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Land Subsidence in Peatlands Due to Rainfall: Case Study in Pundu, Central Kalimantan

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ABSTRACT

Land subsidence can be caused by peatland soil compaction, drainage practices, an extended dry season, or both. But what frequently happens is drainage brought on by land conversion or by little rain during the dry season. The purpose of this study is to ascertain how much rainfall impacts peat land subsidence. From September to December 2019, the study was carried out at Katari Estate, PT BGA, TBK. Pundu, Central Kalimantan. The survey method is the one that was employed for the study, and it consists of two stages: the preliminary survey and the major survey. While the primary survey was done to collect research data, such as monthly rainfall data and land subsidence during 2014 to 2018, preliminary surveys were carried out to choose study areas. On lag 1, lag 2, and lag 3, linear and polynomial regressions were performed to examine the link between rainfall and land subsidence. The findings demonstrated that the annual Linear Regression Lag 1 was the optimum regression between rainfall and land subsidence on peatlands. This indicates that this year's land sinking was influenced by the rainfall from last year. according to the formula Y = -0.004 X + 1.209, where R2 = 0.582. This equation is derived from the association between Y, which is land subsidence from 2015 to 2018, and X, which is average rainfall from 2015 to 2018. The regression between previous month's rainfall and this month's land subsidence each year (from 2015 to 2018) reveals a weak association.

Keywords*: Rainfall, Land Subsidence, Peatland, Regression, correlation*

1. INTRODUCTION

The primary source of water for plantations or agriculture is rainfall. There are three different forms of rainfall in Indonesia: 1) the monsoon pattern, which has a U-shaped pattern with one peak of low rainfall. 2) The Munson pattern's opposite, the equatorial pattern, and 3) The pattern local, which is a pattern of precipitation with two peaks like the letter M. 2018's Prasetyo & Pusparini There are two peaks of rainfall in a year in Central Kalimantan, which has an equatorial rainfall pattern. However, as a result of global warming, there may be climate anomalies or changes that cause the peak of the rainfall to shift.

In Central Kalimantan, there are numerous oil palm plantations that are either owned by PBS (big private businesses) or by smallholder oil palm plantations. Peatlands are currently being created as a result of the growth of oil palm plantations.

Papua Island (2,425,523 ha), Sumatra Island (1,767,303 ha), and Kalimantan Island (1,048,611 ha) make up the majority of the estimated 5,241,473 ha or 35.17% of the total area of Indonesian peatlands that are suitable for cultivation (Masganti et al., 2020)

Peatlands, however, present a number of challenges when used for agricultural or plantation purposes, including: 1) flooding; 2) irreversible drying; 3) sinking after drying (in drainage); 4) limited carrying capacity; 5) acidic pH; 6) low macro and micronutrient content; Masganti and colleagues 2020

The subsidence of peat after the peat is drained is one of the properties of peat that impacts the productivity of peat.

According to Pratama et al. (2020), peat fires and the protracted dry season both contribute to ground subsidence. According to the study's findings (Aswandi et al., 2017), the amount of peat soil surface has decreased as a result of changes in land use and the installation of drainage canals. a loss in carbon of 38.54–58.52 percent. The maximum annual land subsidence is 5.6 cm.

According to van Asselen et al. (2018), peat oxidation and compaction are the main causes of ground sinking. El Nino and La Nina, two climate abnormalities, are to blame for the prolonged dry season. La Nina is a wet dry season, whereas El Nino is a protracted dry season or dry dry season.

If this sinking is not stopped, the peat's thickness will gradually decline over time, which will be detrimental to the ecology because bog serves an essential role as a carbon and water reserve for the existence of all living things (Budi Triadi, 2020). According to the American NGO Greenpease, if peat as a source of carbon runs short, life as we know it will be wiped out. This is undeniable since only living creatures that contain chlorophyll are able to receive solar energy, which is only available to plants. A photosynthetic process is required to utilize solar energy, and the basic materials for this process are CO2, which is produced when peat decomposes, and H2O, which plants absorb from the soil as a result of rainfall (Holl et al., 2020). There has never before been any study that looks at how rainfall affects land sinking. When does rainfall have an impact on peat soil subsidence.

Examining the variables that affect the subsidence of the peat soil, such as rainfall, but which rainfall affects the subsidence of the peat, is required to sustain the presence of peat. According to the preceding statement, research into how rainfall affects peat subsidence is required. So that measures can be taken to stop or slow down the collapse of peatlands, research is being done to determine how rainfall affects peatland subsidence.

It is understood that a number of causes, such as oxidation (decomposition) brought on by drainage activities, soil compaction during land clearing, (c) There is a protracted dry season, which is correlated with rainfall. the underdog. The type of rainfall that affects the subsidence of the peat soil is still unknown, though. Is this rain from last month or last year? The amount of water in the peat soil will vary depending on the amount of rainfall. If the rainfall is heavy, the area will be flooded or the soil will become anaerobic (reductive), but if the rainfall is light, the water table will drop and the soil will become aerobic (oxidative). Due to the decomposition of the organic matter that makes up peat soil, this oxidative soil state promotes land sinking in peat soil. However, it is important to investigate if rainfall affects soil subsidence in peatlands. especially in Central Kalimantan's peatlands. Studying the formation of the link between rainfall and soil subsidence in peatlands is equally important.

2. MATERIALS AND METHODS

2.1. Time and Place of Research

The study was conducted from August to October 2019 in one of the plantations in PT. BUMITAMA GUNA JAYA AGRO, East Kotawaringin Regency, Pundu District, Central Kalimantan Province.

2.2. Research Techniques

This study was carried out using a survey approach that had two stages, a preliminary survey and a main survey. The purpose of the preliminary survey is to choose the site of the study. To gather the necessary data, the primary survey was carried out.

The study site was chosen from PT Bumitama Gunajaya Agro's (PT. BGA) plantation because it has mature peat, particularly saprik peat, and it is a good place to examine subsidence and rainfall. Rainfall data from 2014 to 2018 and data on soil subsidence from 2014 to 2018 were gathered for this investigation.

2.3. Data Analysis

Simple regression analysis is employed in several models, including Linear and Polynomial Regression models, to determine the link between rainfall and soil subsidence, and the maximum R2 is sought (close to 1).

3. RESULTS AND DISCUSSION

A. Research Location

The research site was Block G-55a, Katari Agro Estate (KAGE), specifically the block whose land is composed of Sapris peat soil, known as *TYPIC HAPLOSAPRIST* according to soil taxonomy and located in Division 5 of Region 3B of PT. BGA.

B. Rainfall

Data from the Katari Agro Estate (KAGE) Afdeling office from 2015 to 2018 is shown in table 1.

Table 1 Monthly rainfall at PT. BGA. Tbk. Pundu, Central Kalimantan (2014 – 2018)

Moth	**RAINFALL YEAR**					**Average**
	2014	2015	2016	2017	2018	**RAINFALL** /Month
January	215	223	348	277	61	227
February	239,5	220	406	284	142	263
March	254	297	302	437	342	344
April	252,5	424	425	351	521	430
May	409,5	228	354	174	161	229
June	270,5	238	126	126	153	161
July	35	95	126	141	41	101
August	10	43	11	112	176	85
September	7,5	-	228	124	303	164
October	21	156	368	103	332	240
November	273,5	476	437	132	635	420
December	400	386	129	371	374	315
CH mm/Th	2.388	2.783	3.258	2.632	3.241	2.979

Table 1 contains data about rainfall. Then, as shown in figure 1, a monthly rainfall chart is created every year from 2015 to 2018 as well as a monthly average rainfall chart from 2015 to 2018 in order to determine the rainfall pattern in PT. Bumitama Guna Jaya. Tbk. Pundu Central Kalimantan. The average rainfall pattern from 2014 to 2018 at PT. Bumitama Guna Jaya. Tbk. Pundu, Central Kalimantan, may be seen in chart 1 as an equatorial pattern. The Equatorial rainfall pattern is a monthly pattern with 2 (two) rainy seasons, which occur in April and November.

The monthly rainfall graph for each year, from 2015 to 2018, is somewhat different. Because of the dynamics in the graph's structure, a climate anomaly might exist. The graph looks like this.

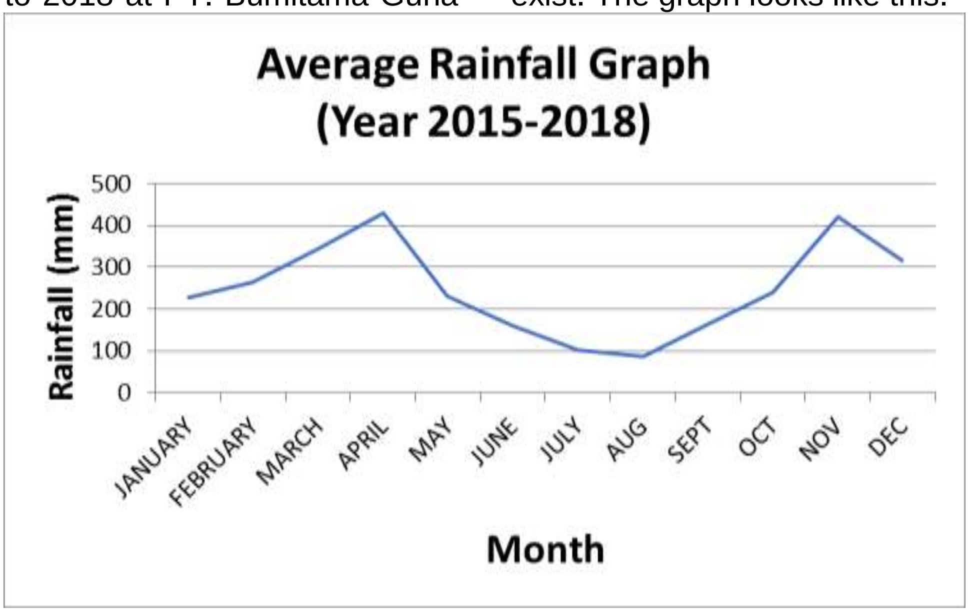

Figure 1. Graph of Average Monthly Rainfall from the year (2015 – 2018) at PT. BGA. Tbk.

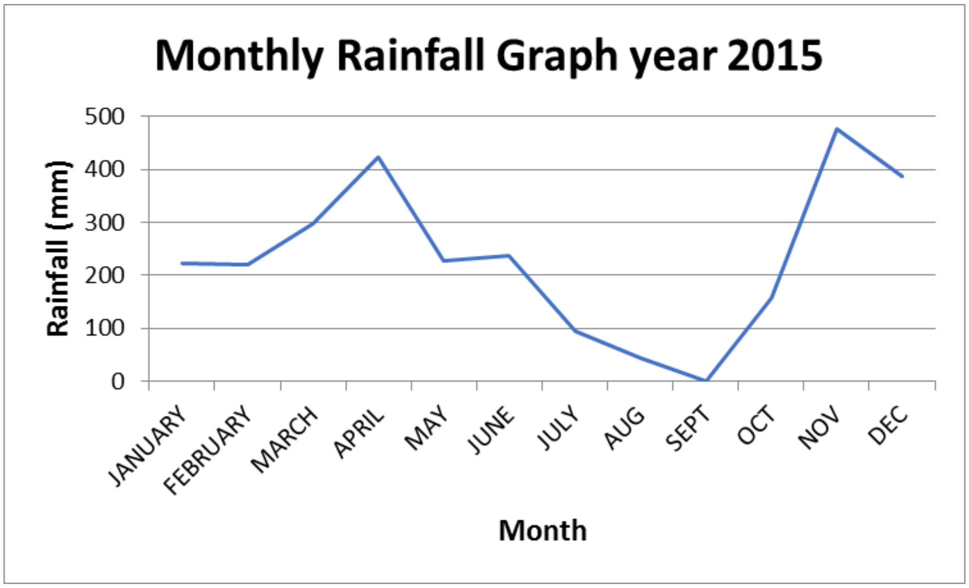

Figure 2. 2015 monthly rainfall graph

The monthly rainfall graph for 2015 reveals that there were two (two) rainfall peaks, which happened in April and November. This demonstrates that the Equatorial Rainfall Pattern is the predominant one in Central Kalimantan. There was an El Nino in 2015. (long dry season)

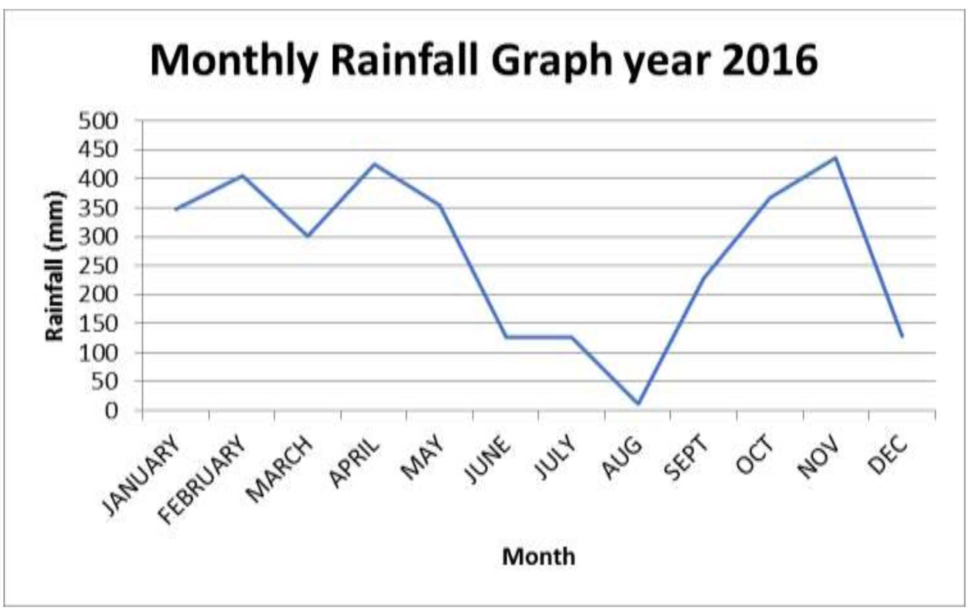

Figure 3. 2016 Monthly Rainfall Graph

Figure 3 displays the monthly rainfall dynamics that have changed or are different from those of 2015. There were three rainy season peaks in 2016, occurring in February, April, and November. This is apparently because a climate anomaly in 2015 led to an El Nino, which was followed by a La Nina the following year (wet dry season).

In addition, Figure 4's depiction of the rainfall dynamics in 2017 is worth a look. Here shows where the rainiest month is, which is unusual because the total amount of rain in 2017 (2632 mm) is quite low compared to the years before and after. Then, as seen in Figure 5, if we examine the dynamics of rainfall in 2018. If we look at Figure 5's graph, the 2018 peak of rainfall is followed by two additional peaks in April and November, indicating an equatorial trend, and then the amount of rainfall returns to normal, or 3241 mm.

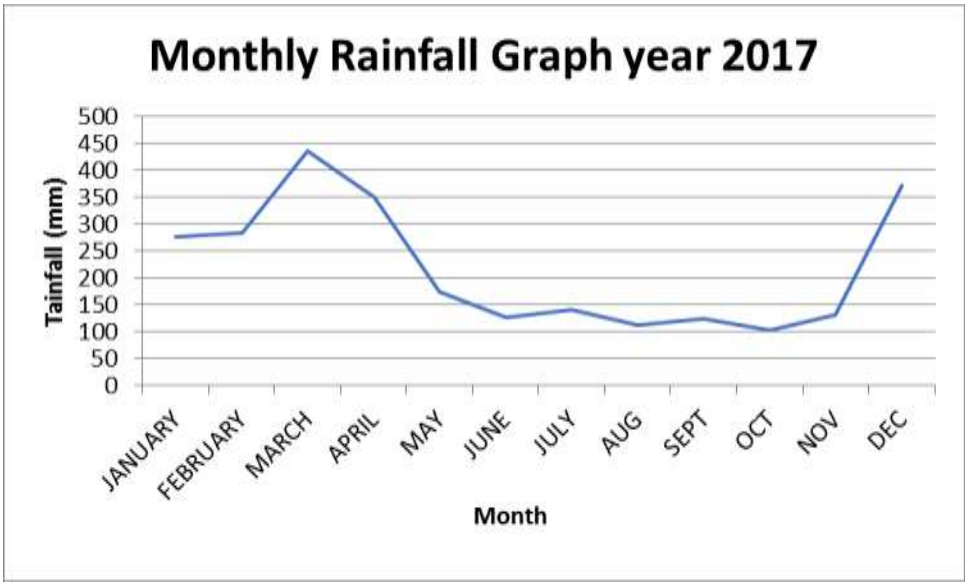

Figure 4. Monthly Rainfall Graph for 2017

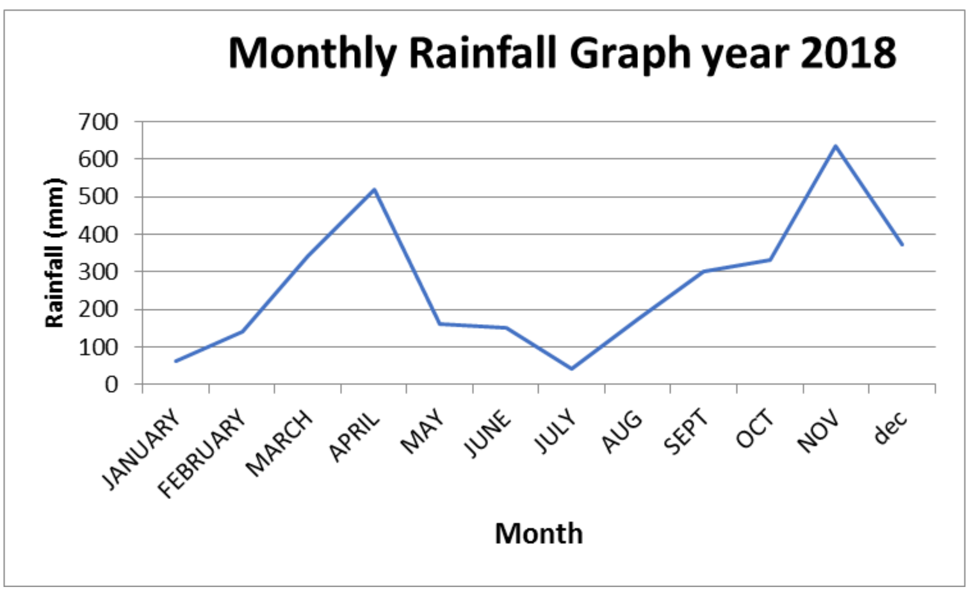

Figure 5. Monthly Rainfall Graph for 2018

Changes in the average rainfall patterns in numerous Indonesian regions provide evidence of the phenomenon of climate change in that country (BMKG, 2021). According to the study's findings, an equatorial rainfall pattern can be seen in the average rainfall from 2015 to 2018. However, a very noticeable change can be seen if you examine the annual rainfall pattern from 2015 to 2018. According to study (Jayanti, 2016), changes in rainfall patterns lead to shifts in the seasons.The pattern of precipitation will shift in the fifth year, which will result in a change in the seasons, after returning to normal in the preceding four years. In this instance, it is anticipated that it will return to 2015 in 2019. This is what we need to be on the lookout for, and we can utilize it to get ready for how to prevent land sinking in peat.

Table 2. *Subsidence of peat soil in block G 55a, PT. BGA. Tbk. Pundu, Central Kalimantan*

Months	***PEAT SUBSIDENCE IN BLOCK G 55a***				**Average**
	2015	**2016**	**2017**	**2018**	
January	0	2,2	-0,6	-0,6	0,25
February	-0,5	-0,2	-0,2	0,6	-0,07
March	0,2	-0,2	3,8	-2,4	0,35
April	0,7	0	-0,8	0,8	0,18
May	0,4	0,2	-0,2	0,4	0,2
June	0,5	1,6	0,6	1	0,93
July	1,2	-1	-0,2	1,5	0,38
August	0	2,1	0,3	0,5	0,73
September	2	1,1	0,3	-0,5	0,73
October	0,8	-0,4	-0,2	-0,5	-0,07
November	-0,8	-1,4	1	0	-0,3
December	-1,2	-1,2	0,8	-0,5	-0,53

A. Soil subsidence

The dynamics of peat sinking in Afdeling Katari PT BGA, Tbk. Pundu Central Kalimantan from 2015 to 2018 are shown in Table 2. In Figure 6, a graph of soil subsidence in peat over four years, from 2015 to 2018, is displayed. A positive value implies that the soil subsidence brought on by accelerated decomposition due to aerobic (oxidative) soil atmosphere produced by insufficient rainfall (subsidence). High numbers of increasing or rising ground levels as a result of rain and flooding of peatlands are indicated by negative numbers (-).

The rate of soil subsidence (subsidence of the soil surface) on land is highest in June, August, and September, as can be seen in Figure 6 above.

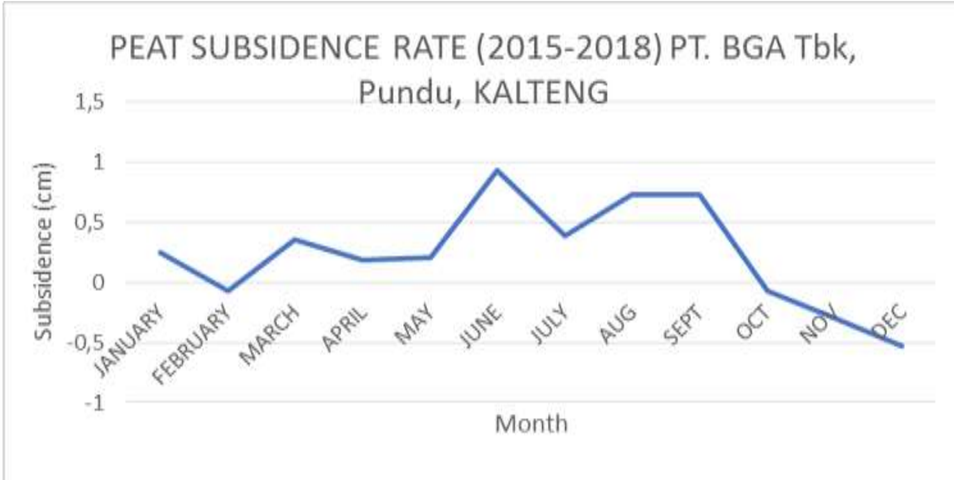

Figure 6. land subsidence on peat land in (2015 – 2018) PT. BGA Tbk

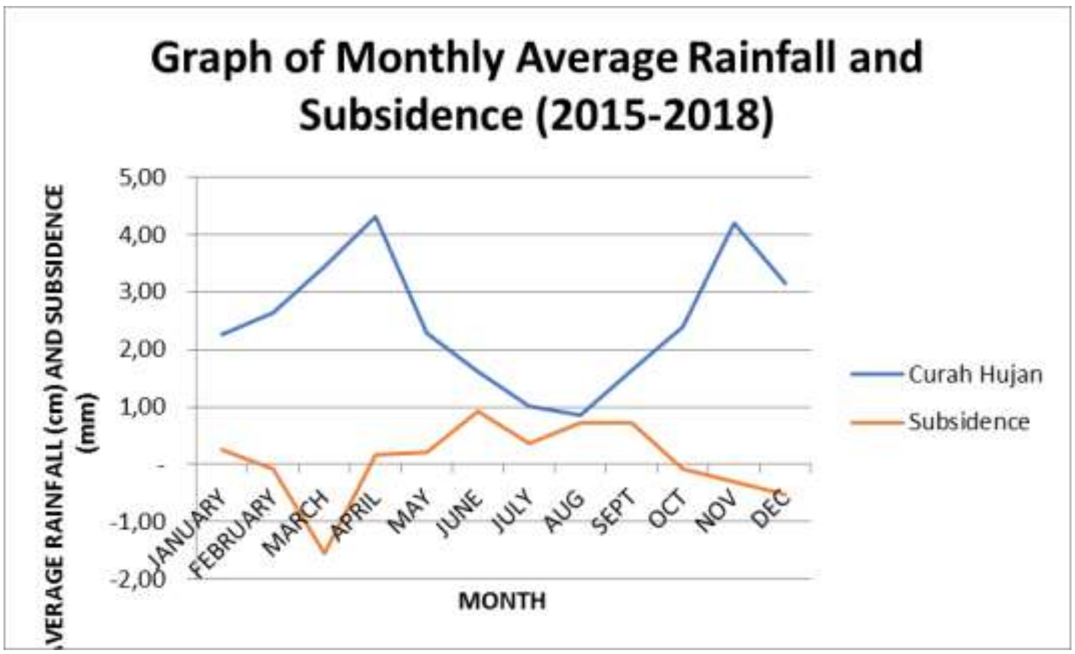

Figure 7. Graph of Monthly Average Rainfall and Subsidence (2015-2018)

The monthly averages of rainfall and soil subsidence from 2015 to 2018 are shown in Figures 7 and 8. Figuring 7. As can be seen, when rainfall is low (as in June, July, and August) and subsidence is high (as in March, April, and October and November), respectively. When rainfall is high (as in March, April, and October and November), however, there is no soil subsidence on peatlands; instead, there is elevation of the land surface (LUMP UP). The following simple linear and polynomial regressions must be used to conduct a regression analysis of the link between rainfall and subsidence in order to ascertain the extent to which rainfall impacts land subsidence.

A. The relationship between rainfall and subsidence

The average subsidence and rainfall statistics for the years (2015–2018) for PT. BGA Tbk. Pundu, Central Kalimantan, are shown in Table 3. Table 4 provides more information on the connection between rainfall and peat soil subsidence.

Table 3. Data on average land subsidence and rainfall for the year (2015 – 2018)

Months	**SUBSIDENCE (cm)**	**CH (cm)**
January	0,25	2,3
February	-0,07	2,6
March	0,35	3,4
April	0,18	4,3
May	0,2	2,3
June	0,93	1,6
JUly	0,38	1,0
August	0,73	0,9
September	0,73	1,6
October	-0,07	2,4
November	-0,3	4,2
December	-0,53	3,2

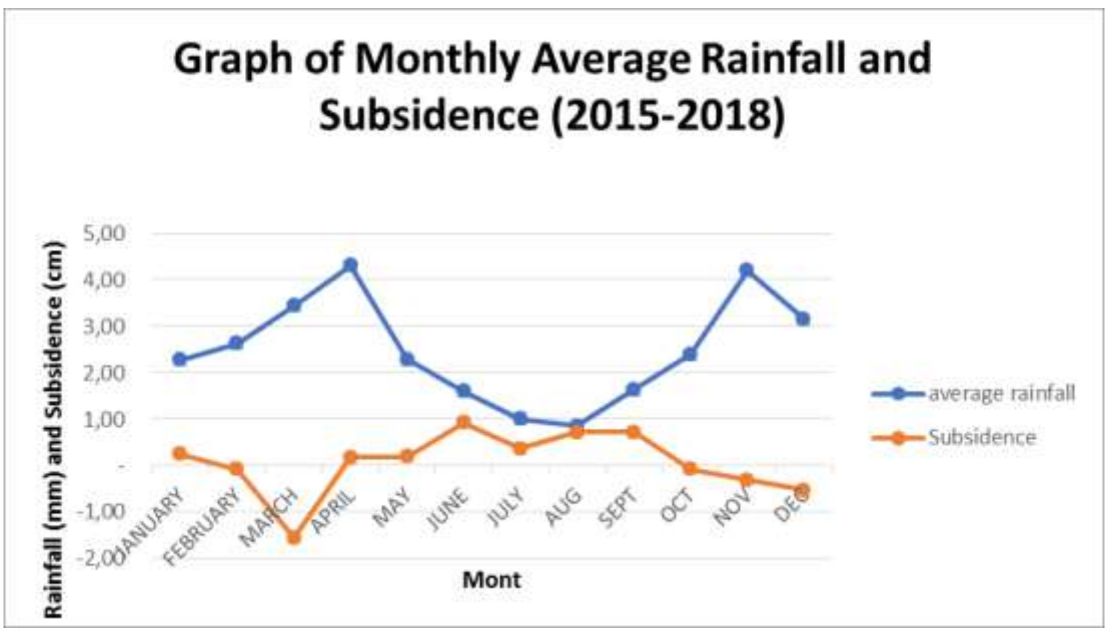

Figure 8. Graph of Subsidence Relationship with Rainfall (average) per month 2015-2018

Regression analysis was done between the current year's rainfall and the subsidence of lags 0, 1, 2, and 3 in 2015, 2016, 2017, and 2018 accordingly. Then, using lags of 0, 1, 2, and 3, a regression analysis was conducted between rainfall and average subsidence from 2015 to 2018. Table 4 shows that for the monthly regression for each year, the regression in 2015 had the highest R2 at lag 0, as shown by the equation Y = -0.038x + 1.163 with R2 = 0.414, however there was no significant link in 2016. While in 2017, the polynomial regression equation at lag 0 was Y = 0.009x2 - 0.457x + 4.442 with R2 = 0.732, showing a link between rainfall and subsidence. Additionally, there is no discernible connection between monthly rainfall and sinking in 2018. Since the linear regression is negative (-), the higher the rainfall, the lower the sinking, as indicated by the monthly lag regression of 0, there is a relationship between monthly rainfall and monthly land subsidence. According to negative polynomial regression, however, the converse is true up to a certain amount of rainfall: the higher the rainfall, the lower the subsidence. The equation Y = -0.403 X + 1.029 with R2 = 0.582 represents the best annual regression between rainfall and subsidence, while the best linear regression between rainfall and subsidence is achieved with positive lag 1. This equation, which indicates that the rainfall from the previous year caused the sinking this year, is more acceptable. It was said by van Asselen et al. (2018).

Table 4. Regression Analysis Results between Rainfall and Land Subsidence

Years	**Lag**	**Regresi Linier**	**R^2**	**Regresi Polinomial**	**R^2**
		Monthly regression			
2015	Lag-0	y = -0,038x + 1,163	0,414	y = 0,000x^2 - 0,067x + 1,387	0,437
	Lag-1	y = -0,015x + 0,774	0,096	y = 0,000x^2 - 0,020x + 0,809	0,097
	Lag-2	y = 0,003x + 0,452	0,005	y = 0,001x^2 - 0,087x + 1,072	0,357
	Lag-3	y = -0,002x + 0,544	0,002	y = -0,000x^2 + 0,007x + 0,482	0,005
2016	Lag-0	y = -0,028x + 0,996	0,104	= 0,000x^2 - 0,043x + 1,115	0,105
	Lag-1	y = 0,019x - 0,161	0,058	y = -0,002x^2 + 0,158x - 1,249	0,199
	Lag-2	y = 0,008x + 0,318	0,013	y = 0,002x^2 - 0,091x + 1,095	0,108
	Lag-3	y = 0,024x + 0,040	0,113	y = 0,001x^2 - 0,049x + 0,602	0,163
2017	Lag-0	y = 0,041x - 0,528	0,165	y = 0,009x^2 - 0,457x + 4,442	0,732
	Lag-1	y = 0,038x - 0,470	0,138	y = -0,002x^2 + 0,145x - 1,527	0,158
	Lag-2	y = -0,023x + 0,767	0,052	y = -0,007x^2 + 0,381x - 3,171	0,243
	Lag-3	y = -0,028x + 0,842	0,044	y = 0,003x^2 - 0,177x + 2,240	0,054

2018	Lag-0	y = -0,015x + 0,450	0,078	y = $0,001x^2$ - 0,106x + 1,458	0,283
	Lag-1	y = -0,037x + 1,168	0,404	y = $-8E\text{-}05x^2$ - 0,032x + 1,100	0,405
	Lag-2	y = -0,003x + 0,174	0,002	y = $-0,000x^2$ + 0,018x - 0,098	0,012
	Lag-3	y = 0,002x + 0,080	0,001	y = $-2E\text{-}05x^2$ + 0,003x + 0,063	0,001
2015 – 2018		Annual regression			
	Lag-0	Y = -0,037x + 1,005	0,406	Y = $0,001x^2$ - 0,111x + 1,799	0,473
	Lag-1	Y = -0,043x + 1,209	0,582	Y = $-0,001x^2$ + 0,033x + 0,401	0,655
	Lag-2	Y = -0,005x + 0,300	0,009	Y = $0,002x^2$ - 0,13x + 1,584	0,184
	Lag-3	Y = 0,018x - 0,234	0,098	Y = $0,000x^2$ - 0,000x - 0,046	0,102

That although compaction also plays a role in land sinking, oxidation has a larger role. This indicates that the subsidence of peat soil takes at least a year, particularly the oxidation or breakdown process from equation lag 1.

4. Conclusion

Annual rainfall has an impact on the subsidence or subsidence of peat soil. The subsidence this year is influenced by last year's rains. Lower rainfall results in more land subsidence

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