International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

Vol. 38 No. 2 May 2023, pp. 117-123

Meteorological Drought Analysis Using The Theory Of Run Method In Lusi Watershed, Central Java

Shylva Rahmah Maharani[1], Rahmat Gernowo[2], Rina Dwi Indriana[3*]

[1]Undergraduate student Physics Department – Faculty of Sains and Mathematics,
Diponegoro University, Semarang

[2,3]Physics Department – Faculty of Sains and Mathematics,
Diponegoro University, Semarang

[2] rahmatgernowo@lecturer.undip.ac.id

[3]Co-author: rinadwiindriana@lecturer.undip.ac.id

Abstract – Reduced water reserves can be caused by decreased rainfall. During the dry season along the Lusi River, Central Java, water quantity decreased, so that the area along the Lusi River passes in drought conditions. This study aims to determine the longest duration of drought and the largest cumulative number of droughts, in the Lusi watershed for a ten-year period. The level of drought in the Lusi watershed was analyzed using the Theory of Run method. The results obtained were the longest drought duration of 9 months and the largest cumulative drought amount of -486 mm and the Lusi watershed was classified as a meteorological drought.

Keywords – drought, Lusi watershed, Theory of Run

I. INTRODUCTION

Climate change is one of the causes of drought anomaly. The frequency of drought, the level of drought, and the duration of drought can be affected by climate change [1]. A drought is a natural event due to reduced rainfall which reduces the availability of water in an area for a certain period. Lack of water affects the amount of surface runoff in a watershed. Drought is divided into meteorological drought, agricultural drought, and hydrological drought. Agricultural drought is characterized by reduced water content in the soil, hydrological drought is characterized by reduced availability of surface water and groundwater, and meteorological drought is characterized by reduced rainfall in certain periods [2]. According to research conducted in 2012, the Lusi Watershed is used to support agricultural needs in Blora Regency including the need for irrigation water, the need for water for fisheries, and the need for water for animal husbandry. Rainfall, irrigation efficiency, and water requirements for land preparation all affect irrigation water requirements. The type of agriculture developed and the area used for cultivation determine the water requirements for fisheries. The type of livestock and water requirements for livestock determine the water requirements for livestock [3]. Drought in Blora, Central Java, in 2021 caused a water crisis. The government sent water to villages affected by drought. The number of villages experiencing drought includes 171 villages and 14 sub-districts in Blora Regency [4]. The Jratunseluna River Basin Unit consists of 2 main watersheds (DAS), namely the Jratun Watershed (Jragung and Tuntang Rivers) and the Seluna Watershed (Serang, Lusi, and Juana Rivers). In the Seluna watershed, there are three main springs, one originating from the mountains in Boyolali flowing into the Serang River, then coming from the limestone mountains in Blora and Grobogan flowing into the Lusi River, and the third coming from the Muria mountains in Kudus, Pati, and Jepara flowing through the Juana River. [5],[6]. This research location is the Lusi Watershed (DAS).

The Lusi Watershed is one of the watersheds in the Banjarejo District area, Blora Regency, Central Java, which has an area of 2,093 km2. The problem that occurs along the Lusi River during the dry season is that there is no flow in the riverbed, so the area through which the Lusi River passes is dry. The Lusi watershed is used primarily for agriculture and animal husbandry. This problem usually occurs from June to October [6]. Based on these problems, there has been no previous research related to drought research in the LUSI watershed, so the Lusi watershed was used as the location of this research. Rainfall analysis can be done using TRMM (Tropical Rainfall Measuring Mission) satellite data and ground data. Several studies have concluded that there is a high correlation between TRMM data and ground data. Correlation results are better when analyzed using monthly data. The validation results of the TRMM data on the ground data yielded the result that the TRMM data could be used as input data or a substitute for rainfall data [7],[8],[9],[10],[11],[12,[13],[14],[15]. Decreasing rainfall over a long period or duration causes drought. Drought can be analyzed using several methods with the advantages and disadvantages of each method [16]. In this study, the Theory of Run method is used as a research method to analyze meteorological drought in the Lusi watershed. The theory of run method compares the length of the water deficit and the amount of water deficit. The Theory of Run method was chosen because it has the advantage of calculating the longest duration of drought and the largest number of droughts over a certain period of time in an area [17].

II. Method

Geographically, the Lusi River Basin is located at 110°43'41.6” – 111°35'19.8” E and 6°49'48.1” – 7°16'57.4” S. Rainfall stations spread across the Lusi watershed in Blora Regency consist of Ngawen, Jiken, Tunjungan, Greneng Reservoir, Bogorejo, and Kunduran rain stations, then the rain stations in Grobogan Regency consist of the Brati, Kradenan, and Gabus rain stations (Fig.1). This study uses TRMM satellite rainfall data from 2011 to 2020 [16].

One method for analyzing drought in an area is the theory of run method. The theory of run method is a method that aims to determine the drought index in the form of the longest drought duration and the largest number of droughts. The longest duration of drought is obtained by calculating the value of the surplus and deficit of rainfall. The surplus value can be called a surplus if the value resulting from subtracting the value of monthly rainfall from the average value of monthly rainfall for ten years is not negative or a value above zero (0). Vice versa, a deficit value is negative or the value is below zero (0). The principle of calculating the theory of run follows a single variable process (univariate) [17].

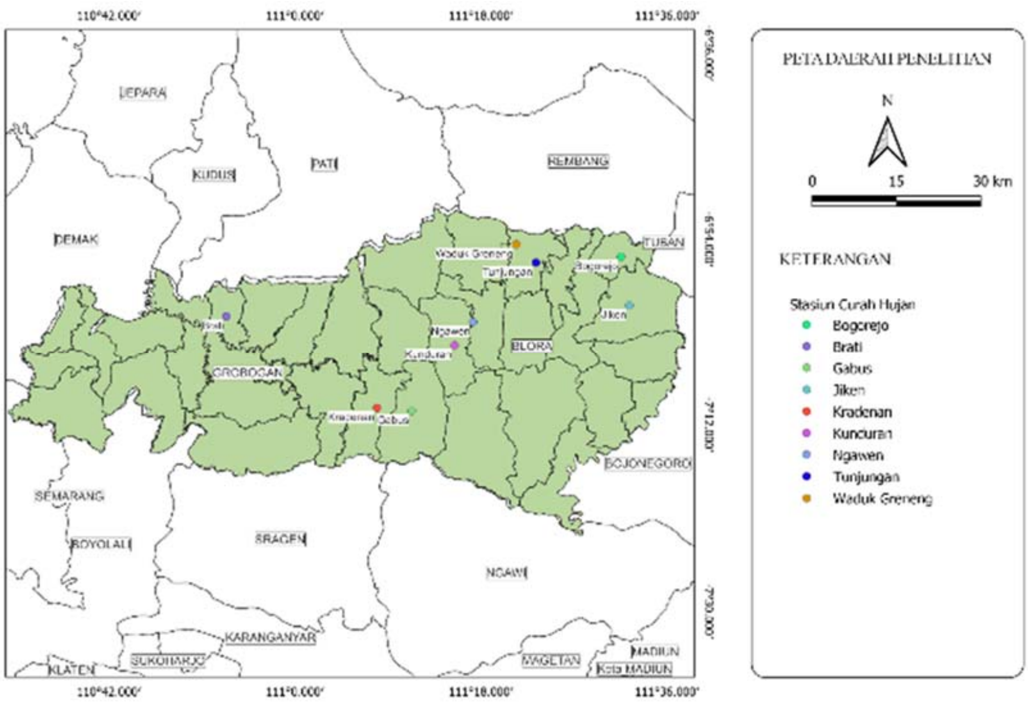

Figure 1. Lusi watershed map.

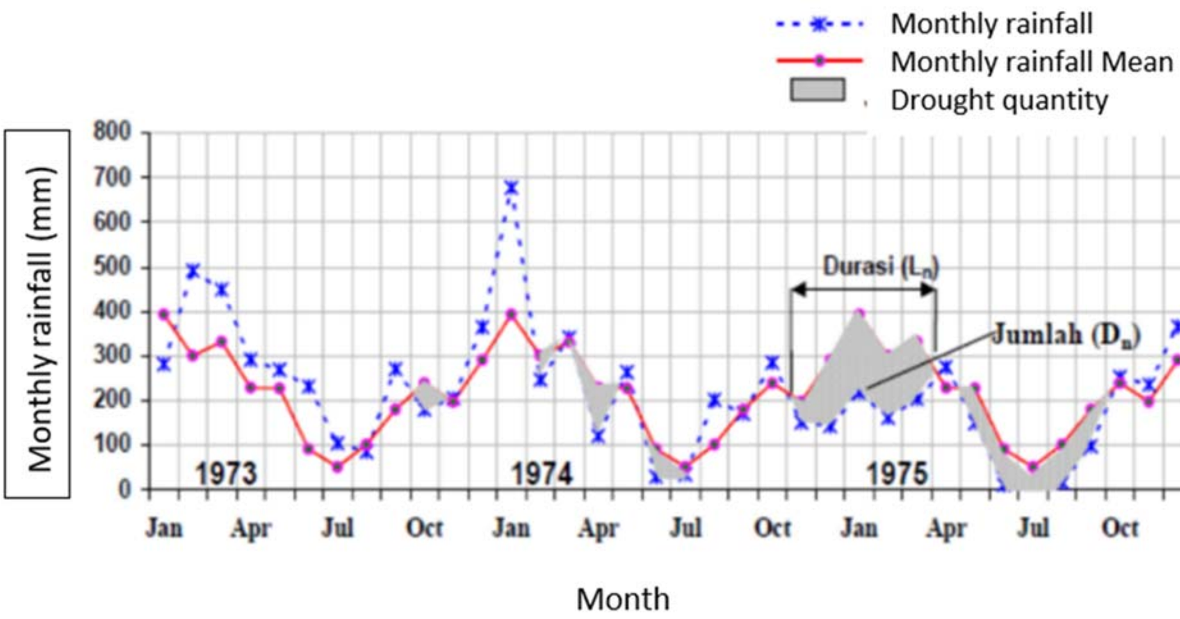

Figure 2. Sample data of calculation Rainfall quantity and period (Based on Indonesian Construction and Buildings **Guidelines Number Pd T-02-2004-A)**

Fig. 2 shows the data series, *X (t,m),* from the hydrological variables: the rain in month m and year t. By specifying the long-term monthly average rainfall as the depreciation value, *Y (m),* the data series is truncated in several places, giving rise to a new variable. The new understanding arising from the intersection produces variables such as the part above the normal line (positive run), *D (t,m*) is called a surplus. The part that is below the normal line (negative run) is called a deficit.

The number of parts that continuously experience a deficit is called the amount of dryness with units of millimeters. The length of months that occur in the deficit section continuously is called the duration of the drought with units of months. After the value is determined, two new data series can be formed from the rainfall data series, namely the duration of the drought (L_n) and the number of droughts (D_n). If $Y(m) < X(t,m)$, then

$$D(t,m) = X(t,m) - Y(m) \quad (1)$$

$$D_n = \sum_{m=1}^{i} D(t,m)A(t,m) \quad (2)$$

$$L_n = \sum_{m=1}^{i} A(t,m) \quad (3)$$

where *A(t,m)* is an indicator worth 0 if *Y (m) = X (t,m)*, *A(t,m)* is an indicator worth 1 if *Y (m) < X (t,m)*, and *A(t,m)* is an indicator of deficit or surplus. For *(t,m)* is year t, *m* is month, *Y (t,m*) is the m month, X (t,m) is the series of monthly rainfall data m year t, D_n is the number of droughts from m to m+I (mm), and L_n is drought duration from m to m month to m+1 (month) [17].

III. Result and Discussion

1. Lusi Watershed Data Statistical Parameters.

Calculation of statistical parameters for monthly rainfall data at rain stations required in the Run method drought calculation includes the average value (mean). The results of calculating the average value and monthly rainfall data for the Lusi watershed are presented in Table 1.

Table 1. Rainfall in 2011-2020 base on satellite (TRMM) data

Year	month											
	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agust	Sept	Okt	Nov	Des
2011	289	197	302	288	172	58	30	7	58	114	430	378
2012	362	216	272	150	81	95	5	6	16	162	243	408
2013	442	344	307	331	196	274	113	44	25	101	187	334
2014	580	268	289	203	121	81	108	40	8	35	196	314
2015	283	309	319	273	139	34	9	12	6	22	236	248
2016	236	382	205	249	208	126	122	117	277	215	250	236
2017	287	330	286	229	161	104	37	7	60	250	386	238
2018	276	486	318	120	40	56	6	24	18	80	255	323
2019	340	304	327	335	89	4	17	19	17	41	126	308
2020	304	391	311	299	196	31	87	63	78	182	242	474
Xi	3398	3228	2935	2478	1402	863	535	338	563	1202	2550	3259
n	10	10	10	10	10	10	10	10	10	10	10	10
mean	340	323	294	248	140	86	53	34	56	120	255	326

2. Surplus and Deficit Values of the Lusi Watershed

The surplus and deficit values are obtained by subtracting the monthly rainfall data in each year from the average value of rainfall data for that month using equation (1). The calculation of surplus and deficit values is presented in a graph in Figure 3 to Figure 5.

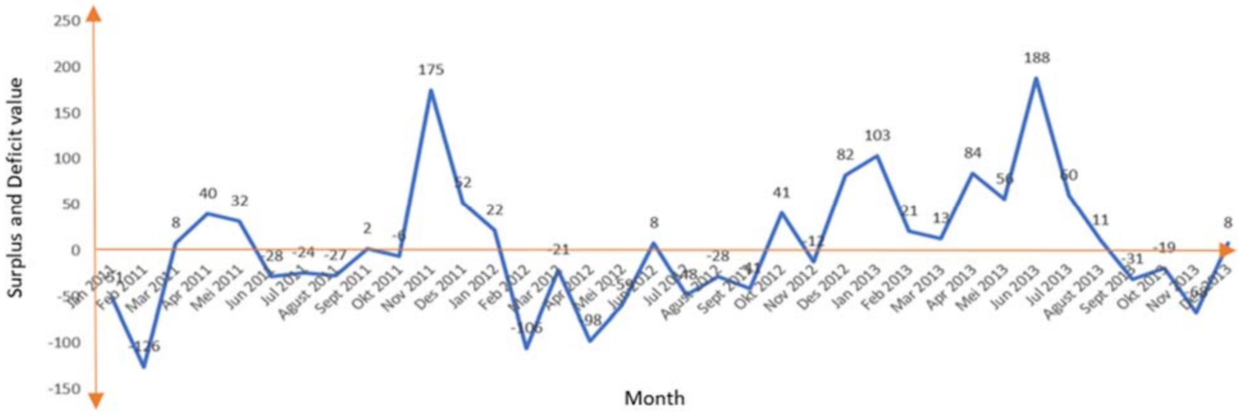

Figure 3. Surplus and Deficit value watershed Lusi in 2011 – 2013

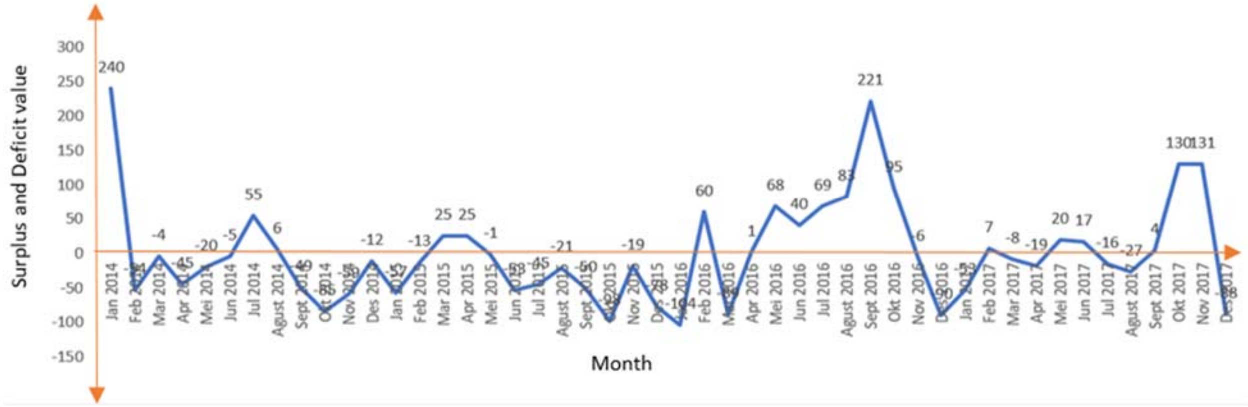

Figure 4. Surplus and Deficit value watershed Lusi in 2014 – 2017

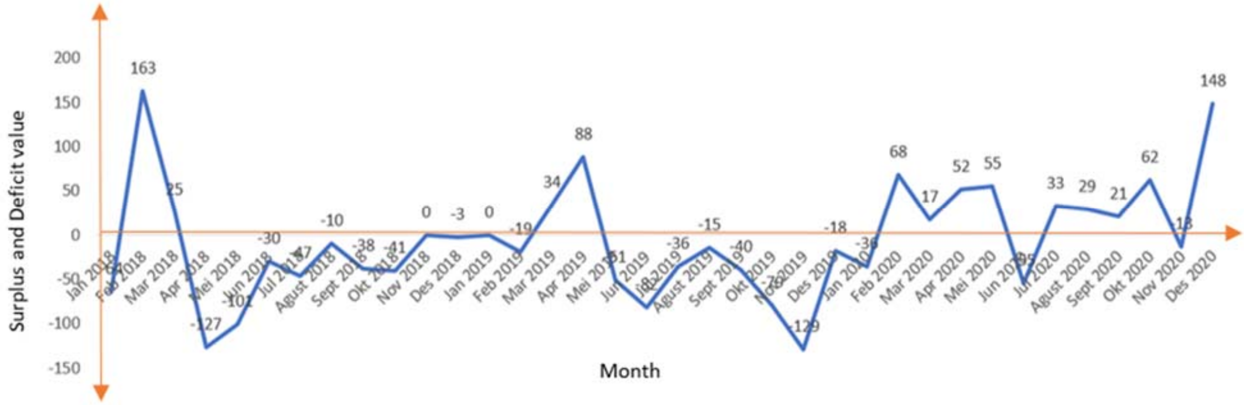

Figure 5. Surplus and Deficit value watershed Lusi in 2018 - 2020

3. Drought Duration

Drought duration is the amount of time a certain monthly rainfall, a deficit against a threshold value, namely the average value. Using equation (3) the duration of the drought can be calculated. The results of calculating the duration of the drought are presented graphically in Fig. 6.

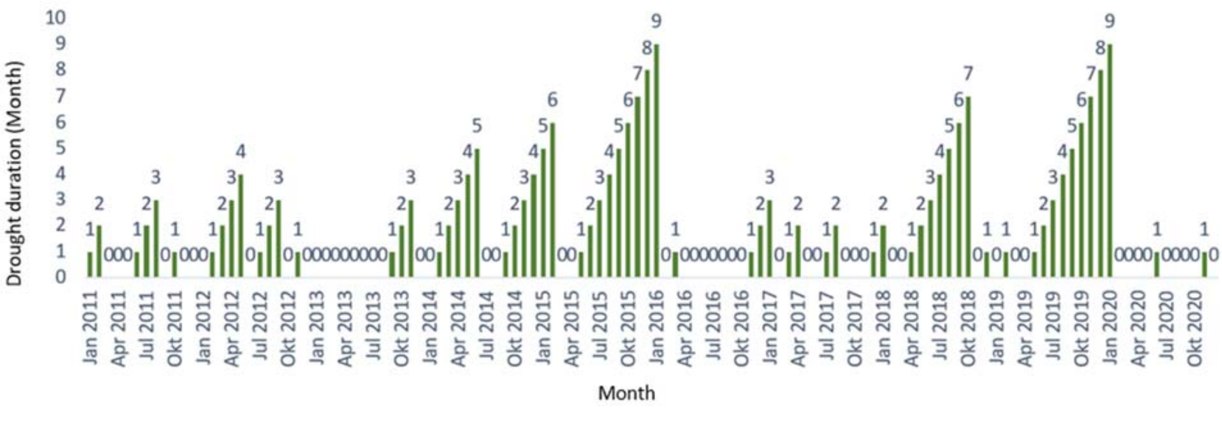

Figure 6. Drought duration Lusi watershed in 2011-2020

Referring to Fig. 6, the longest drought occurred from May 2015 to January 2016. The second longest drought occurred from May 2019 to January 2020. The two longest droughts for nine months were a continuation of the previous year's drought, namely 2015 and 2019. The longest drought itself is the length of the duration of the drought without a surplus value between the deficit values.

4. Total Drought

If the run is a surplus (positive) then it is given a zero (0) and if it is a deficit (negative) then it is given a value equal to the existing negative value. If there are consecutive negative values, the negative values are added up (accumulated) until they are separated again by zero (0) and the calculation starts all over again. Calculation of the cumulative number of droughts in the Lusi watershed is presented in Table 2.

Table 2. Drought quantity of Lusi watershed in 2011-2020

Year	Month											
	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agust	Sept	Okt	Nov	Des
2011	-51	-177	0	0	0	-28	-52	-79	0	-6	0	0
2012	0	-106	-127	-225	-284	0	-48	-77	-117	0	-12	0
2013	0	0	0	0	0	0	0	0	-31	-50	-118	0
2014	0	-54	-59	-104	-124	-129	0	0	-49	-134	-193	-205
2015	-262	-275	0	0	-1	-54	-98	-120	-170	-268	-287	-365
2016	-469	0	-89	0	0	0	0	0	0	0	-6	-96
2017	-149	0	-8	-27	0	0	-16	-43	0	0	0	-88
2018	-152	0	0	-127	-228	-258	-305	-316	-354	-395	0	-3
2019	0	-19	0	0	-51	-133	-170	-184	-224	-303	-432	-450
2020	-486	0	0	0	0	-55	0	0	0	0	-13	0

The largest cumulative number of droughts was in January 2020 at -486 mm and the smallest number of droughts was in December 2018 at -3 mm. The largest droughts come from the cumulative droughts from the previous months, from May 2019 to January 2020. The Lusi watershed drought is classified as a type of meteorological drought based on reduced rainfall, degree of drought, and length of the drought period. The drought that occurs in the Lusi watershed is also influenced by climate change which causes changes in the pattern and distribution of rainfall so that rainfall is uneven. Climate change is also one of the factors causing crop failure.

IV. CONCLUSION

Based on the calculations and analyses that have been carried out using the Theory of Run method, the conclusions are:

The longest duration of drought occurred from 2015 to 2016 and from 2019 to 2020 for 9 months. The drought is a follow-on drought that started in May and ended in January. The largest number of cumulative droughts occurred in 2020. The cumulative number of droughts was -486 mm. The drought is a cumulative drought in 2019 that started from May 2019 to January 2020. The Lusi watershed drought is classified as a type of meteorological drought based on reduced rainfall, degree of drought, and length of the drought period. The drought that occurs in the Lusi watershed is also influenced by climate change which causes changes in the pattern and distribution of rainfall.

REFERENCES

[1] Mishra, Ashok K., dan Vijay P., and Singh. A Review of Drought Concepts. *Journal of Hydrology*, 202 -206. 2010.

[2] Nalbantis I., and Tsakiris G. Assessment of Hydrological Drought Revisited. *Water Resources Management* 23 (5): 881-897. 2008

[3] Adidarma,W.K., L. Marwati, O. Subrata dan Levina. Mitigasi Kekeringan-Monitoring dan Pemetaan.Bandung: Badan Penelitian dan Pengembangan Sumber Daya A ir. 2011

[4] Blorakab. Tanggap Darurat Bencana Kekeringan 2021, Bantuan Air Bersih Terus Dilakukan. *https://www.blorakab.go.id*., 30 Agustus 2021, diakses 15 Desember 2022.

[5] BPUSDATARU Seluna. Rencana Pengembangan Bendungan Banjarejo Kabupaten Blora, *https://www.bpusdataru-seluna.jatengprov.go.id.,*14 September 2012.

[6] Departemen Pekerjaan Umum Balai Besar Wilayah Sungai Pemali Juana. Studi dan Basic Desain Rencana Pengelolaan SDA SUB DAS LUSI. Semarang (ID): Departemen PU. 2008

[7] Sonjaya, I. Analisa Standardized Precipitation Index (SPI) di Kalimantan Selatan. Banjarbaru (ID*)*. Stasiun Klimatologi Banjarbaru. 2007

[8] UN-ISDR. Drought Risk Reduction Framework and Practices. United Nations International Strategy for Disaster Reduction. 2009.

[9] Krisnayanti D. S., Welkis D. F., Hepy F. M., dan Legono D. Evaluasi Kesesuaian Data Tropical Rainfall Mission (TRMM) dengan Data Pos Hujan Pada Das Temef di Kabupaten Timor Tengah Selatan. *Jurnal Sumber Daya Air* Vol.16, No.1. 2020.

[10] Hariarta I. W. Verifikasi Data Curah Hujan TRMM di Sumbawa Menggunakan Metode Inverse Distance Weighting, Mean,dan Point.Banten: Sekolah Tinggi Meteorologi, Klimatologi G Geofisika. 2015.

[11] Pawitan H. dan Sophaheluwakan A. Validasi dan Korelasi Data Satelit TRMMpada Tiga Pola Hujan di Indonesia. *Jurnal Meteorologi dan Geofisika*. 2014.

[12] Noor R. A., Ruslan M., Rusmayadi G., dan Badaruddin. Pemanfaatan Data Satelit Tropical Rainfall Measuring Mission (TRMM) Untuk Pemetaan Zona Agroclimat di Kalimantan Selatan. Program Pascasarjana Universitas Lambung Mangkurat. 2016.

[13] Pangestu, I. T. 2020. Analisis Korelasi Data Curah Hujan BMKG dengan TRMM (Studi Kasus Stasiun BMKG di Sumatera Utara).Lampung: Skripsi. Universitas Lampung.

[14] Rusli, S. R. Evaluasi Penggunaan Data Hujan Berbasis Satelit (TRMM) Tidak Terkoreksi Dalam Aplikasi Model Neraca Air. *Jurnal Sumber Daya Air*, 3(2),115-120. 2017.

[15] [15] Syaifullah, M. D. Validasi Data TRMM Terhadap Data Curah Hujan Aktual di Tiga DAS di Indonesia. *Jurnal Meteorologi dan Geofisika*,15(2), 109-118. 2014.

[16] [16] Galway and NUI Maynooth.Public Works of Ireland. NASDA. TRMM Data Users Handbook.Earth Observation Center. National Space Development Agency of Japan. 2001.

[17] Departemen Pekerjaan Umum. Perhitungan Indeks Kekeringan Menggunakan Teori Run. Bandung (ID): Departemen PU. 2004