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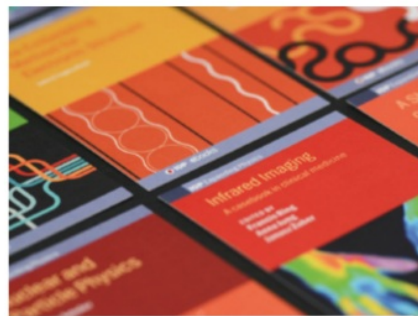
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Is there a correlation between rainfall and soil moisture on peatlands in South Sumatra?

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Abstract. Data of this study was obtained from direct measurement using an integrated observation system namely *SEnsory* data transmission *Service* *Assisted* by *Midori Engineering* laboratory (SESAME). The SESAME directly measures and records groundwater levels, soil moisture, skin temperature, and rainfall in peatland areas. There are two SESAME stations was used in this study, that are located in the Peatland Hydrological Unit (PHU) Lumpur River 1 and PHU Lumpur River 2. This study aims to find a correlation between Rainfall and Soil Moisture on peatlands in South Sumatra represented by the two PHUs. The results of statistical analysis show that rainfall has a significant linear correlation with soil moisture. The correlation coefficients obtained at PHU Lumpur River I and PHU Lumpur River II were 0.78, 0.64 respectively. Furthermore, the result of the empirical equation can be used to obtain the value of soil moisture based on the value of rainfall at this research location if one day soil moisture sensors are damaged.

1. Introduction

One of the important ecosystem types found in Indonesia is peatland. Peat is generally defined as the accumulation of plant remains found under conditions that are flooded with water, acid and low in nutrients. An area covered by a layer of peat is known as peat land [1]. Tropical peatlands cover an area of around 40 million ha, of which around 50% are located in Indonesia. That means around 10.8% of the land area in Indonesia is peat land. Indonesia's peatlands are spread on several islands, including Sumatra, Kalimantan, Sulawesi and Papua. Almost 35% of the total peatland in Indonesia is found on the island of Sumatra. The main distribution of peatlands on Sumatra Island is in Riau, Jambi and South Sumatra [2], [3].

Already known, that peatlands areas are vulnerable to fire. In 2015, the El Niño phenomenon are coincided with the positive Indian Ocean Dipole (IOD) phenomenon. It is well known that El Niño phenomenon and positive IOD cause rain deficits in the Indonesian region [4], [5]. This causes extreme climate events in Indonesia to trigger many environmental problems. For example, forest fires during 2000-2002 have caused forest loss in Indonesia. In addition, previous studies have also revealed that fires on peatlands and forest vegetation in Indonesia in 1997, El Niño phenomenon produce about 0.81 and 2.57 Gt of carbon into the atmosphere [6].



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To better predict forest fires, especially peat fires, since July 2017 the Indonesian government through the Peat Restoration Agency (BRG) has initiated a system of direct observation of hydrological and climatological parameters on peatlands in South Sumatra called Sensory data transmission service Assisted by Midori Engineering laboratory (SESAME). The parameters measured are Rainfall (RF), Soil Temperature (T), Soil Moisture (SM), and Groundwater Level (GWL) [7][8].

Previous studies relating to the characteristics and correlations between hydrological and climatological parameters include: there has been a strong correlation between GWL and RF [9], [10], a linear correlation between GWL and SM [11], a strong correlation between RF and SM in low soil layers [12], hydrological characteristics and climatological variations on peat swamp areas around Mahakam and Kapuas [13]. The aim of this study is to determine the correlation between rainfall and soil moisture on peatland in South Sumatra using SESAME measurement data.

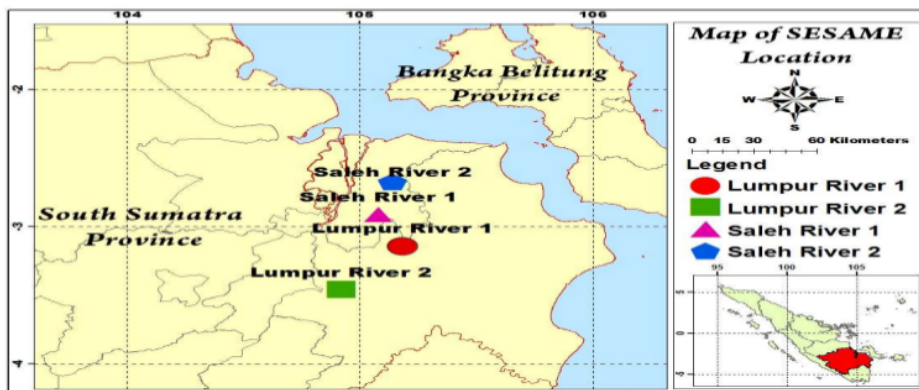


Figure 1. Map of the study locations.

2. Methodology

2.1. Data

The data of Rainfall and Soil Moisture was taken for the period of 1 July 2017 - 30 June 2018. The location of the study was done in the Peat Hydrology Unit (PHU) in Ogan Komering Ilir Regency, South Sumatra Province. This PHU has 2 locations where the hydrological and climatological parameter measuring devices are installed called the SESAME system. Both locations are Lumpur River 1 (SL1) and Lumpur River 2 (SL2). The coordinates are: -3.1436443, 105.1843584 (SL1); and -3.4583709, 104.9209707 (SL2). The map of the location as shown in Figure 1.

The SESAME system is a telemetry system. The SESAME system can be expected in many ways even only for climate change countermeasures. The demand for the telemetry system is estimated more than 14,000 measurement spots for four application cases such as (i) control of the ground water level in peat land, (ii) estimation of the immobilized carbon dioxide amount in peat forest, (iii) early warning system against floods and other natural disasters, and (iv) weather observation [7].

Data that has been obtained will be analyzed statistically through linear regression analysis, linear correlation, and t test.

2.2. Linier regression

Linear regression analysis is used to form relationships between variables. This analysis can estimate the value of a variable with other variables through the regression line equation:

$$y = a + bx \quad (3.1)$$

where a is the intercept and b is the slope or gradient line. y is the dependent variable and x is independent regression. Then the constants a and b can be calculated using the following equation [14]:

$$a = \frac{(\sum y \sum x^2) - (\sum x \sum xy)}{N(\sum x^2) (\sum x)^2} \quad (3.2)$$

$$b = \frac{N(\sum xy) - (\sum x \sum y)}{N(\sum x^2) (\sum x)^2} \quad (3.3)$$

2.3. Linier correlation

Correlation is a way to determine how well two (or more) variables vary in time or space. The correlation coefficient can be written with [14]:

$$r_{xy} = \frac{1}{N-1} \sum_{i=1}^N \frac{(x_i - \bar{x})(y_i - \bar{y})}{s_x s_y} \quad (3.4)$$

where s_x and s_y are standard deviations for two data records. For $r = \pm 1$, the data point (x, y) is along a straight line and the sample is said to have a perfect correlation. Where s_x and s_y are the values of each time-series standard deviation, which is defined as,

$$s_x = \sqrt{\frac{1}{N} \sum_{i=1}^N (x_i - \bar{x})^2} \quad (3.5)$$

2.4. t test

The t test is one of the statistical tests used to test the truth of a hypothesis which states that between two samples taken from the same population there is no significant difference. The t test for one sample belongs to the descriptive hypothesis. The t test is used to determine whether the independent variables partially have a significant or not effect on the dependent variable. The degree of significance (α) used is 0.01. To test the significance of two types of data can be calculated through the correlation coefficient between the two data, namely by calculating the t value using the following equation

$$t = r_{xy} \sqrt{\frac{n-2}{1-r_{xy}^2}} \quad (3.6)$$

where r_{xy} is the correlation coefficient was obtained and n is the amount of data. If the hypothesis follows the normal distribution t with the $n-2$ degrees of freedom and the critical limits of the normal distribution t usually at $\alpha = 0.05$, then we can determine the value of t_{table} based on the t distribution table as shown in Table 1. If the value of $t_{count} > t_{table}$ is obtained, the hypothesis is accepted, which means that between two samples taken from the same population there is no significant difference [15][16].

Table 1. Critical value of t test

n	α				
	0.10	0.05	0.025	0.01	0.005
1	3.078	6.314	12.706	31.821	63.657
2	1.886	2.920	4.303	6.965	9.925
3	1.638	2.353	3.182	4.541	5.841
4	1.533	2.132	2.776	3.747	4.604
5	1.476	2.015	2.571	3.365	4.032
6	1.440	1.943	2.447	3.143	3.707
7	1.415	1.895	2.365	2.998	3.499
8	1.397	1.860	2.306	2.896	3.355
9	1.383	1.833	2.262	2.821	3.250
10	1.372	1.812	2.228	2.764	3.169
11	1.363	1.796	2.447	3.143	3.707
12	1.356	1.782	2.365	2.998	3.499
...					

3. Result and Discussion

SESAME measurement data for period 1 July 2017 - 30 June 2018 are processed to obtain the time series graph. The time series graph obtained is shown in Figure 2 and Figure 3. Figure 2 shows that the number of rainfall at PHU Lumpur River 2 (SL2) is bigger than that of Lumpur river 1 (SL1). At both stations it was seen that the highest value of rainfall occurred in March 2018 and the lowest occurred in September 2017.

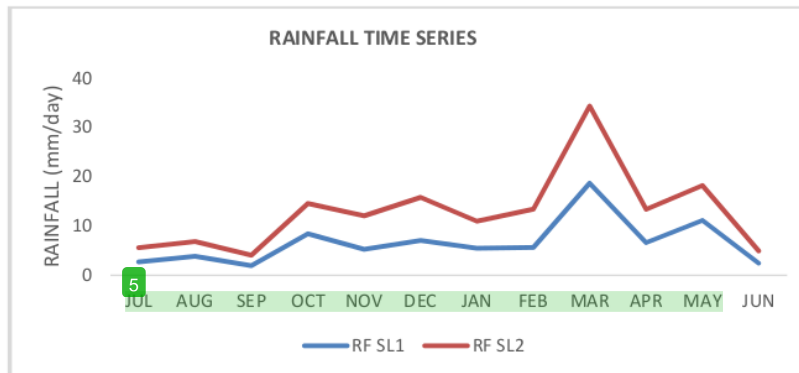


Figure 2. Time series graph of rainfall

Figure 3 shows that in general the value of soil moisture in PHU Lumpur River 1 is greater than that of Lumpur river 2. In both stations it was seen that the highest value of soil moisture occurred in March 2018 and the lowest occurred in September 2017.

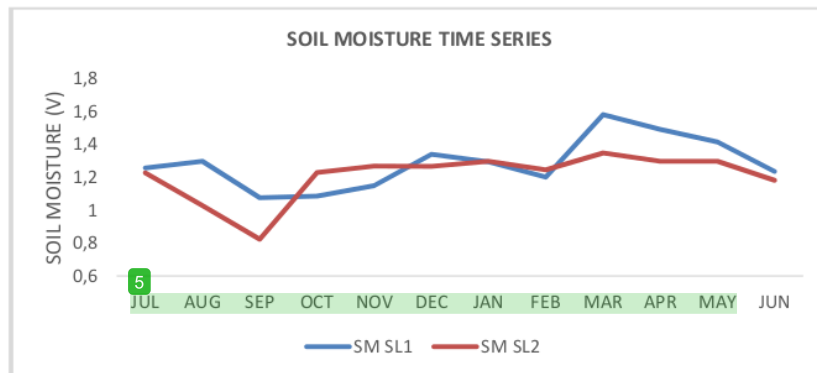


Figure 3. Time series graph of soil moisture

Figure 2 and Figure 3 show that the highest values of these two parameters occur in the same month, and so is the lowest value. These results indicate there is a correlation between rainfall and soil moisture, where the higher the rainfall, the higher the soil moisture and vice versa. But there is an interesting thing that the rainfall at SL2 is higher than rainfall SL1, whereas soil moisture at SL1 is higher than SL2. This is probably due to differences in the type of material in these two locations, where the material at SL1 is estimated to be more porous than in SL2 [17], [18].

Data processing is then carried out to find correlation coefficients and empirical equations between the two parameters. The correlation coefficient obtained at SL1 is 0.78 and in SL2 is 0.64. The empirical equation obtained for SL1 is $y = 0.0346x + 1.0783$ and for SL2 is $y = 0.0251x + 1.0537$, where y is the soil moisture parameter and x is the rainfall parameter. The correlation graph is shown in Figure 4.

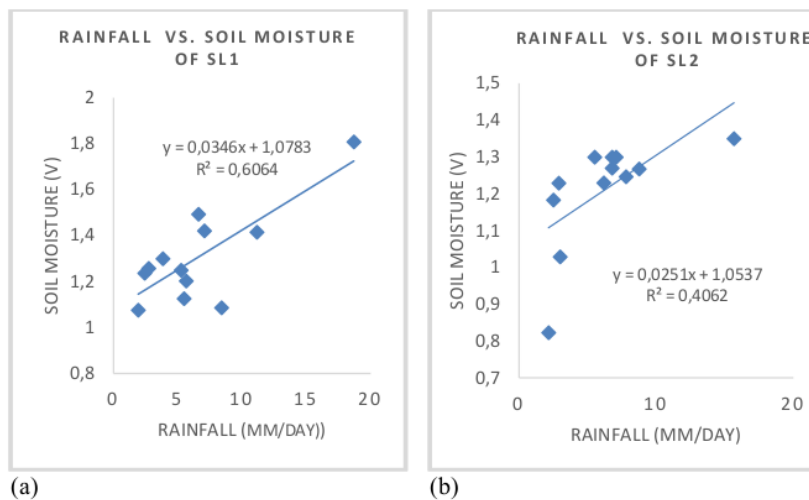


Figure 4. Graph of rainfall vs. soil moisture of (a) SL1 and (b) SL2

To test the significance of the correlation of the two parameters, a t test was carried out. It has been obtained for SL1 the t_{count} value is 3.942 and for SL2 is 2.637, while the t_{table} value for the two parameters is 1.812. These results indicate that $t_{count} > t_{table}$ means that the correlation of the two parameters is significant. These results are in line with previous research which obtained a strong correlation between rainfall and soil moisture on low land [12].

4. Conclusion

The analysis shows that the rainfall data is significantly correlated with the soil moisture data. Therefore, the result of the empirical equation can be used to obtain the value of soil moisture based on the value of rainfall at this research location if one day soil moisture sensors are damaged.

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