Ground water level of peatlands under different land uses

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ABSTRACT

Fires in Indonesia tropical peatlands are always associated with peatland conversion. Land use change usually occurs from secondary forest or abandoned peatland to agricultural land or plantation. However, land use change in Indonesia is inevitable because high demand of land for food supply and industry. Peatlands which are usually associated with wetlands, become dry due to drainage during land clearing and plant growth process. Therefore, the relationship between ground water level (GWL) and fires on tropical peatlands is close. The research objective is to analyze the level of fire vulnerability on peatlands based on the GWL fluctuation under different land uses. GWL measurement was conducted manually every week from February to December 2014 in the field and ditch on three different land uses. Automatic water level measurement tool also conducted from March to December 2014, but only on the field. The results showed that GWL fluctuation both on ditch and field followed the variation of precipitation. GWL fluctuation under different land uses also significantly different, and automatically results different fire vulnerability.

Keywords: *fluctuation, water level, precipitation, automatic measurement*

INTRODUCTION

Decomposition of organic matter for thousand of years in Southeast Asia swamp forest forms a huge carbon store in the form of peatland (Jauhiainen et al., 2014). Tropical peatland in Southeast Asia cover 24.8 million ha, 56% of tropical peatland total area or 6% of the total peatland area in the world, and estimated contain 68.5 Gt of carbon, or about 11% of the world's total carbon stock (Page et al., 2011). However, the conversion of peatlands in Southeast Asia have been occurred due to the high level of illegal logging in peat swamp forests (Miettinen et al., 2011). In addition, land conversion also occurs due to the high demand of peatlands for agriculture and/ plantations (Miettinen, et al., 2012). The land use change of peatland for plantation or agriculture is usually equipped with drainage for both land clearing and cultivation process. Peatland that associated with swamp forests and usually submerged, turned into dry land or irrigation land for plantations.

The land use change to agriculture and plantation is common in Indonesia peatland due to the high demand of agriculture land, mainly because the high conversion of potential land in

Java island, which encourage the use of suboptimal field such as peatlands (Ashari, 2003, Nursyamsi et al., 2016). In Central Kalimantan, massive conversion of peatland occurred since the failure of Mega rice project (MRP) development that resulted a huge fire in 1997 (Hooijer et al., 2014). The conversion of peatlands to agriculture and plantation purposes will affect the level of groundwater level (GWL). GWL is very important for peatland ecosystems sustainability as well as crop productivity on peat soil. Usually, declining of GWL changes peatland from a carbon sink to a carbon emitter (Couwenberg et al., 2009). Furthermore, lowering of GWL also makes the ground surface become dry and vulnerable to fires (Page et al., 2002; Schrier-Uijl et al., 2013).

On the dry season, the most part in Indonesia peatland is usually experiences to forest fires. The main problem of this condition is due to the drop of GWL condition. Recently, Indonesia Government issued the PP no. 57/2016 as the revision of Government Regulation no. 71/2014 on Peat Ecosystem Protection and Management. One important clause in this rule is about GWL preservation at minimum of 0.4 m below the peat surface. According to the rule, 0.4 m is a safe boundary for unburned peat. Therefore, the GWL

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fluctuation can be used as a standard for peat soil fire vulnerability. Furthermore, GWL level condition also one of the crucial factors for the sustainability of peatland management and related to crop productivity on peatland. The variety of land use are likely to influence the peat soil GWL. Therefore, the groundwater levels on different land uses as one standard for peatland amendment need to be studied. This study objectives is to estimate the peat soil fire vulnerability related to the fluctuation of ground water level on different land use in tropical peatlands.

MATERIAL AND METHOT

Fig. 1. Study plot.

The 2.5 m of ditch was built during a MRP around 1997 and widened on 2012. The water source on the ditch and field only from the rain without water overflow from the other channels. GWL was measured on the field and drainage ditch in each plot. The measurement was conducted by manual and automatic logger. The manual measurement was carried out every week from February to December 2014 on ditch and on the field, that located perpendicularly about 16 m from the ditch. Automatic measurements performed hourly only on the field using an automatic water pressure sensor (U20-001-01, Onset Computer Corporation, USA), from March to December 2014. Both of

measurement were perform in a perforated PVC pipe inserted vertically deep on the peat soil.

The simple seasonal variety of GWL were calculated for each site and land-use type. The linear regression with 95 % confidence interval ($p < 0.05$) was analyzed for the GWL as a function of precipitation. The paired t-test was used to the GWL data of each site.

RESULTS AND DISCUSSIONS

Seasonal variation in precipitation data

Precipitation data (CH) were recorded at a climatic station located at Tjilik Riwt Airport, Palangkaraya (the capital of Central Kalimantan Province; $2^{\circ} 16' 0''$ S, $113^{\circ} 55' 59''$

E), which is about 20 km from the research location, as the most complete daily rainfall data in Central Kalimantan (Fig. 2). The dry season,

which is commonly defined as months with monthly precipitation <100 mm (Hirano et al., 2015), only occurred on July and August.

Fig. 2. Daily precipitation data at Palangkaraya station, Central Kalimantan (BMKG, 2014)

Monthly rainfall ranging from 41 to 610 mm month⁻¹, or about 238.1 mm in average.

GROUND WATER LEVEL

Manual measurement

Similar pattern of ground water level (GWL) fluctuation was showed between the

field and ditch (Fig. 2). GWL was high in the wet season from December to June and low in the dry season from July to November following a seasonal variation in precipitation (Fig. 3). The lowest and the highest GWL results were in LS and in LD, respectively. However, even the lowest rainfall occurs in July, but the lowest of GWL coincide in October with -114 cm and -105 cm for LK and LS, respectively.

Fig. 3. Daily GWL Variations through manual measurements, a) on the field, and b) on the ditch.

Automatic measurements

Hourly automatic measurement showed a detail variation of GWL compare than that of manual measurement. However, the pattern was

similar between manual and automatic measurement where the lowest and highest GWL were measured in LS and LK, respectively (Fig. 4). The lowest GWL also occurs at the end of the 2014 dry season, of

which October reaching -166, -159, and -170, for LK, LS, and LT, respectively.

Result of manual measurement between three different land uses showed no significant different (paired test, $p > 0.05$). However, in contrast, using automatic measurement showed significant different of GWL data between LS, LK, and LT (paired test, $p > 0.05$). It was

indicated that even have similar pattern, but automatic measurement having a better result of GWL data. Particularly, for modelling and prediction, automatic measurement should be considered as important.

Fig. 4. Automatically GWL measurement from 3 different land uses

Factor Affecting Gwl

GWL on the field and on the ditch following the variation of precipitation (Fig. 5). However, when precipitation variate, the GWL not suddenly changed. The lowest precipitation was measured on July, but deepest GWL resulted on October at the same year. It was suggested that the GWL response to precipitation does not necessarily occur, but fluctuates slowly following the precipitation pattern. It was influenced by soil condition and or microclimates condition (A. Meijide et al., 2017). All GWL were significantly affected by precipitation ($p > 0.05$), but not for LK (Fig. 6). The relationship between GWL and

precipitation in LK is not significantly associated. It was indicated that even the main source of GWL is from precipitation, but the vegetation that affect the soil condition probably also have a significant contribution to the GWL fluctuation. GWL fluctuation probably affected by land use changes. Well maintained field especially for plantation tends to have high bulk density that automatically the water repellent capability become better (Wakhid et al., 2017). Kononen et al. (2015), found that different land use change results different peat soil characteristic. In addition, the land fire changed extremely the peat soil characteristic. Then the changing of physical and chemical properties of peat soil also will affect the GWL fluctuation.

Fig. 5. Comparison of GWL and precipitation: a) GWL and precipitation of LK; b) GWL and precipitation of LS; c) GWL and precipitation of LT; d) GWL and precipitation of ditch in LK; e) GWL and precipitation of ditch in LS; f) GWL and precipitation of ditch in LT.

GWL condition in LK was not significantly different to LT ($p > 0.05$), even other land was significantly different. Probably it was related to former condition of LK where the previous LK condition was also a burnt land that used for a rubber crops. Moreover, plant structure density is likely also affect GWL fluctuations. GWL condition in LS is significantly different to others land, of which GWL condition in the field and ditch were deeper (Figs. 3 and 4). This is likely due to a different land use that make the water use were different each other.

Furthermore, the upper peat layer of LT experienced a reduction due to a peat fire. Therefore, the GWL condition was shallower compare to LS with less experienced to peat fires. This shallow GWL condition results were similar to another burning peatland in Central Kalimantan (Hirano et al., 2014). While in LK, GWL tends to be shallower because the land previously also often experienced to fire.

Fig. 6. Relationship between GWL and precipitation: a) GWL and precipitation in LK; b) GWL and precipitation in LS; c) GWL and precipitation in LT; d) GWL of ditch and precipitation in LK; e) GWL of ditch and precipitation in LS; f) GWL of ditch and precipitation in LT.

The GWL fluctuation on ditch showed more affected by precipitation rather than field. Ditch as a free vegetation directly affected by an instance precipitation compare to the field with a vegetation (Fig. 6). Moreover, a ditch also become an accumulation of dissolved peat soil water that usually increase on the rain events. A managed peat land usually having a higher crop productivity, increase the weight of peat soil content, and results better water holding capacity (Kononen et al., 2015). In addition, the soil compaction under dense vegetation cover also affect the water capacity due to the small

soil pore (Hooijer et al., 2012). Although the average of GWL in LT is shallower compare to other field but the peat fire risk level in the field is higher than other land in the dry season. On the dry season, GWL condition in LT is the deepest (Figure 4). In addition, without productive crops, the land is tending to be left without any one care. While in other fields, particularly in LK, the GWL condition was shallow even in the dry season due to the existence of productive crops, and well preserved by land owners.

CONCLUSION

Seasonality of GWL fluctuation in tropical peatland was followed the seasonality of precipitation. Moreover, it was found that GWL under different land use was significantly different. Different vegetation clearly results the different soil condition that contribute to the GWL fluctuation. Peatland reforestation or making an agricultural land for shallow peat is also important because most of the lower GWL condition that vulnerable to peat burning is conducting on grassland or unmanaged peatland. Management of the field including GWL and vegetation is one of better way to prevent the forest fire on tropical peatland.

REFERENCES

- A. Meijide, Alexander Röhl, Yuanchao Fan, Mathias Herbst, Furong Niu, Frank Tiedemann, Tania June, Abdul Rauf, Dirk Hölscher, Alexander Knohl., 2017. Controls of water and energy fluxes in oil palm plantations: Environmental variables and oil palm age. *Agricultural and Forest Meteorology*, 239: 71–85.
- Ashari, 2003. Tinjauan tentang alih fungsi lahan sawah ke non sawah dan dampaknya di Pulau Jawa. Review of rice field conversion and their impact on Java Island. *Agro Economic Research*. Volume 21 No. 2, 83–98.
- Couwenberg, J., Dommain, R., Joosten, H., 2009. Greenhouse gas fluxes from tropical peatlands in South-east Asia. *Global Change Biology*. 16:1715–1732. <http://dx.doi.org/10.1111/j.1365-2486.2009.02016.x>.
- Hirano, T. et al. 2014. Carbon dioxide emissions through oxidative peat decomposition on a burnt tropical peatland. *Global change biology*, 20: 555–65. <http://dx.doi.org/10.1111/gcb.12296>.
- Hirano, T., Kusin, K., Limin, S., Osaki, M., 2015. Evapotranspiration of tropical peat forests. *Global change biology*, 21:1914–1927. <http://dx.doi.org/10.1111/gcb.12653>.
- Hooijer, A., Page, S., Jauhiainen, J., Lee, W.A., Lu, X.X., Idris, A., Anshari, G., 2012. Subsidence and carbon loss in drained tropical peatlands. *Biogeosciences* 9:1053–1071. <http://dx.doi.org/10.5194/bg-9-1053-2012>.
- Hooijer, A., Page, S., Navratil, P., Vernimmen, R., Van der Vat, M., Tansey, K., Konecny, K., Siegert, F., Ballhorn, U., Mawdsley, N., 2014. Carbon emissions from drained and degraded peatland in Indonesia and emission factors for measurement, reporting and verification (MRV) of peatland greenhouse gas emissions-A summary of KFCP research results for practitioners. IAFCP, Jakarta, Indonesia.
- Jauhiainen, J. et al., 2014. Heterotrophic respiration in drained tropical peat is greatly affected by temperature—a passive ecosystem cooling experiment. *Environmental Research Letters*, 9(10), p.105013.
- Könönen, M. et al. 2015. Physical and chemical properties of tropical peat under stabilised land uses. *Mires and Peat*, Volume 16, pp.1–13.
- Miettinen, J., Shi C., and Liew S. C. 2011. Deforestation rates in insular Southeast Asia between 2000 and 2010. *Global Change Biology*, 17, 2261–2270, doi: 10.1111/j.1365-2486.201102398.x.
- Miettinen, J. et al., 2012. Extent of industrial plantations on Southeast Asian peatlands in 2010 with analysis of historical expansion and future projections. *GCB Bioenergy*, 4: 908–918.
- Nursyamsi, D., Noor, M., Maftu'ah, E., 2016. Peatland management for sustainable agriculture. In: Osaki, M., Tsuji, N. (Eds.), *Tropical Peatland Ecosystems*. Springer, Japan. http://dx.doi.org/10.1007/978-4-431-55681-7_34.
- Page, S.E., Siegert, F., Rieley, J.O., Boehm, H.V., Jaya, A., Limin, S.H., 2002. The

amount of carbon released from peat and forest fires in Indonesia during 1997. *Nature* 420: 61–65.

Page, S.E., Rieley, J.O. & Banks, C.J., 2011. Global and regional importance of the tropical peatland carbon pool. *Global Change Biology*, 17: 798–818.

Schrier-Uijl, A.P., Silvius, M., Parish, F., Lim, K.H., Rosediana, S., Anshari, G., 2013. Environmental and Social Impacts of Oil Palm Cultivation on Tropical Peat – A

Scientific Review. Round table on Sustainable Palm Oil (Kuala Lumpur, Malaysia).

Wakhid, N., Hirano, T., Okimoto, Y., Nurzakiah, S., Nursyamsi, D., 2017. Soil carbon dioxide emissions from a rubber plantation on tropical peat. *Science of Total Environment*. 581–582: 857–865.
<http://dx.doi.org/10.1016/j.scitotenv.2017.01.035>.