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Climate Change Effects on Noel Puames River Area Rainfall in Kupang District

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Abstract: The Noel Puames River is the main river in the Raknamo reservoir used for various purposes, such as irrigation water needs, raw water, fisheries, and others. In the rainy season, the Noel Puames River has enough large discharges, while, in the dry season, the Noel Puames River has almost no base flow. This study aims to determine the effect of climate change on rainfall characteristics in the Raknamo watershed. The methods used include the collection of rainfall data and watershed maps. The rainfall data were used by the Raknamo and Camplong rainfall stations for 25 years of observation resulting in the characteristics of rainfall decrease from time to time, especially the maximum daily rainfall. Annual rainfall tends to increase at Camplong station, but not at Raknamo station, which has the closest location to the Raknamo watershed. There has been a climate change in the Raknamo watershed as indicated by the Z value, which is not equal to zero ($Z \neq 0$) although not significant except in March and September.

Keywords: effect, climate change, rainfall characteristics, Noel Puames.

气候变化对古邦区诺埃尔·普阿姆斯河地区降雨的影响

摘要：诺埃尔·普阿姆斯河是拉克纳莫水库的主要河流，用于灌溉用水、原水、渔业等各种用途。在雨季，诺埃尔·普阿姆斯河有足够大的流量，而在旱季，诺埃尔·普阿姆斯河几乎没有基流量。本研究旨在确定气候变化对拉克纳莫流域降雨特征的影响。使用的方法包括收集降雨数据和流域图。拉克纳莫和坎普隆雨量站使用降雨数据进行了 25 年的观测，导致降雨量时时减少的特点，尤其是最大日降雨量。坎普隆 站的年降雨量趋于增加，但距离拉克纳莫流域最近的拉克纳莫站没有。如 Z 值所示，拉克纳莫流域发生了气候变化，尽管除 3 月和 9 月外并不显着，但 Z 值不等于零（Z ≠ 0）。

关键词：影响，气候变化，降雨特征，诺埃尔·普阿姆斯。

1. Introduction

East Nusa Tenggara (NTT) is a region in Indonesia that, according to Koppen, is included in the category of semi-arid climate areas. The rainy season on the island of Timor occurs within 3–4 months, and the dry season is 8–9 months. The striking difference between the rainy and dry seasons is that wind currents containing much moisture from Asia and the Pacific Ocean to the NTT region have reduced and resulted in fewer rainy days in NTT compared to areas close to Asia. The average annual rainfall in Timor Island is ± 1,287 mm. NTT, especially Timor Island, is located in

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the southern part of Indonesia, which has experienced a decrease in rainfall that affects the management of natural resources for various needs. In a larger area, research on natural resources in other semi-arid regions of the world had been done.

Masih et al. [1] conducted research in Iran on the variability of water discharge and allocation in the context of sustainable natural resource management in the semi-arid area of Karkheh. In a semi-arid region with high inflow (dependable flow) variability between the rainy and dry seasons, it is difficult to meet multi-sector water needs throughout the season, especially during the dry season [1]. One of the main problems relates to the operation of the reservoir. For this reason, adaptive reservoir management to local climatic conditions is almost the same as the threat of global climate change is very necessary [2, 9]. Liebe et al. [3] conducted a study in Ghana on the storage capacity estimation of small reservoirs in semi-arid environments. Nandalal and Sakthivadivel [4] researched the planning and management of multipurpose reservoir systems and focused on optimizing the use of water sources or water shortage factors. The study scope was on watersheds and reservoirs.

A semi-arid climate is a regional climate that receives less rainfall than the potential evapotranspiration, and this semi-arid region covers 31% of the world's area. Montenegro and Ragab [5] stated that in a semi-arid area, the frequency of rainfall events is below the average and erratic that it often causes drought. In this regard, the challenges of managing natural resources will be even greater with the current global climate change.

The climate change will also impact efforts to manage natural resources. Global warming causes climate change and increases the frequency and intensity of extreme weather events. The Intergovernmental Panel on Climate Change [6] stated that global warming could cause significant changes in precipitation and wind patterns. Clean water is used in connection with efforts to anticipate the climate change that occurs; it is necessary to manage and use clean water during the rainy and dry seasons.

The relationship between rainfall, temperature, surface runoff, flood frequency, and peak flow in eight rivers in Xinjiang, China, was examined by Changchun et al. [7]. Almost in all areas of Xinjiang, they observed increasing changes in temperature and rainfall intensity since 1980 and increasing surface runoff in rivers in Xinjiang since 1990. Global warming has also impacted regional hydrological cycles.

The Raknamo watershed (DAS) occupies an area of 38.34 km^2 and is currently used for various purposes such as irrigation, raw water, micro-hydro power (PLTMH), and others. This study aims to find out the effect of climate change on the rainfall patterns in the Raknamo watershed and determine the characteristics of the rainfall.

2. Materials and Methods

The research location is the Noel Puames River in the Raknamo watershed, Kupang District. The location map is presented in Fig. 1. The maximum daily rainfall data for 25 years (1993–2017) had been used from the nearest rainfall posts, namely Camplong and Raknamo rainfall posts.

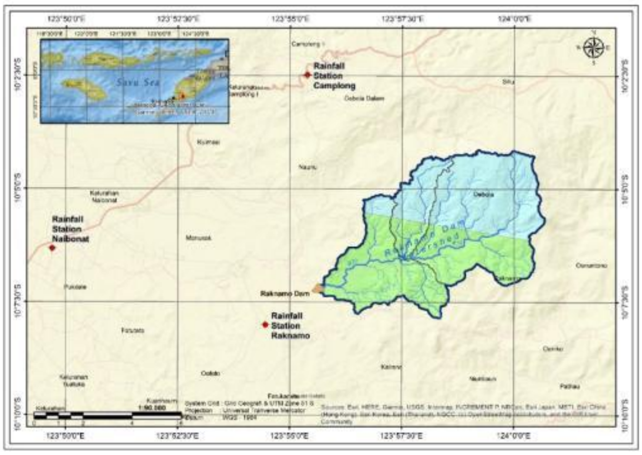

Fig. 1 Research location map

The maximum daily rainfall data, monthly average rainfall, and annual average rainfall are presented in Table 1.

Table 1 The annual rainfall and maximum daily rainfall in the Raknamo watershed

No.	Year	Annual Rainfall (mm)		The Average Monthly Rainfall (mm)		Maximum Daily Rainfall (mm)	
		Camplong	Raknamo	Camplong	Raknamo	Camplong	Raknamo
1	1993	1857.00	1298.30	154.75	108.19	89.00	95.00
2	1994	1253.00	1268.00	104.42	105.67	145.00	150.00
3	1995	1073.00	1930.30	89.42	160.86	120.00	129.40
4	1996	147.00	1589.00	12.25	132.75	66.00	146.60
5	1997	171.00	1632.10	14.25	136.01	18.00	105.50
6	1998	1023.00	1381.10	85.25	115.09	36.00	111.00
7	1999	1940.00	1837.00	161.67	153.08	122.00	111.90
8	2000	2046.00	2010.90	170.50	172.63	110.00	147.50
9	2001	1521.00	1419.50	126.75	118.52	115.00	89.10
10	2002	1310.00	1181.60	109.17	98.47	98.00	100.10
11	2003	1530.00	1910.10	127.50	159.18	140.00	140.50
12	2004	927.00	1296.50	77.25	108.04	95.00	100.00

Continuation of Table 1

13	2005	1092.00	1039.40	91.00	86.62	95.00	175.30
14	2006	1503.00	1520.30	125.25	126.69	119.00	127.90
15	2007	1157.00	900.80	96.42	75.07	60.00	114.60
16	2008	1845.00	1687.80	153.75	140.65	137.00	143.50
17	2009	1144.00	1001.00	95.33	77.05	118.00	77.20
18	2010	1272.00	1568.00	106.00	131.08	76.00	87.00
19	2011	1760.00	1891.30	146.67	157.27	87.00	104.90
20	2012	1227.00	793.40	102.25	71.13	56.00	76.90
21	2013	1702.00	1416.90	141.83	129.03	138.00	112.20
22	2014	954.00	1019.10	79.50	90.52	118.00	85.30
23	2015	951.00	839.00	79.25	76.58	69.00	80.60
24	2016	911.00	1105.50	75.92	108.08	82.00	108.60
25	2017	1379.40	1473.00	107.20	107.20	36.21	100.90

The analysis of climate change using the Mann-Kendall-Sens (Makesens) method with rainfall data to produce a "Z" value, which indicates whether climate change has occurred and projections for the next few years [4, 8, 10, 11].

$$s = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(X_j - X_k) \quad (1)$$

$$\sigma s = \sqrt{n\,(n-1)(2n+5)/18} \quad (2)$$

Z = (S - 1)/ σs if S > 0

0 if S = 0 (3)

(S + 1)/ σs if S < 0

To determine the trend magnitude, the non-parametric Sen's method was used with the assumption that the trend is linear, and the procedure starts from Eq. 1 to 3. The two methods combined are called the Makesens method [12, 13].

$$f(t) = Qt + B \quad (4)$$

$$Qi = \frac{Xj - Xk}{j - k} \quad (5)$$

$$Q = Q[(N+1)/2] \text{ if N is odd} \quad (6)$$

3. Results and Discussion

The changes in rainfall characteristics were predicted using regression analysis of rain data to obtain a correlation between the elements of rainfall and time [14]. The rainfall elements studied include average of annual rainfall and maximum daily rainfall.

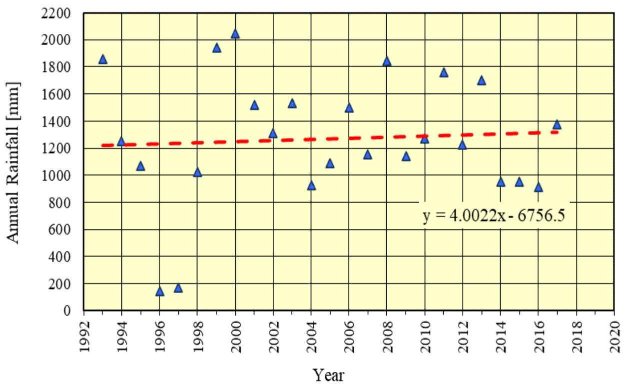

Fig. 2 Graph of the average annual rainfall at the Camplong rainfall station

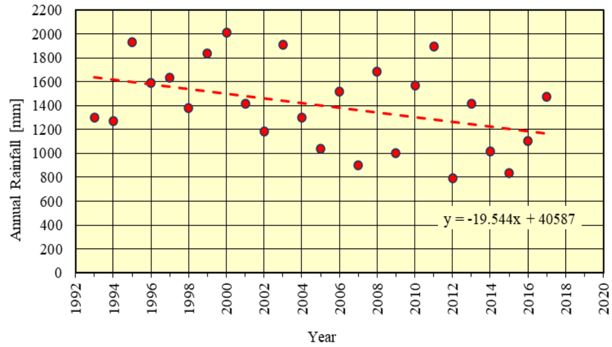

Fig. 3 Graph of the average annual rainfall at the Raknamo rainfall station

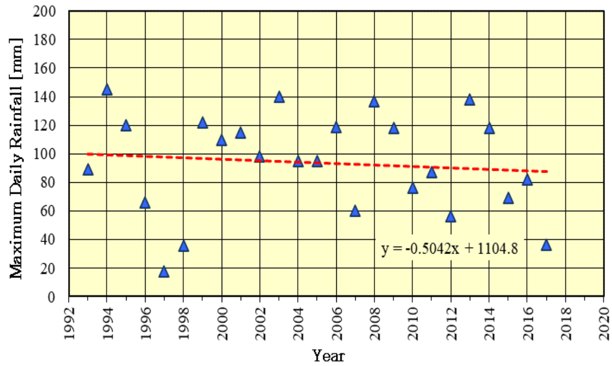

Fig. 4 Graph of the maximum daily rainfall at the Camplong rainfall station

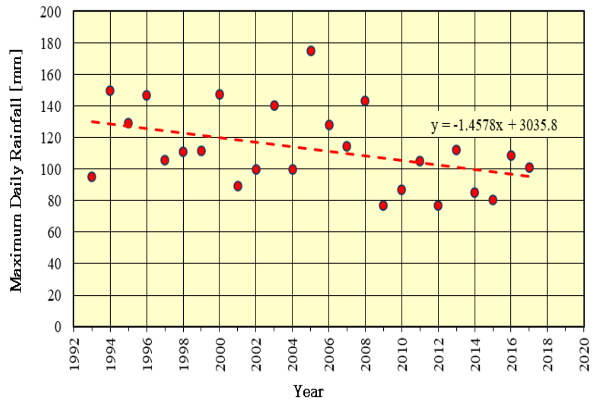

Fig. 5 Graph of the maximum daily rainfall at the Raknamo rainfall station

Fig. 2 shows an increase in annual rainfall at the Camplong rainfall station, but it is inversely proportional to the Raknamo rainfall station. The maximum daily rainfall in the two ground stations, there has been a decreasing trend for the last 25 years. It shows a change in the characteristics of the annual average rainfall and maximum daily rainfall that tends to increase with time even though the variance value is insignificant.

The Mann-Kendall equation was used to analyze the climate change in the study area. The results are presented in Tables 2 and 3.

Table 2 The results of the Makesens method

Time series	The first year	Last Year	n	Test Z	Signific.	Q	B
January	1993	2017	25	-0.02		-0.23	341.85
February	1993	2017	25	-1.10		-4.34	352.73
March	1993	2017	25	-1.61		-5.88	236.98
April	1993	2017	25	-0.35		-0.24	51.41
May	1993	2017	25	0.93		0.32	6.90
June	1993	2017	25	-0.83		0.00	2.90
July	1993	2017	25	-0.24		0.00	0.00
August	1993	2017	25	0.50		0.00	0.00
September	1993	2017	25	1.72	+	0.00	0.00
October	1993	2017	25	-0.52		0.00	0.00
November	1993	2017	25	-0.05		-0.07	91.60
December	1993	2017	25	-0.12		-0.54	231.64
Average	1993	2017	25	-1.75	+	-1.62	137.61
Annual	1993	2017	25	-1.75	+	-19.43	1651.28
Max Daily	1993	2017	25	-1.52		-1.10	116.50

The result of the Makesens' analysis can be said that is a climate change in the research location by looking at the Z ≠ zero (Z ≠ 0) but not significant except in March and September.

Table 3 The results of the recapitulation of climate change calculations are based on the Mann-Kendall method

Rainfall	Year		n	Mann-Kendall Test Trend											
	From	To		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Maximum daily rainfall (mm/day)	1993	2017	25	-0.22 Neg, NS											
Monthly rainfall (mm/month)	1993	2017	25	-0.55 Neg, NS	-1.83 Neg, YS	-2.63 Neg, YS	-1.92 Neg, YS	-1.41 Neg, NS	-1.85 Neg, YS	-2.71 Neg, YS	0.42 Pos, NS	0.82 Pos, NS	-0.68 Pos, NS	0.55 Neg, NS	-1.74 Neg, YS
Annual rainfall (mm/year)	1993	2017	25	-1.94 Neg, YS											

Abreviation

PYS = Positive Yes Significant

PNS = Positive No Significant

NYS = Negative Yes Significant

NNS = Negative No Significant

NT = No trend

Table Z for Normal Standard

$Z_{0.1} = 1.645$ ………... α = 10%

$Z_{cal.} > Z\alpha$ …………… Yes Significant (YS)

$Z_{cal.} < Z\alpha$ …………… No Significant (NS)

$Z_{cal.} = 0$ …..………… No Trend (NT)

According to Table 3, the maximum daily rainfall climate indicator shows a negative but not significant trend. As for the monthly rain indicator from the beginning to the end of the year, the variation in the results produced each month such as in January, May, and November has a negative but not significant trend. February, March, April, June, July, and December have negative and significant trends. Positive and insignificant trends occurred in August, September, and October. Table 3 also shows climate change indicator trends in the annual rainfall indicators. Overall, based on the data for the year of the study, the results show negative and significant trends.

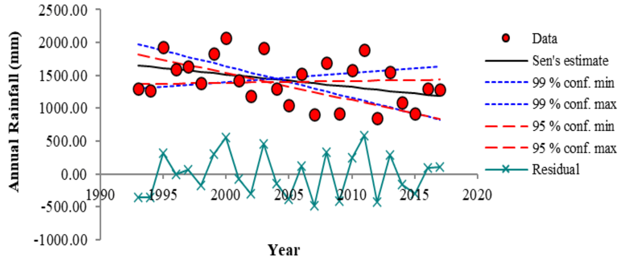

Fig. 6 Annual rainfall chart for Noel Puames - Raknamo (1993–2017)

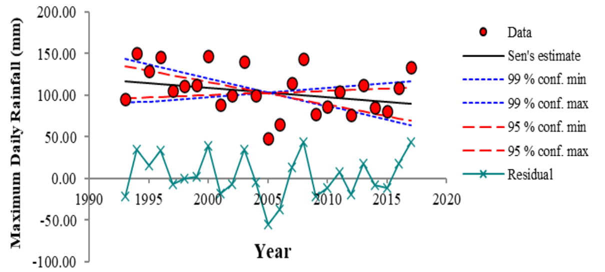

Fig. 7 Maximum daily rainfall chart for Noel Puames - Raknamo (1993–2017)

After detecting the absence of climate trend with the Mann-Kendall method, an analysis of the magnitude of the trend value is carried out using the Sen method to anticipate climate change, especially the maximum daily rainfall:

f(year) = Q (years – first data year) + B = -1.99 (year – 1993) + 116,497 (7)

This equation was used to find estimates of climate change in the maximum daily rainfall variable (Fig. 8).

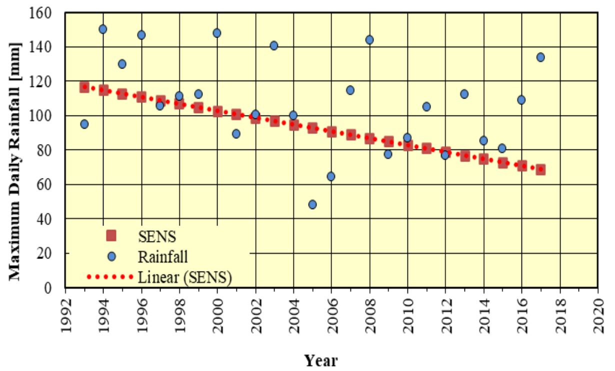

Fig. 8 Graph of maximum daily rainfall (1993–2017)

Fig. 8 shows the decrease in the maximum annual daily rainfall in the Raknamo watershed for the last 25 years based on the Raknamo rainfall station.

4. Conclusion

Based on the analysis above, the maximum daily rainfall climate indicator shows a negative but not significant trend. As for the monthly rain indicator from the beginning to the end of the year, the variation in the results produced each month such as in January, May, and November has a negative but not significant trend. February, March, April, June, July, and December have negative and significant trends. Positive and insignificant trends occurred in August, September, and October.

The maximum daily rainfall is presented in the following equation:

f(year) = Q (years – first data year) + B = -1.99 (year – 1993) + 116,497

This equation was used to find estimates of climate change in the maximum daily rainfall variable.

Based on the results of the analysis and discussion can be concluded as follows: 1) Climate change causes changes in the characteristics of rain in the Raknamo watershed, namely annual rainfall, monthly rainfall, and maximum daily rainfall tend to decrease, especially for the annual rainfall; and 2) There has been a change in climate in the Raknamo watershed that is indicated by the Z value not being equal to zero ($Z \neq 0$) but not significant except in March and September.

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