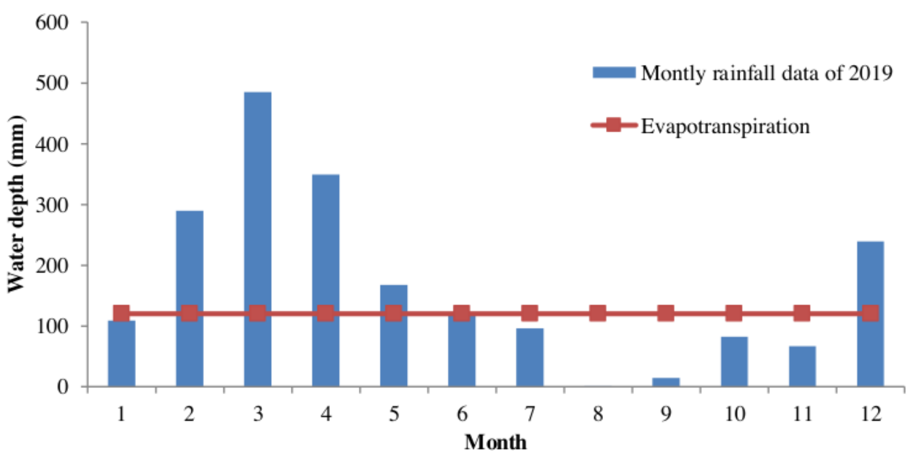

Figure 3. Relationship between rainfall and evapotranspiration

-----Accredited by Directorate General of Higher Education Indonesia, No. 21/E/KPT/2018, Valid until 9 July 2023-----

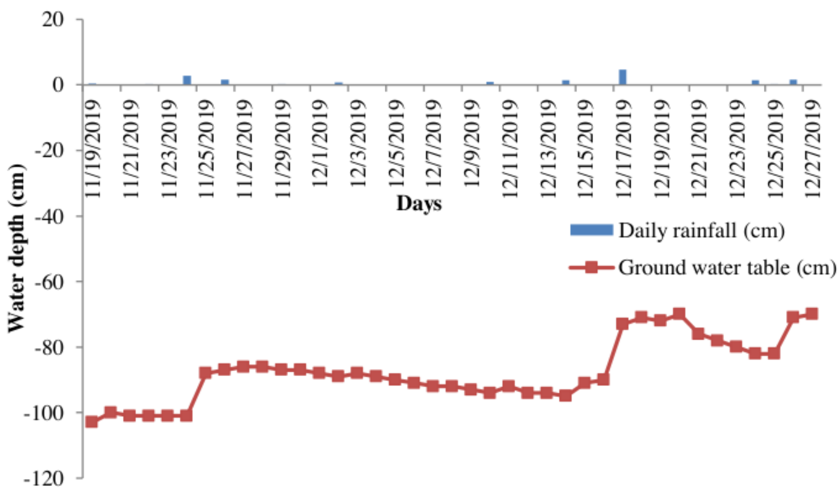

Figure 4. Relationship between rainfall with groundwater tables

Fluctuations in water levels in the channels are also strongly influenced by rainfall. The water level in the upstream is higher than it in the downstream, this shows the real impact of holding water with canal blocking. The initial rain in November could only raise 9 cm of water, and the increase was only seen in the rain in December to 18 cm from the initial water level (November). The average difference between the upstream and downstream water levels was 10 cm (at the beginning of the rainy season). This is in line with the results of Dhiaksa and Candraqarina (2018) and Holidi *et al* (2019) that the function of the canal blocking was to raise the water level in the upstream channel. The increase in water level was expected to wet the peatlands area, and could also serve to reduce the rate of water loss. Installation of canal blocking has been able to raise the water level in the upstream which was constantly increasing (9 cm/day). The difference in the peak water level upstream and downstream can reach 100 cm.

Figure 5 shows very clearly that the filling of water in the channel only comes from rain, there is no tidal effect. Rain on 17 December 2019 by 47 mm was able to raise the water level in the channel from 113 to 120 cm. Drainage control was carried out at a height of 140 cm. Land surface was at a height of 180 cm, so that disposal of water at the level of 140 cm was expected to be able to maintain the water level 40 cm below the surface of the land.

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

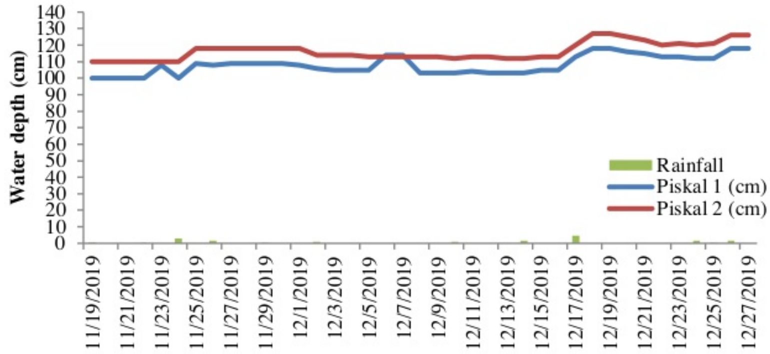

Figure 5. Relationship of water level in the channel with daily rainfall

Soil Conditions

The characteristics of peat soils are still classified as Hemic (half-mature) in the class of peat maturity. The purpose of Hemic is that peat is half-weathered and some of its parent material is still recognizable and brown in color and can be squeezed in 15-75% fiber material. The depth of the peat is above 400 cm. Soil observation in the field can be seen in Figure 6.

Figure 6. Drilling and observing the level of peat maturity (November, 2019)

Based on peat profile sampling as deep as 100 cm, at a depth of 0-20 cm it was obtained Sapric maturity level (mature) with the method used was enough to squeeze the peat soil with a grip, then at a depth of 20-50 cm Hemic maturity was obtained and at a depth of 50-100 cm was obtained maturity level Fibric (immature). The level of soil decomposition determines the ability of the soil to drain water. At the hemik level generally the soil permeability value is at a moderate level. Thus the level of peat maturity will determine the design of the water drainage system.

Measurement of soil permeability serves to determine the speed of water in penetrating the soil in a certain period. In experiments in the first hole the average flow rate was 1 cm in 90 seconds. Table 1 shows the results of the first experiment in the first hole that in 90 seconds water can enter the ground as high as 1 cm. While in the second hole in 80 seconds water can enter the ground as high as 1 cm. So,

-----Accredited by Directorate General of Higher Education Indonesia, No. 21/E/KPT/2018, Valid until 9 July 2023-----

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

on peatlands the flow rate of water to 1 cm takes 80-90 seconds. This convention is relatively slow for peatlands size. The slow flow rate is due to the top soil layer having accumulated dust from combustion. With this condition the soil pores are blocked so that the permeability of the upper soil is slow to 0.0125 cm.second^{-1}.

Table 1. Measurement of flow rates on peatlands

Time	*h* (cm)	t (time)	Permeability	*h* (cm)	t (time)
t 0	15	0' (zero second)	t 0	15	0' (zero second)
t 1	16	1' (60 seconds)	t 1	16	0,5' (30 seconds)
t 2	17	2' 22" (142 seconds)	t 2	17	1'43" (103 seconds)
t 3	18	4' 31" (2271 seconds)	t 3	18	2'56" (176 seconds)
Δ h	1	90 seconds	Δ h	1	80 (seconds)

The pore value of soil drainage was assumed from the relationship between incoming rainfall and the increase in groundwater level. Entering the middle of November there had started to rain. The increase in rain was also not so obvious raising the groundwater level. This was because the channel was still empty and the peat water percolation was still very high. At the time of the November 24 rain, 28 mm was relatively able to raise groundwater in the land from 85 cm to 70 cm and from 101 to 88 cm, this mean that 28 mm of rain could raise groundwater levels by 10-15 cm on average. From this data we can predict the drainage pore value was only around 0.4-0.5 or 40-50%. Pore drainage around 0.5, then 50% of the land area is solids that cannot be filled with water. Whereas peat drainage pore is generally very high, usually between 0.7. The higher the value of the pore drainage space, the less the peat solids. In the peat area at the top which is burning, the upper layer already contains a lot of dust, so that the micro pores have increased. When observing the condition of the blocking canal that was made permanently, it had been operating and functioning properly, so that the water loss was minimal.

The value of the weight of the contents of the top is also relatively high, ranging between 0.6-0.7 g.cm^{-3} Though for peatlands is below that. Maulana *et al*. (2019) stated that burned peatlands showing the weight of contents is in the range of 0.12 g.cm^{-3} to 0.68 g.cm^{-3} with an average of 0.30 g.cm^{-3}. While the research of Prayoto *et al*. (2017) shows that the peat soil weights in Riau area are 0.10-0.13 g.cm^{-3} in which the peat pore space is dominated by very fine pores (± 40% v/v) and very pore drainage fast (± 30% v/v).

Evaluation of Groundwater Depths to the Critical Value of 40 cm

At the time of observation in early November the condition of the land was still dry and it had not rained yet. The groundwater level is far from the permitted limit (40 cm), the groundwater level is at 80 cm at the observation point near the channel. While those who are more than 50 m from the channel show the number 103 cm. From this condition it is clear that the peat soil is very dry, especially on the surface. This condition causes the land to burn easily and at the time of the visit the land is in a burning condition.

The compliance point of 40 cm below the surface of the land for peatland management is based on Indonesian Government Regulation

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

(PP) Number 71 year of 2014 concerning Protection and Management of Peat Ecosystems. Peatlands are classified as deep and rainfall in 2019 is very small. Although the rain had started to fall in November, it was still unable to raise the groundwater level to close to the critical level of 40 cm. Evaluation of the status of water using the Surplus Excess Water approach -40 cm shows that during November-December there is still a water deficit, which means that the whole day is still below the 40 cm (Figure 7). So that in that period the land could still be a fire.

In the early November period fires still occurred, and this was very reasonable because the groundwater level was 90-100 cm. Starting the second week it rained and began to increase groundwater levels. Entering the end of December 20-25, the water level significantly increase. This shows good channel blocking performance. Groundwater in the end of December is at a depth of 70 cm. This means that there has been a filling of groundwater as deep as 30 cm within a period of approximately 40 days.

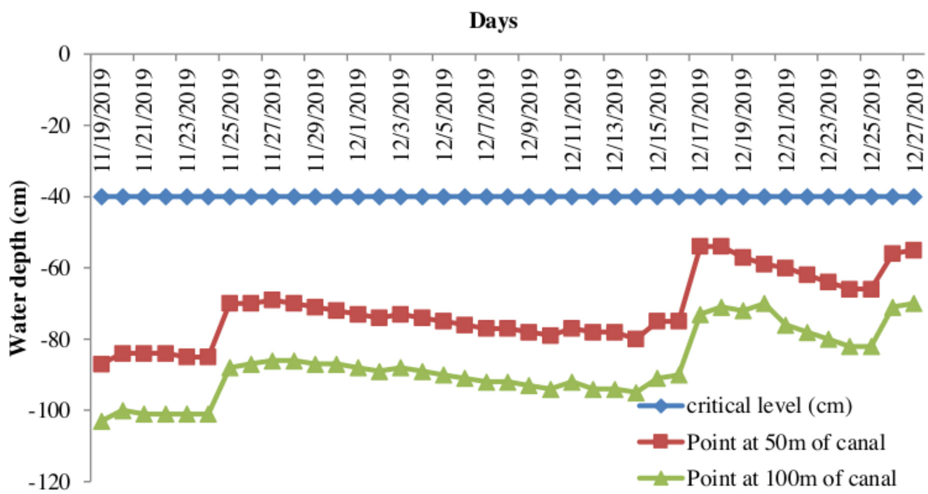

Figure 7. Groundwater level dynamics compared with the 40-cm critical value

Evaluation of Blocking Canal Performance

To see the effects of blocking canal construction, water levels were observed in canals and on land (Figure 8). At the beginning of the rainy season November-December (early) rainfall has not significantly affected the increase in water levels in the channel and groundwater. The high loss of water in peatlands causes the process of filling groundwater is relatively slow.

Based on observations on 4 December 2019, the water level in the canal is 60 cm from the average ground level (Figure 9). The depth of the groundwater which is at a distance of 50m from the channel is still at 93 cm below the surface of the ground. A value of 93 cm indicates a critical figure, because it still does not meet the criteria for peatland compliance which must be at a minimum level of 40 cm. When drilling, the condition of the burned peat

-----Accredited by Directorate General of Higher Education Indonesia, No. 21/E/KPT/2018, Valid until 9 July 2023-----

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

was in the upper layer with a thickness of 40-50 cm. While the depth below is still relatively humid.

A: How to make blocking canals

B: Almost ready blocking annal

Figure 8. Observation of water levels near blocking canals built in November 2019

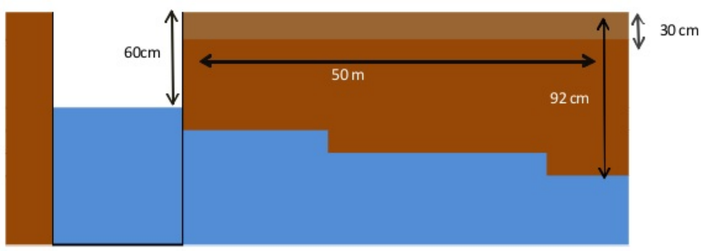

Figure 9. Illustration of surface water levels and groundwater levels in the field

Figure 10 shows a decrease in groundwater level every 10m, up to 50 far from the channel (water source) that occurred on December 4, 2019 in the burned land. A reduction in the average groundwater depth of 3-5 cm occurs every 10m additional distance. In the first 10 m the groundwater level is at a depth of about 70 cm, and at a distance of 50 m from the groundwater table at 92 cm. The conditions are quite different because the land has not received much rainwater, so there has not been a filling process (rewetting). It is clear that the land had previously been over drained, so that more water was needed for refilling.

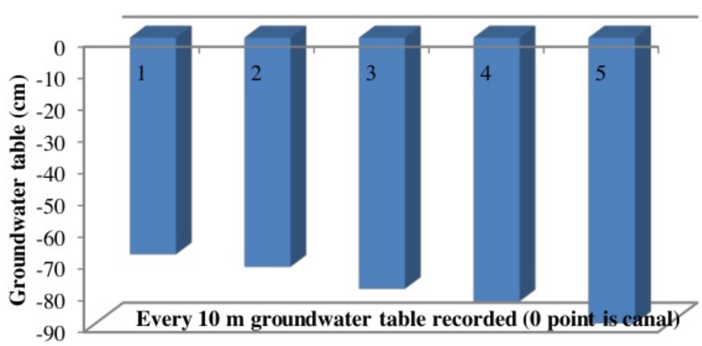

Figure 10. Decreasing groundwater level in peatlands on fire to the canal (4 December 2019)

 ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

Other data revealed by the results of groundwater surface dynamics research on planted landscapes with pineapple (Armanto *et al*., 2016-2019; 2013; 2016) stated that there is only a decline at an average of 10 cm per distance of 50 m from the canal. This condition causes the land is still not integrated. because at a distance of 300 m from the ground the water channel is still at 70 cm. the importance of cultivating land so that it is planted with food crops. Farmers will try to keep the water from disappearing so that it enters the dry season where all channels have been closed.

Arrangement of Operation Model

Figure 11 showed the distribution of monthly rainfall in 2015 where rainfall is very little. Total rainfall is only 2,019 mm. year^{-1}. The dry month occurs for a very long period of 6 months, so the danger of fire due to a decrease in the groundwater level is very high. A similar condition was experienced in 2019 where rainfall was only 2,025 mm, so this year there was also a fire. Dry months occur for 5 months. In November, which is usually already raining a lot, it turns out that there is still a water deficit. After a period of 4 years, annual rainfall is less than 2500 mm.

Other data revealed by the results of groundwater surface dynamics research on peatlands planted with pineapple (Armanto *et al*., 2017) states that there is only a decline in an average of 10 cm per distance of 50 m from the canal. This condition causes the land is still not degraded. because at a distance of 300m from the groundwater channel is still at 70 cm. the importance of cultivating land so that it is planted with food crops. Farmers will try to keep the water from disappearing so that it enters the dry season where all channels have been closed.

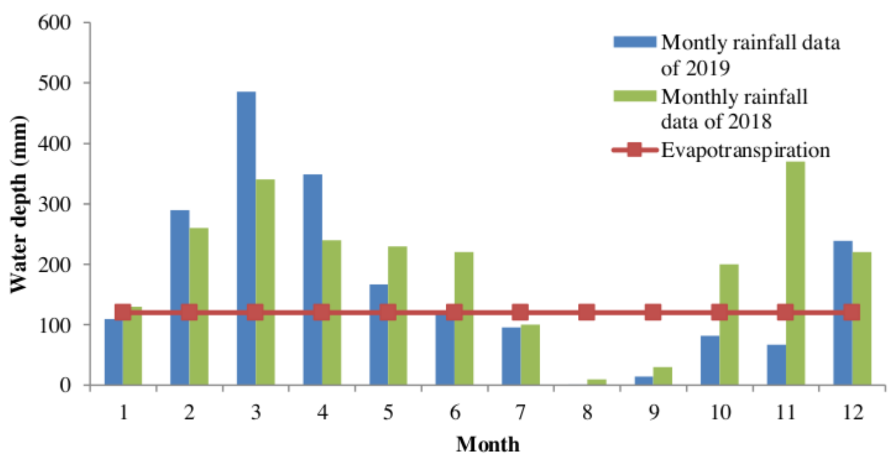

Figure 11. Monthly rainfall in the dry year influences the 2015 and 2019 Elnino climatic condition vs Evapotranspiration (ET0).

Regarding water resource rigidity, an operational model in the field is needed that provides guidance to field officers to immediately take water management actions.

-----Accredited by Directorate General of Higher Education Indonesia, No. 21/E/KPT/2018, Valid until 9 July 2023-----

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

Table 2. Water level control operating system in the field level on peatlands

Montly operation	Goal of control	Secondary network operation	
		Dry climate	Normal climate
January	Controlled drainage	The door is closed	The door is opened
February	Controlled drainage	The door is closed	The door is opened
March	Retention	The door is closed	The door is closed, retention 240 cm
April	Retention	The door is closed	The door is closed, retention 240 cm
May	Retention	The door is closed	The door is closed, retention 240 cm
June	Retention	The door is closed	The door is closed, retention 240 cm
July	Retention	The door is closed	The door is closed/ Adding water from the pump
August	Retention/rewetting	The door is closed / Adding water from the pump	The door is closed/ Adding water from the pump
September	Retention/rewetting	The door is closed / Adding water from the pump	The door is closed/ Adding water from the pump
October	Controlled drainage	The door is closed	The door is closed
November	Controlled drainage	The door is closed	The door is closed
December	Controlled drainage	The door is closed	The door is closed

A: Peat landscape B: Flooded peatlands

Figure 12. Flooded land conditions in February 2020

This model is arranged based on soil characteristics, and micro-climate especially rainfall conditions. Table 2. shows the monthly network operation model at fieald level to be disseminated to field officers or head of farmer group.

-----Accredited by Directorate General of Higher Education Indonesia, No. 21/E/KPT/2018, Valid until 9 July 2023-----

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

There are a number of basic assumptions for operating the model is that the model is built on a system unit of 1000 m in length and 250 m in width. The network pattern is a pair of combs where the secondary channel is connected only next to it and the rest is permanently closed (not penetrated into the primary channel). At the connected end, a control dam with a controlled drainage system is needed. Overflow pipe, installed at a depth of 10 cm from the top so that the channel can be filled with water. At present, the water level control field is 40 cm deep. This condition applies to disposal in the rainy season, but before the dry season water level control must be carried out at a depth of 10 cm. This means that in April the canal block must be closed at least 10 cm from the surface.

To test the model, in the rainy season a field visit is conducted. The land was flooded at the end of January and by February (Figure 12) the land had been flooded. The bulkhead building with a 40 cm opening is relatively effective to keep the water from getting too high (flood). In this condition the land has a pool of between 10-20 cm, so that annual plants can still grow if made dike or embankment (raising the soil). This is potential where control of drainage at a height of 40 cm for the rainy season is able to keep the land from being flooded.

Making Community Based Programming

To develop a prevention and control program on forest and peat fires, the research team from Sriwijaya University held an FGD (Focus Group Discussion) with residents. Participants who attended were from the village government, farmer groups, community leaders, environmental leaders and the Fire Care Community Team (MPA). This activity is to explore the root causes of fire and the hope of citizens in future prevention. A description of the ongoing meeting with citizens can be seen in Figure 13. The results of this activity can be summarized as follows:

1) Fires occurred in September, November, and even in early December there were still several hotspots. The cause of fire-prone is because the land is classified as deep peat soils where the depth reaches 4-5 m. During the dry season the groundwater level drops above 100 cm, and the surface water source is dry. So that the top is very easy to burn and the movement is faster due to dry climate conditions and strong winds. The cause of the burning of the land itself is not yet known with certainty, allegedly by irresponsible persons outside the Kedaton Village. The loss was huge and some residents who lived around the site were evacuated. Not to mention the loss of planted gardens
2) Some of the past programs which were not well targeted have been carried out in the area among 50 ha of paddy fields. Peatland development is clearly a risk, because deep peat is not suitable for food farming. Plants do not grow well, so farmers run out of business capital, which is ultimately abandoned land. Abandoned vacant land causes easy interference, especially the danger of fire. For this reason, the condition of this land must be immediately

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

rehabilitated or other uses used in accordance with the function of the peat ecosystem.

3) For firefighting operations during the dry season, the firefighting team found it difficult because access to the location was difficult. So, it is necessary to repair roads or normalize the canals (main drain) along 10 km. The condition of the canal is overgrown with water plants, so that the *ketek* (small wooden ship) is difficult to move. Besides the lack of equipment facilities such as suction hoses, expenditure hose, communication equipment and operational costs of the outage team.
4) In the future there is expected to be regular socialization and training before the dry season arrives. At least the activity has been running since April. Extinguishing teams at the village level required a Decree (SK) from the local government, and received monthly incentives. The team leader is given at least a GPS and Android device for communication and monitoring of land developments, and the team's readiness in combating fires.
5) In fire-prone areas, guard houses (POSKOs) are needed to gather together for discussions, coordination, and temporary rest areas. So, there is the enthusiasm of the firefighting team to help patrol the environment, together with ABRI or policy.
6) The construction of a perimeter dike is needed to prevent fires from entering from the outside, while this can be done by normalizing a 1 km river. The name of the proposed river is the Tapa river.
7) The community also hopes that boring wells will be provided, to meet the residents' clean water as well as water reserves to prevent fires from spreading (wetting the surface).
8) The village government hopes that the budget for preventing and managing forest and land fires will be given directly to the village level, especially related to technical operational costs. At least a portion is given directly to the village level.
9) Communities around peat hope that there will be additional incentives related to agriculture, animal husbandry and fisheries to assist farming, so that they can be compensated to protect the land from fire.
10) For religious fields, it is expected that religious leaders, religious teachers and religious scholars bring the material to the importance of protecting nature, human implementation as caliphs on earth to protect the earth, especially peatlands. The material was delivered at community events such as recitals, celebrations, and Friday sermons.
11) The community agreed that the land could be immediately restored through revegetation of forest plants. It's just that forest plants that produce quickly and easily thrown into the market so that it can be used as income for the community. The pattern of agroforestry is considered appropriate. The proposed forest plants are *Albizia chinensis*. Furthermore, the government is expected to be able to facilitate the development of water systems, land management, and

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

preparation of sengon and pineapple seeds.

12) The next step is to find partners to collect pineapple and sengon crops. Sengon plants can be harvested if they are 4-5 years old. Several companies in South Sumatra, among others, PT Sumatra Alam Anugrah in Indralaya, have the opportunity to collaborate. An example of land use for sengon-pineapple agroforestry can be seen in Figure 13.

A: Discussion with local people

B: Involving students in the research

Figure 13. Meeting conditions with the local community at the research sites

Related to the prevention of forest and land fires in line with the research of Maulana *et al*., (2019) that the priority activities are repair and construction of canal blocks, rehabilitation of water bodies such as rivers and reservoirs; increasing fire patrol activities, and providing incentives for people who will open land. To improve the economic growth of the region, it has to be supported by infrastructure improvements such as roads, bridges and electricity networks.

For zero burning land clearing (without burning) the community cannot afford because it requires mechanical equipment and operating costs. For that there must be incentives. Murniati and Suharti (2018) reported that manual land clearing costs around 3.5 million per ha, and mechanically around 6.5 million. Meanwhile, controlled combustion can cost 1.5 million/ha. Therefore, zero burning efforts in land clearing can only be done if there is a cost incentive and equipment from the government (Figure 14).

CONCLUSIONS AND RECOMMENDATIONS

Based on the results and discussion of this research, the following conclusions and recommendations can be made as follows:

1) Peat maturity at the research location at a depth of 0-20 cm was sapric level with the method used is enough to squeeze the peat soil with a grasp, then at a depth of 20-50 cm was found hemic level and depth 50-100 cm was obtained fibric level (immature).

2) The physical soil properties showing the level of water discharge was relatively slow 0.0125 cm/second. This condition occurs at the top, where there is accumulation of residual dust from burning in the soil pores, thus the surface soil permeability becomes slow.

-----Accredited by Directorate General of Higher Education Indonesia, No. 21/E/KPT/2018, Valid until 9 July 2023-----

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

Figure 14. Multiple cropping pineapple with *Albizia chinensis*

3) The effect of blocking canal construction is very good, within 30-40 days it is able to raise the groundwater level by 30 cm. It is estimated that in January the land will meet the 40 cm standard.

4) Operations in the field for water level control are using a retention system. Dry climatic conditions with annual rainfall less than 2500 mm is by blocking canals since the end of the rainy season, which is April. With this model, it is expected that the 40 cm figure can be maintained until September, and the peak dry season of groundwater is still at 70 cm. During normal rainfall (> 2500 mm/year) water conservation can be carried out in May.

5) For the program sustainability, a partnership network is needed. The government has to immediately facilitate peatland management by building partnerships. Plant cultivation should be adaptive forest plants that benefit for local people. The results of the Focus Group discussion on the land use model of Agroforestry are the right solution. *Albizia chinensis* in combination with pineapple plants are the best pattern for land use (Imanudin et al., 2019b). Some of the short-term efforts related to fire prevention and control are the providing of fire extinguishers, the construction of a road embankment, the normalization of main rivers and canals, the construction of a boring well, the construction of security control (Posco), the training, monitoring and provision of morning incentives for the village firefighting team.

ACKNOWLEDGMENT

This research was funded by UNOPS with contract number 2019/IND/BRG/Sriwijaya University/006. We would like to say thank you for everybody who has supported this research since the site selection, implementation and funding.

REFERENCES

Armanto M.E., E. Wildayana, M.S. Imanudin, H. Junedi, and Mohd. Zuhdi. 2017. Selected Properties of Peat Degradation on Different Land Uses and the Sustainable Management. Journal of Wetlands Environmental Managements. Vol 5(2); 14-22. July-December 2017.

-----Accredited by Directorate General of Higher Education Indonesia, No. 21/E/KPT/2018, Valid until 9 July 2023-----

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

Web-link: http: //ijwem.unlam.ac.id/index.php/ijwem

Armanto, M.E., E. Wildayana, M.S. Imanudin, H. Junedi and Mohd. Zuhdi. 2016. Comparing Chemical Properties of Peats under Stabilized Land Uses. Proceeding of the ISSAAS 2016 International Congress, 5-7 November 2016, Vietnam National University of Agriculture, Hanoi, Vietnam

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 Q3). Web-link: http://jssm.umt.edu.my/?page_id=132

Armanto, M.E., M.S. Imanudin and E. Wildayana. 2016-2019. Food Agricultural Development Model in Peatlands based on Land Capability to support Forest and Land Fire Prevention. Research Grant Report. Sriwijaya University Research Contract. Nr. 0014/UN9/SK.LP2M.PT/2019 on 21 June 2019

Armanto, M.E., M.S. Imanudin, E. Wildayana, H. Junedi and M. Zuhdi. 2016. Managing Actual Problems of Peatlands 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

Astiani, D., Burhanuddin., Lisa M. Curran., Mujiman and Ruspita Salim. 2017. Effects of drainage ditches on water table level, soil conditions and tree growth of degraded peatland forests in West Kalimantan. Indonesian Journal of Forestry Research 4(1): 15-25.

BMKG Class I Palembang. 2019. Data online Pusat Database-BMKG. Web-link: http://dataonline.bmkg.go.id/home akses tanggal 10 April 2020

Dhiaksa, A., Chandraqarina, W. 2018. Evaluation of design canal blocking drainpile type in Sei Ahas Central Kalimantan. Jurnal Sumberdaya Air. Vol. 14(2): 111-124.

Holidi, M.E. Armanto, N. Damiri and D.D.A. Putranto. 2019. Characteristics of Selected Peatland Uses and Soil Moistures based on TVDI. Journal of Ecological Engineering, Vol 20(4); 194-200, April 2019 (SCOPUS Q3). IF: 0.22. https://doi.org/10.12911/22998993/102987

Imanudin, M.S. and M.E. Armanto. 2013-2015. Land Drainage Planning for Sustainable Food Crop Cultivation in the Delta Telang II Tidal Swamp Reclamation Area, South Sumatra. Final Research Report of DIKTI, National Education Ministry of Indonesia, Jakarta.

Imanudin, M.S. and M.E. Armanto. 2016-2017. Groundwater Control System in Tertiary Channel of Tidal Land in South Sumatra for Watermelon Cultivation after Rice (Planting Season II). Research Grant Report. Sriwijaya University.

Imanudin, M.S., E. Wildayana and M.E. Armanto. 2018. Option for Land and Water Management to Prevent Fire in Peat Land Areas of Sumatera Indonesia. Journal of Wetlands Environmental Managements. Vol 6(1); 12-26, Jan-June 2018. Web-link: http://ijwem.unlam.ac.id/index.php/ijwem

Imanudin, M.S., M.E. Armanto and Bakri. 2019a. Determination of Planting Time of Watermelon under a Shallow Groundwater Table in Tidal Lowland Agriculture Areas of South Sumatra, Indonesia. Irrigation and Drainage, Vol 68(3); 488-495, July 2019 (SCOPUS Q2). IF: 0.53. https://onlinelibrary.wiley.com/doi/pdf/10.1002/ird.2338

Imanudin, M.S., Satria, J.P., M.Said, and Rahmat, R. 2019b. 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., M.E. Armanto and D. Probowati. 2015. Integrated Forest Fire Control Strategies in Efforts to Support the Zero Smoke Program in South Sumatra. Proceedings of the National Seminar on Environmental Ethics in Food & Energy Resource Exploration, PPLH Unsri, Palembang 11-12 November 2015

Imanudin, M.S., M.E. Armanto and E. Wildayana. 2018. Option for land and water management to preventFire 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., M.E. Armanto and R.H. Susanto. 2017a. The Study of Watermelon Crop Response under Shallow Water Table at Initial Growth for Developing Drainage Planning at Tidal Lowland Agriculture. Paper presented in 13th ICID International Drainage Workshop, Ahwaz, Iran, 4-7 March 2017.

Imanudin, M.S., S.J, Priatna, E. Wildayana and M.E. Armanto. 2017b. Variability of Ground Water Table and Some Soil Chemical Characteristics on Tertiary Block of Tidal Lowland Agriculture South Sumatra Indonesia. SAINS TANAH – Journal of Soil Science and Agroclimatology, Vol 14 (1); 1-6, 2017. Web-link: http://dx.doi.org/10.15608/stjssa.v14i1.655

Imanudin, M.S., S.J. Priatna, Bakri and M.E. Armanto. 2020. Field Adaptation for Watermelon Cultivation under Shallow Ground Water Table in Tidal Lowland Reclamation Area. Journal of Wetlands Environmental Managements. Vol 8(1); 1-10, April 2020. Web-link: http://ijwem.unlam.ac.id/index.php/ijwem

Imanudin, M.S., S.J. Priatna, M. Said and R. Rahmat. 2019b. Land and Water Management in Pineapple and Albizia Chinensis Agroforestry Systems in Peatland. Sriwijaya Journal of Environment. 4(2) 52-58

Junedi, H., M.E. Armanto, S.M. Bernas and M.S. Imanudin. 2017. Changes to Some Physical Properties due to Conversion of Secondary Forest of Peat into Oil Palm Plantation, Sriwijaya Journal of Environment, Vol. 2(3): 76-80.

Kettridge, N.M., R., Turetsky, J.H. Sherwood., D.K. Thompson., C.A. Miller, B.W. Benscoter., M.D. Flannigan., B.M. Wotton., and J.M. Waddington. 2015. Moderate drop in water table increases peatland vulnerability to post-fire regime shift. Article in Scientific Reports. | DOI: 10.1038/srep08063

Maulana, S.I., L. Syaufina, L.B. Prasetyo and M.N. Aidi. 2019. Formulating peatland fire prevention strategy in Bengkalis Regency: An application of analytical hierarchy process. IOP Conf. Series: Earth and Environmental Science 399. doi:10.1088/1755-1315/399/1/012021

Murniati and S. Suharti. 2018. Towards zero burning peatland preparation: Incentive scheme and stakeholders role Biodiversitas. 19 (4): 1396-1405.

PP Number 71 year of 2014. Peraturan Pemerintah (PP) Indonesia tentang Perlindungan Dan Pengelolaan Ekosistem Gambut. LN. 2014 No. 209, TLN No. 5580, LL SETNEG: 28p.

Prayoto, M. Ishihara, R. Firdaus and N. Nakagoshi. 2017. Peatland Fires in Riau, Indonesia, in Relation to Land Cover Type, Land Management, Landholder, and Spatial Management. Journal of Environmental Protection, 8, 1312-1332. doi: 10.4236/jep.2017.811081.

Putra, E.I., M.A. Cochrane, Y. Vetrita, L. Graham and B.H. Saharjo. 2018. Determining critical groundwater level to prevent degraded peatland from severe peat fire. IOP Conf. Series: Earth and Environmental Science 149. 012027 doi :10.1088/1755-1315/149/1/012027

Putri, R.A., Rinaldi and Sigit Sutikno. 2019. Analisis pengaruh penyekatan kanal terhadap pembasahan di lahan gambut (studi kasus: desa Lukun, kecamatan Tebing Tinggi Timur, kabupaten Kepulauan Meranti) Jom FTEKNIK Volume 6 Edisi 2 Juli s/d Desember 2019 1-8

Sumarga, E., Hein, L., Hooijer, A., & Vernimmen, R. 2016. Hydrological and

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

economic effects of oil palm cultivation in Indonesian peatlands. Ecology & Society, 21(2).

Surahman, A., Shivakoti, G. P., & Soni, P. 2019. Climate Change Mitigation Through Sustainable Degraded Peatlands Management in Central Kalimantan, Indonesia. International Journal of the Commons, Vol 13(2): 859–866. DOI: http://doi.org/10.5334/ijc.893

Taufik, M., A.A. VeldhuizenJ.H.M. WöstenH.A.J. van Lanen. 2019. Exploration of the importance of physical properties of Indonesian peatlandsto assess critical groundwater table depths, associated drought and fire hazard. Geoderma 347:160–169

Uda, S.K., Lars Hein and Elham Sumarga. 2017. Towards sustainable management of Indonesian tropical peatlands. Wetlands Ecology Manage (2017) 25: 683–701

Van BEERS, W.F.J. 1983. The Auger Hole Method. A field measurement of the hydraulic conductivity of soil below the water table. International Institute for Land Reclamation and Improvement/ILRI P.O. Box 45,6700 AA Wageningen, The Netherlands.

Wildayana, E. and M.E. Armanto. 2018a. Dynamics of Landuse Changes and General Perception of Farmers on South Sumatra Wetlands. Bulgarian Journal of Agricultural Science. Vol 24(2), 180-188, April 2018 (SCOPUS Q3). http://www.agrojournal.org/24/02-02.html

Wildayana, E. and M.E. Armanto. 2018b. Formulating Popular Policies for Peat Restoration Based on Livelihoods of Local Farmers. Journal of Sustainable Development. Vol 11(3), 85-95, June 2018. http://www.ccsenet.org/journal/index.php/jsd

Wildayana, E. and M.E. Armanto. 2018c. Utilizing Non-Timber Extraction of Swamp Forests over Time for Rural Livelihoods. Journal of Sustainable Development. Vol 11(2); 52-62, April 2018. http://www.ccsenet.org/journal/index.php/jsd/article/view/72716/41077

Wildayana, E., M.E. Armanto, M.S. Imanudin, and H. Junedi. 2017. Characterizing and Analyzing *Sonor* System in Peatlands. Journal of Wetlands Environmental Managements. Vol 5(2); 6-13, July-December 2017. ISSN: 2354-5844. DOAJ. Web-link: http://ijwem.unlam.ac.id/index.php/ijwem

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

Wösten, J.H., Hooijer, H., Sideris, C. 2006b. Tropical Peatland water management modelling of the Air Hitam Laut catchment in Indonesia. Intlernational Journal River Basin Management Vol. 4(4): 233-244.

Wösten, J.H.M., Van Den Berg, J., Van Eijk, P,G.J. M. Gevers, Giesen, W.B., J.T. Hooijer, A. Aswandi Idris, P.H. Leenman, Dipa Satriadi Rais, C. Siderius, M.J. Silvius, N. Suryadiputra & Iwan Tricahyo Wibisono. 2006a. Interrelationships between Hydrology and Ecology in Fire Degraded Tropical Peat Swamp Forests, International Journal of Water Resources Development. Vol. 22(1): 157-174, DOI: 10.1080/07900620500405973

Journal of Wetlands Environmental Management Vol 9, No 1 (2021) 1 - 21 http://dx.doi.org/10.20527/jwem.v8i2.228 ----- Accredited by Directorate General of Higher Education Indonesia, No. 21/E/KPT/2018,

ORIGINALITY REPORT

12%	12%	1%	12%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Lambung Mangkurat University Student Paper	5%
2	Submitted to Universitas Lambung Mangkurat Student Paper	3%
3	Submitted to Sriwijaya University Student Paper	2%
4	ijwem.ulm.ac.id Internet Source	2%
5	mafiadoc.com Internet Source	1%

Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	Off		