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Water-table Depth and Peat Subsidence Due to Land-use Change of Peatlands

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Abstract. The aims of the study were to reveal changes in the water-table depth and peat subsidence due to land-use change in West Kalimantan. The location of the study is peatland in Kubu Raya District-West Kalimantan, namely on four types of peatland-use, including secondary peat forest (SPF), shrubs (SB), oil palm plantation (CPP) and corn field (CF). The research parameters include depth of groundwater and peat subsidence. The results show that the conversion of peatland to other peatlands causes an increase in peat subsidy. The research parameters include water-table depth and peat subsidence. The results show that the land-use change of peatlands to other peatlands causes an increase in peat subsidence. The increase in subsidence in measurement II (October 2016) coincides with an increase in water-table depth and measurement V (April 2017) of 74.6%-90.9%. There is a tendency to increase water-table depth in August and October 2016 and January 2017, especially on SB, OPP and CF. SPF has a deeper water-table depth and deeper subsidence than other land. This is due to the deeper peat soil depth of the SPF (509 cm) while the other relatively shallow areas range from 108.2 to 115.5 cm. The correlation between water-table depth and subsidence shows a close relationship and significant ($p<0.01$, $r = 0.824$).

1. Introduction

The peatland is one of many wetland types the most endangered in Indonesia because of human activities. The conversion of peat swamp forests into plantations and production forests can threaten the existence and destruction of the land. The greatest peat land damage occurring through deep drainage can lead to a decrease in the water table-depth resulting in changes in natural ecosystem from anaerobic conditions to aerobic, excessive drying with irreversible drying and compaction ([1], [2], [3], [4], [5]). Uncontrolled burning can increase decomposition of the peat involving loss of peat soil organic matter and increased CO_2 emissions of soil into the atmosphere [5].

The components of peat subsidence consist of oxidation, compaction and shrinkage and peat consolidation [6]. These processes together affect the subsidence of peat. Peat oxidation includes peat decomposition in the aerobic zone above the soil surface causing decomposition of peat organic matter and the release of CO_2 emissions into the atmosphere [7], [8]. The process of compaction and shrinkage is a process that cannot be separated as compaction [6]. These processes encourage increased bulk density. Peat consolidation occurs due to the compression of saturated peat below the water-table depth and caused by loss of buoyancy of the top peat. The primary condolidation is caused by the loss of water from the pores of the peat soil, it occurs rapidly when water-table depth is released, especially in the presence of drainage systems. Secondary consolidation is a function of the resistance of the solid peat is a slow process [6].

The aims of the study were to reveal changes in the water-table depth and peat subsidence due to land-use change in West Kalimantan. This study is one of several studies of land, characteristics of physical, chemical and biological of peat soil and CO_2 emissions from some peatlands in Kubu Raya Regency, West Kalimantan Province.

2. Methods

2.1. Study area and land conversion history

Location of the study is peatland in Kabupaten Kubu Raya, West Kalimantan consisting of 4 types of peat land uses, namely: secondary peat forest (SPF), shrubs (SB), oil palm plantation (CPP) and corn field (CF). Secondary peat forest as the control location of all objects of research is forest changed where its vegetation has been cleared at the beginning of land clearing for agricultural land development and settlement areas of the National Transmigration Program since the 1980's. Nevertheless, the current condition of the observation is still a forest area whose vegetation is about 25 years old.

The shrubs are a former secondary forest that has undergone further disruption. So that, potency of the forest is limited, such as scrub and undergrowth. Oil palm plantation at the location of study was opened around early 2000 and gradually until 2010. The initial development of oil palm plantations includes secondary forest and shrubs burning and secondary and tertiary drainage making. Corn field is a farmland managed by the community independently. The planting of corn is done gradually, such as burning, processing and fertilizing the land every two times a year. The garden is surrounded by tertiary drainage (Figure 1).

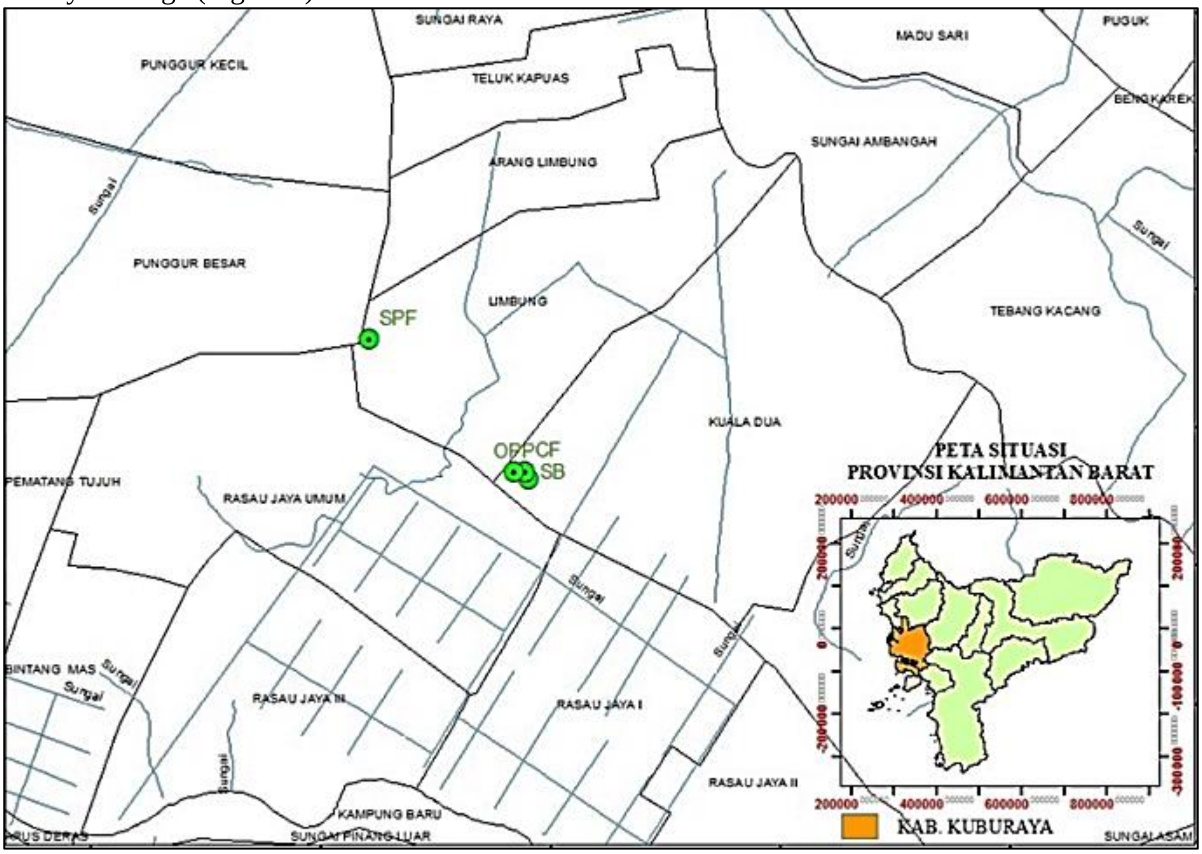

Figure 1. Sampling sites on the study area of secondary peat forest (SPF), shrubs (SB), oil palm plantation (OPP) and corn field (CF)

2.2. *Sampling and Measurements*
This research activity includes observation and measurement in field and analysis of research data. The workings both in the field and in the laboratory are outlined based on the research purposes. Each location of study was taken 5 (five) sampling points as replicates. Each of the four land types has 20 samples. The research parameters include water-table depth and subsidence of peatland

Each sampling point of water-table depth data collection is counted based on the distance of the water level to the soil surface. The subsidence of peatland are measured by the scale of decreasing on the stakes listed and fixed permanently into the soil. That subsidence is sized by cm units within 2 months. The water-table depth is used by cm units in a period of 10 days (3 times per month). The collecting data of the study is quantitative data, including parameters of water-table depth and peat subsidence. All data is tabulated and presented in table with standard deviation (SD).

3. Results and Discussion

3.1. *Water-table depth*
Based on land type, water-table depth of SPF is the deepest. It is significantly from other land types (OPP, SB and CF). The water-table depth average of SPF from June 2016 to March 2017 is 51.9 cm, 54.7 cm, 57.2 cm, 60.7 cm, 54.3 cm, 56.3 cm, 61.6 cm, 52.9 cm, 54.7 cm, and 60.2 cm, respectively. The lowest water-table depth in land of CF is following 23.9cm, 26.8cm, 47.6cm, 32.0cm, 34.2cm, 31.7cm, 32.9cm, 39.2cm, 35.6cm, 29.8 cm, 28.7 cm, and 48.7 cm. Based on the timing of the measurements, the deepest water-table dept is in August 2016. Furthermore, November 2016, December 2016 and April 2017 are relatively shallower than others (Figure 2). There is a tendency for differences in the water-table depth on agricultural land, where CF is more shallow than OPP whereas the land of SB is similar with OPP.

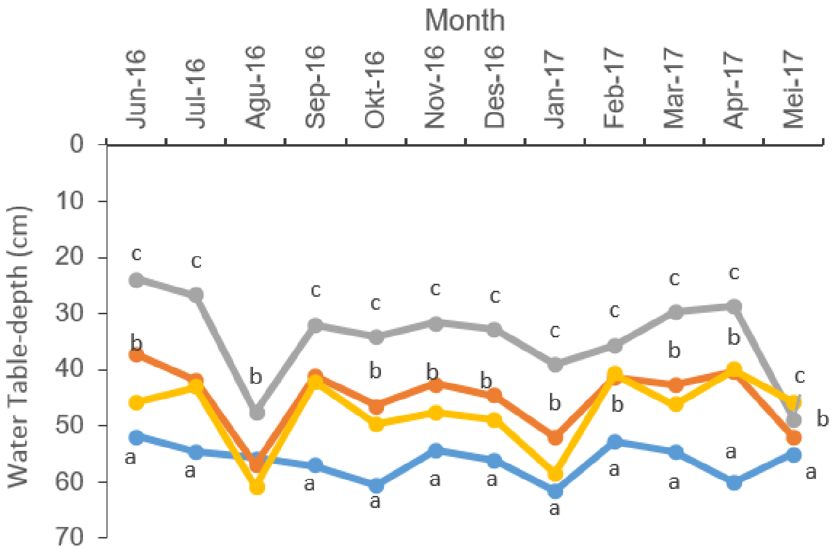

Figure 2. Water-table depth on SPF (blue), SB (orange), CF (gray) and OPP (yellow) for measurement from June 2016 to April 2017. Different letters show significant differences (P <0.05)

3.2. *Subsidence*
Based on land types, peat subsidence of SPF is the deepest. SPF is quite distinct from the other land types. Whereas, from the first to the fifth measurements, land types of SB, CF and OPP are not significantly dissimilar in July, October and December 2016, February and April 2017. The means of the measurements (from I to V) of SPF, SB, CF, OPP are successively 3.3 cm, 2.2 cm, 1.8 cm and 1.7 cm. The measurements of OPP the subsidence tends to increase from the first measurement to the fifth

measurement in April 2017. The fourth land types (SPF, SB, CF and OPP) have subsidence from 74.6% to 90.9% (Figure 3). The three fields (SB, CF and OPP) have almost the same subsidencies.

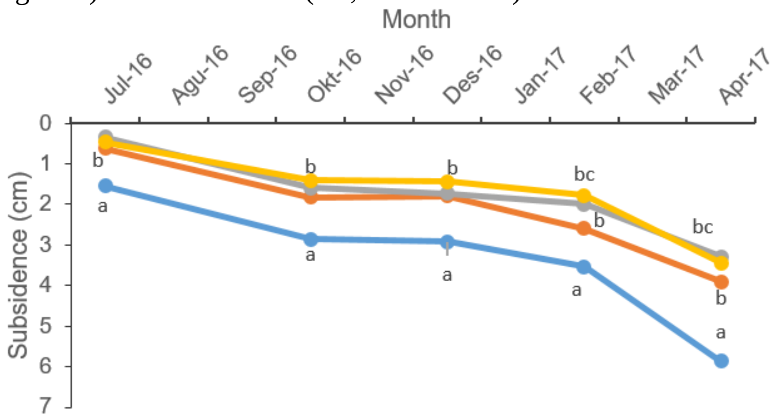

Figure 3. Peat subsidence on SPF (blue), SB (orange), CF (gray) and OPP (yellow) for measurement from June 2016 to April 2017. Different letters show significant differences (P <0.05)

3.3 Effect of peat depth and rainfall on water-table depth

The land of OPP, CF and SB have a shallower water-table depth than SPF, among others: (1) duration of land treatment that has been done mainly on OPP and CF indicated on the age of oil palm, 8-10 years, and the presence of vegetation around (2) peat depth of the SPF is deeper (509 cm) while the other land ranged from 108.2 to 115.5 cm. In SPF land has deeper water-table depth, the condition is supported by the depth of peat soil where SPF land has deeper depth of soil. In relatively shallow peat the ability to hold water is smaller than deep peat. According to [9] in Siak-Riau, that peat swamp has 1 m face of ground water 0.1 m whereas on ground soil 2 m has 0.2 m ground water face. (3) the surface of the deeper land is relatively unequal because of its position against the peat dome

The trend of water-table depth on all types of land at the time of measurement in August 2016 is deeper. This is due to low presepitation and the day of rainfall (40.6 mm - 7 days) whereas June 2016, November 2016, December 2016 and April 2017 are relatively shallower with presipitation and rainy days 461.4 mm-18 Day, 382.2 mm-24 days, 570.9 mm-21 days (Figure 4).

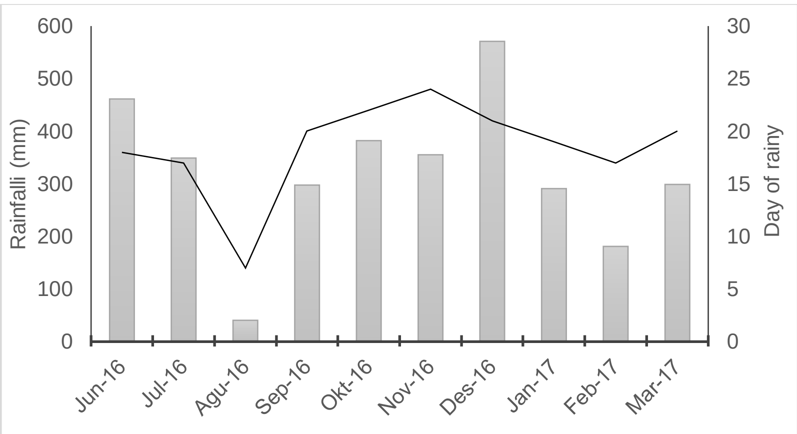

Figure 4. Rainfall (bar) and rainy day (line) from June 2016 to March 2017

3.4 Effect of water content, bulk density and ash on peat subsidence

The physical and chemical properties of peat generally differed between land uses. The differences reflect changes occurring from every land-use activity such as land clearing, tillage and drainage. Such activities can accelerate subsidy processes as indicated by decreased water content and increase in bulk density and ash content on SB, CF and OPP (Table 1).

These differences in properties can be interpreted as a process of peat breakdown (biological decomposition and physical processes). Especially after drainage enhancements (volume and amount), processes including compaction and shrinkage, and consolidation result in an increase in peat bulk density ([6], [13], [14], [15]). Accordingly, peat bulk density was higher in drained land than in undrained forest. The profiles of bulk density can describe the oxidation and compaction process which is a component of subsidency [9]. The process of peat oxidation shows the decomposition of peat into mature peat, one of which is characterized by high ash content.

3.5 Water-table depth in relation to peat subsidence

The subsidy of peat soils on SPF land is deeper than the other land. The similar trend is indicated by the water-table depth pattern. There was a substantial increase in subsidy during the second measurement period (October 2016) and IV (February 2017) along with an increase in water-table depth in the same month (Figure 2). At the site of the study, land burning (November - December 2016) and maize planting around SPF land in January 2017.

There is a close correlation between water-table depth and subsidence and is significantly different ($p <0.01$, $r = 0.824$). References [16] suggest that a deep water table means increasing peat subsidency caused by oxidation as well as increased vulnerability of peat mechanics to fires. The same opinion is also found.

Table 1. Water content, bulk density and peat ash on secondary peat forest, shrubs, corn filed and oil palm plantation [12]

Land-use	Water content (%)	Bulk density (g cm^{-3})	Ash (%)
Secondary Peat Forest (SPF)	73.50 ± 6,60	0.14 ± 0,03	2,60 ± 1,29
Shrubs (SB)	71.15 ± 9,05	0.17 ± 0,02	4,30 ± 0,91
Corn field (CF)	71.97 ± 2,99	0.16 ± 0,02	4,01 ± 1,42
Oil Palm Plantation (OPP)	68.91 ± 10,96	0.22 ± 0,04	3,85 ± 0,19

By [9] that the linear correlation regression between groundwater level (WD) and subsidency (S) in acacia after 6 years of over-draining is 0.21 (S = 1.5 - 4.98 x WD) . In degraded forest 0.35 (S = 0.41 - 6.04 x WD).

The results of this study illustrate that the subsidy of SPF land is greater than maize plantation and oil palm plantation. This is in contrast to some theories that reveal that natural peatlands have low subsidency even close to 0. Conditions at the study sites indicate that mainly OPP and CF fields have been processed from the 1980s with intensive processing from burning, tillage to planting plants and there is a community settlement as its owner. SPF until 2010 is still a natural peatland and located far from the settlement but in the last two years communities and companies began to open land for agricultural activities and corporate road access.

Soewandita [9] reveal that after the initial years of subsidency, the rate of compaction and peat oxidation reaches equilibrium. This is clarified by the mean subsidence data on acacia plantations 1 year after drainage and 4 years, 75 cm and 67 cm, respectively. In the oil palm after 18 years drained subsidency 5.4 cm year-1. Also indicated from the weight value of the contents in 3-7 years and 18 years after the drainage is the same. This indicates that there has been a primary consolidation and even peat compaction [9]. This clarity may explain that there has been a natural conversion of peatland to the SPF and a rapid increase in water-table depth and peat subsidence. The same thing happened at the beginning of the conversion of peatland on SB, OPP and CF begins on land preparation.

4. Conclusions

These findings indicate that the increase in water tabel and peat subsidence in secondary peat forest currently illustrates that the same process occurs at the beginning of the conversion of peatlands on shrublands, oil palm and maize gardens at the start of cultivation. Conversion from natural peat forest causes an increase in water table and peat subsidence quickly, especially early drained land.

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