SOME INSIGHT INTO DIRECT OBSERVATION OF HYDROLOGICAL PARAMETERS IN PEATLAND AREA OF THE SOUTH SUMATERA

Muhammad Irfan[1,2], Wijaya Mardiansyah[1], M. Yusup Nur Khakim[1], Menik Ariani[1], Albert Sulaiman[3] and Iskhaq Iskandar[1,2*]

[1]Department of Physics, Faculty of Mathematics and Natural Sciences, Sriwijaya University, Indonesia;
[2]Graduate School of Sciences, Faculty of Mathematics and Natural Sciences, Sriwijaya University, Indonesia; [3]Agency for Assessment and Application Technology, Jakarta, Indonesia

ABSTRACT: An integrated observation system so-called $\underline{SE}$nsor$y$ data transmission $\underline{S}$ervice $\underline{A}$ssisted by $\underline{M}$idori $\underline{E}$ngineering laboratory (SESAME) has been deployed in the peatland area of the South Sumatera Province, Indonesia since June 2017. The system directly measures and records the groundwater level, soil moisture, skin temperature and rainfall in the peatland area. In this study, we used data recorded at four locations, two sensors located at the Peatland Hydrological Unit (PHU) of the Saleh River and the other two are located at the PHU of the Lumpur River. Data for a period of 17 June 2017 to 31 March 2018 were used to evaluate the characteristics of hydrology and climatology of the peatland in the South Sumatera. It was found that a high rainfall is associated with low skin temperature, high soil moisture, and shallow groundwater level. Furthermore, it was found that the observed groundwater level is significantly correlated with the observed rainfall. Interestingly, the adjusted groundwater level from TRMM rainfall shows a significant correlation with the number of hotspots during dry-season (July-October). Therefore, we may use the observed rainfall for peat fire early morning.

Keywords: Ground Water Level, Hotspot, Peatland, Rainfall, SESAME

1. INTRODUCTION

One of the important ecosystem types found in Indonesia is peatland. Peatland is a wetland ecosystem characterized by the high accumulation of organic materials with a low decomposition rate. Tropical peatlands cover an area of approximately 40 million ha, of which about 50% are located in Indonesia. It means that about 10.8% of the land area in Indonesia is peatland. Indonesia's peatlands are spread over several islands, including Sumatra, Kalimantan, Sulawesi and Papua. 35% of the total peatland in Indonesia are found on the Sumatera Island. The main distributions of peatlands on the Sumatera Island are in Riau, Jambi and South Sumatra [1-3].

The peatland is vulnerable to the fire. In 2015, the El Niño event co-occurred with a positive Indian Ocean Dipole (IOD) event. It has been known that the El Niño and positive IOD events caused deficit rainfall over the Indonesian region [4-5]. This causes the extreme climate events in Indonesia triggering many environmental issues. For example, the forest fire over 2000 – 2002 had caused a huge area of forest loss in Indonesia [6]. In addition, the previous study has also revealed that the fires on the forested peatland and vegetation in Indonesia during the 1997 El Niño event released about 0.81

and 2.57 Gt of carbon to the atmosphere [7].

In order to better predict the occurrence of a forest fire, in particular, the peat fire, since June 2017 the Indonesian government through the Peatland Restoration Agency has initiated a direct observation system of hydrological parameters on peatland area so-called a $\underline{SE}$nsor$y$ data transmission $\underline{S}$ervice $\underline{A}$ssisted by $\underline{M}$idori $\underline{E}$ngineering laboratory (SESAME). The parameters measured are Rainfall (RF), Skin Temperature (T), Soil Moisture (SM), and Ground Water Level (GWL).

In this study, the SESAME data combined with the data from satellite remote sensing was used to evaluate the hydrological characteristics of the peatland area in the South Sumatera for a possible application on the mitigation of extreme climate events. In particular, this study is intended to address the following questions:

1. What is the pattern of RF, T, SM, and GWL on the Peatland Hydrological Unit of Lumpur River and Saleh River in the South Sumatra based on the SESAME data?
2. Is there any relation between GWL and RF?
3. Can we use the RF data to predict the peat fires?

2. DATA

2.1 The *SE*nsory Data Transmission *S*ervice *A*ssisted by *M*idori *E*ngineering Laboratory (SESAME)

SESAME is a comprehensive system that can collect data using sensors, record them on the spot, transmit them to remote sensors via mobile communications networks, process and transmit data, deliver output in an analytical format, and transmit output to a user's computer [8].

Application of the SESAME system is primarily used for data purposes related to climate variations. The number of measurement points ranges from 14,000 points categorized for measurements related to control of Ground Water Level (GWL) on peatlands, the estimated amount of carbon dioxide in peatland, early warning of floods and natural disasters, and weather observation [8].

In Indonesia, in total there are 17 locations where the SESAME was installed. In particular, in the South Sumatra, there is 8 SESAME. This study will be conducted at two Peatland Hydrological Unit (PHU) in South Sumatra, namely PHU Lumpur River and PHU Saleh River. On each PHU, the 2 SESAME system was installed (Figure 1). Detailed location of the SESAME system used in this study is presented in Table 1.
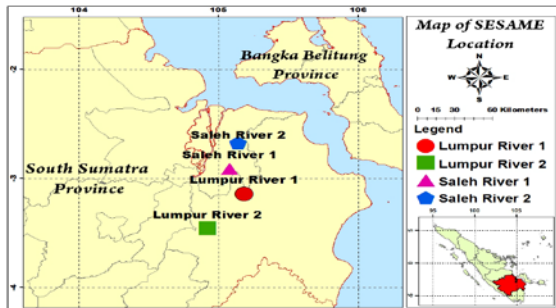

Fig 1. Map of SESAME location in the South Sumatera.

Table 1. Name and location of the SESAME used in this study.

No.	Name	Coordinate of the Location
1.	Lumpur River 1	-3.143, 105.184
2.	Lumpur River 2	-3.458, 104.921
3.	Saleh River 1	-2.911, 105.082
4.	Saleh River 2	-2.677, 105.143

2.2 Tropical Rainfall Measuring Mission (TRMM)

TRMM was developed by the National Aeronautics and Space Administration (NASA) and Japan Aerospace Exploration Agency (JAXA), which produces precipitation data obtained from TRMM meteorological satellites. The TRMM satellite began operations in 1997 [9]. The satellite brings 5 channels of PR (Precipitation Radar), TMI (TRMM Microwave Channel), VIRS (Visible an Infrared Channel), CERES (Clouds and the Earth's Radiant Energy System), and LIS (Lightning Imaging Sensor). In particular, the PR and TMI channels have missions in rainfall estimates. Both channels are able to observe rain structures and play an important role in knowing the mechanisms of global climate change and the monitoring of environmental variations.

Comprehensive data on rainfall on TRMM has been available since 1998 [9-10]. Rainfall data generated by TRMM has a fairly diverse type and shape that starts from level 1 to level 3 [10]. Level 1 is data that is still in raw form and has been calibrated and corrected geometrically. Level 2 is a data that already has a picture of the rain geophysical parameters at the same spatial resolution, but still in the original condition of the rain when the satellite passes through the recorded area. Level 3 is data that already has rain values, especially the monthly rainfall condition which is a combination of rain conditions from level 2. In this study, we used the TRMM data level 3, with a spatial resolution of 0.25 ° x 0.25 ° and a temporal resolution of 3 hours. Data over a period of January 2000 to September 2017 will be used in this study.

2.2 Moderate Resolution Imaging Spectroradiometer (MODIS)

This study used hotspots data obtained by the MODIS satellite. The MODIS satellite is one of the main instruments brought by the Earth Observing System (EOS) Terra and Aqua satellites, part of the US Aerospace program, National Aeronautics and Space Administration (NASA) [12]. The MODIS detects an object on the earth surface that has a relatively higher temperature compared to the surrounding temperature. If the temperature detected is greater or equal to 320 K (noon) and 315 K (night), then it is called a hotspot. This study used daily hotspots data over a period from January 2000 to September 2017.

3. METHODOLOGY

In order to address the above research questions, we first evaluate the hydrological parameters observed by the SESAME system. Note that the final goal of this study is to evaluate the SESAME data for a possible application on the mitigation of extreme climate events, in particular, the peat fires

in the South Sumatera. Note that a previous study has shown that the peat fire is strongly correlated with the groundwater level [13]. Therefore, we first evaluate the relationship between the SESAME rainfall data and the SESAME groundwater level data. This relation is, then, used to create a long-term adjusted groundwater level. The final data is correlated with the hotspot data to obtain a possible mechanism of the peat fires.

The correlation coefficient (***r***) is determined by [14-15]:

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

where S_x and S_y are the standard deviations of each time-series.

4. RESULTS

4.1 Patterns of Observed Hydrological Parameters

Figure 2 shows the daily variations of observed temperature, rainfall, soil moisture and groundwater level at PHU Lumpur River-1 (*see* Table 1). Note that due to limited space, only data at one location just for a period of 1 – 29 July 2017 is presented. As expected, it can be seen that a high rainfall is associated with low skin temperature, high soil moisture and shallow groundwater level. This relation is also applied to other SESAME locations at the PHU Lumpur River and PHU Saleh River.
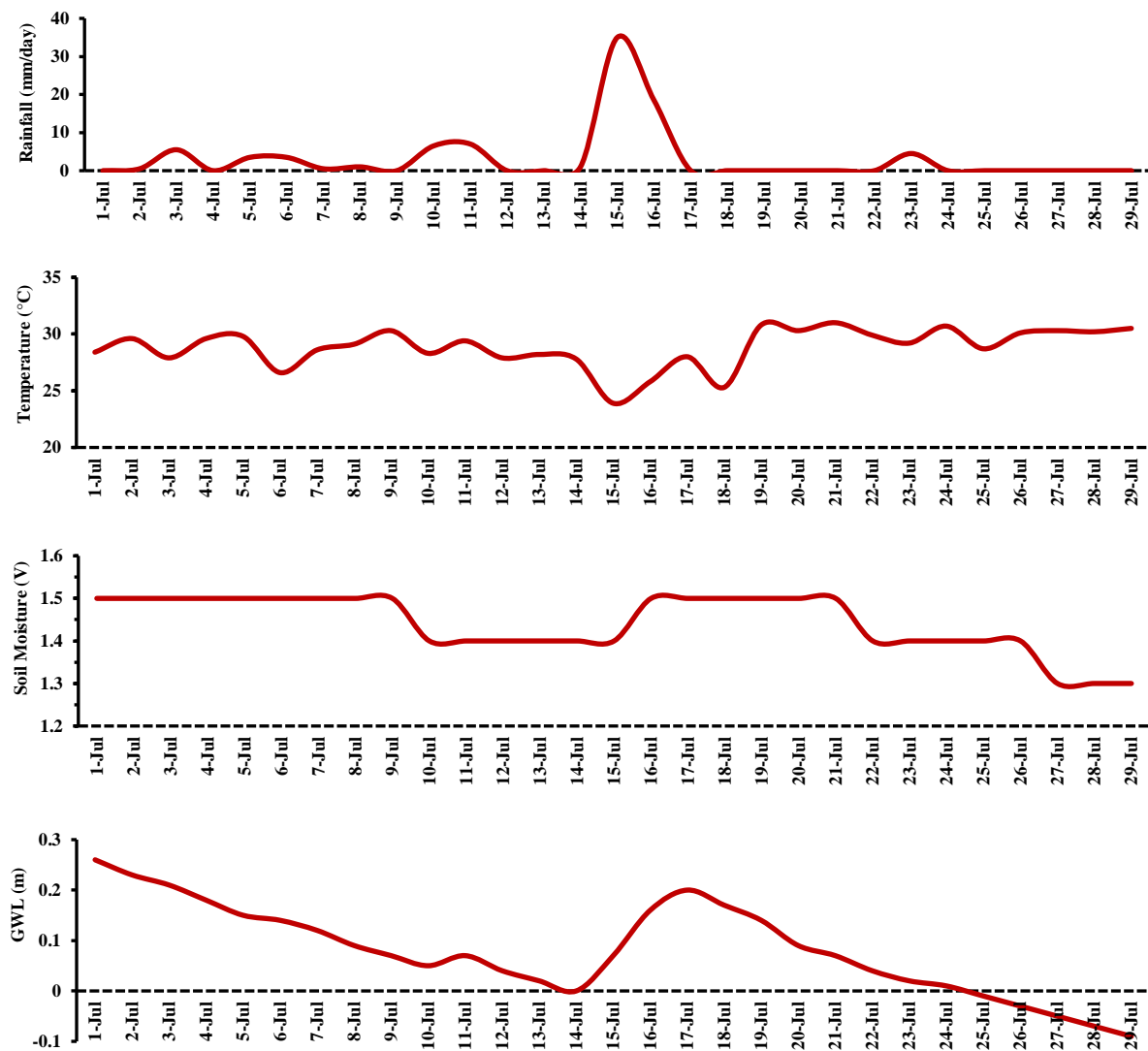

Fig 2. Time series of the observed skin temperature, rainfall, soil moisture and groundwater level at the PHU Lumpur River 1 for a period of 1 – 29 July 2017.

The statistical analysis of hydrological parameters observed at 4 SESAME stations is presented in Table 2. It appears that the maximum values of skin temperature are very high and could reach 50°C. it is argued that high observed skin temperature is due to the position of the temperature sensors. The sensor is stored in a closed-box to avoid vandalism. Thus, it may cause the observed temperature is higher than the actual temperature (outside of the box).

Table 2. Statistics of the SESAME data

Lo	T (°C)		RF (mm)		SM (%)		GWL (cm)	
	Mn	Mx	Mn	Mx	Mn	Mx	Mn	Mx
L1	18	48	0	40	79	167	-43	43
L2	17	50	0	44	49	135	-14	89
S1	19	44	0	85	99	136	-.1	37
S2	22	46	0	27	79	114	-22	27

Note: Mn = minimum, Mx = maximum
L1 = Lumpur River-1, L2 = Lumpur River-2
S1 = Saleh River-1, S2 = Saleh River-2

In addition, it also appears that the maximum values of observed soil moisture are above 100%. It is suggested that this high value is caused by the estimation of the soil moisture on the SESAME system, which is based on the comparison between water mass and soil mass. Note that, the peatland water mass may be greater than soil mass. Therefore, the estimated soil moisture can be larger than 100%.

4.2 Correlations among Observed Hydrological Parameters

First, the correlation between observed rainfall from the SESAME data and the TRMM data was calculated. Figure 3 shows the scatter plot of daily rainfall correlation between the SESAME data at the Lumpur River 1 and the TRMM data for a period 2 July to 29 August 2017. The analysis shows that the TRMM data are significantly correlated with the SESAME data with a correlation coefficient of $r = 0.88$. Similar analysis has also performed on the other SESAME stations and it shows similar results, in which the TRMM data are significantly correlated with the SESAME data. The correlation coefficient for the Lumpur River 2, Saleh River 1 and Saleh River 2 are 0.94, 0.87 and 0.91, respectively. Thus, it is suggested that the TRMM data can be used to represent the rainfall variability at both PHU. Hereafter, the analysis is focused on the Lumpur River 1 data, which is considered to represent three other locations.
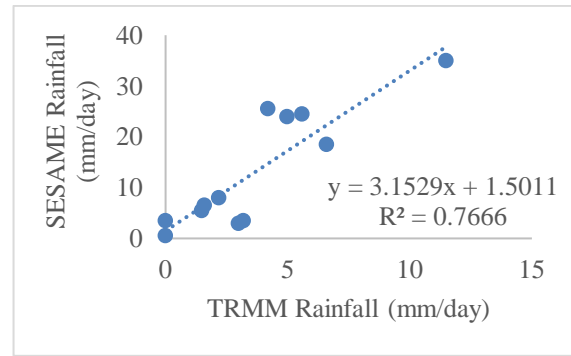

Fig 3. Scatter plot of rainfall correlation between the SESAME data and TRMM data at the PHU Lumpur River-1

Then calculate the correlation of the groundwater level and rainfall observed by the SESAME system. Daily data for a period of 2 July to 12 August 2017 are used for the calculation. Figure 4 shows the scatter plot of the correlation between the observed daily groundwater level and rainfall. The result shows that the observed groundwater level is significantly correlated with the observed rainfall with a correlation coefficient of $r = 0.64$.
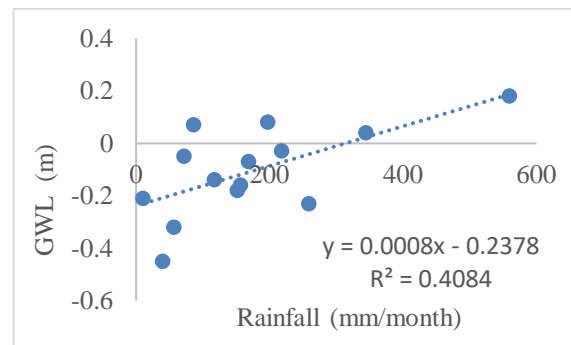

Fig 4. Same as Fig. 3 except the observed groundwater level and rainfall at the PHU Lumpur River 1.

It has been found that SESAME rainfall data and the TRMM data have a strong correlation. It has also been found that the SESAME groundwater level and the SESAME rainfall also have strong correlations. Therefore, the GWL could be estimated from the TRMM rainfall using a linear equation shown in Figure 4. Hereafter, the result of the calculation is called the adjusted GWL.

4.3 Correlations Between the Adjusted GWL and the Number of Hotspots

In order to evaluate the relation between GWL and hotspots in the study area, the seasonal average of the adjusted GWL and the number of hotspots

was first calculated. The analysis is focused on dry-season (July-October). The results are presented in Table 3.

Table 3. Seasonal averaged (2002-2017) of the adjusted GWL and the number of hotspots during the dry season (July – October) at the PHU Lumpur River-1

Year	Adjusted GWL (m)	Number of Hotspots
2002	0.1	70
2003	0.40	6
2004	1.40	30
2005	0.63	14
2006	0.19	55
2007	0.56	6
2008	0.27	5
2009	1.18	29
2010	0.23	3
2011	0.48	33
2012	1.36	14
2013	0.06	8
2014	0.58	44
2015	3.59	125
2016	0.10	1

It is shown that the adjusted GWL does not show robust coherency with the number of hotspots. However, the correlation analysis shows that the adjusted GWL has a high correlation with a number of hotspots with a correlation coefficient of $r = 0.60$.
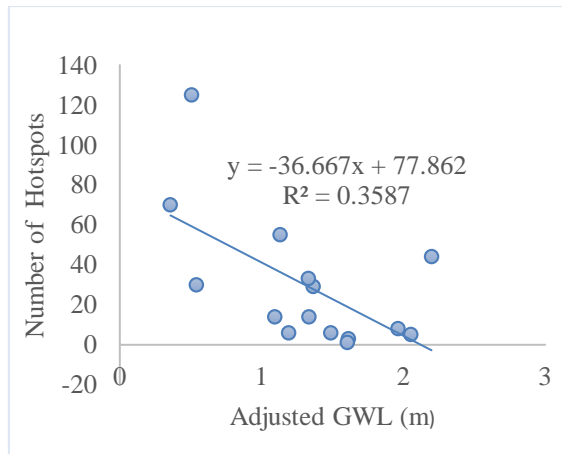

Fig 5. Same as Fig.3 except for the adjusted GWL and the number of hotspots during dry-season (July – October) at the PHU Lumpur River-1

5. CONCLUSION

Hydrological characteristics of two PHU in the South Sumatera, namely the PHU Lumpur River and the PHU Saleh River were evaluated using data recorded by the SESAME system. It is shown that the SESAME system provides valuable hydrological data for monitoring peat fires. However, it should be noted that the SESAME system might overestimate the observed skin temperature as the temperature sensor is installed within a closed-box to avoid vandalism.

The analysis shows that the observed groundwater level from the SESAME is significantly correlated with the observed rainfall. Therefore, we used the regression relation between the observed groundwater level and the observed rainfall to estimate a long-term groundwater level. We called this estimated groundwater level as the adjusted GWL. Seasonally averaged of the adjusted GWL during the dry season (July-October) shows a significant correlation with the number of the hotspot. However, we still need a high temporal resolution of the groundwater level for a better prediction of the peat fire.

6. ACKNOWLEDGMENTS

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