Study of rain pattern and rain characteristics on design flood discharge as the impact of climate change

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ABSTRACT- Climate change brings changes to the characteristics of rain and rain patterns so that it affects the flow of rivers. This study aims to determine the effect of climate change on river flood discharge by paying attention to rain patterns and rain characteristics. This research was conducted in the Bangga watershed, Indonesia. The methods used include Makesens, statistical standard deviation, Oldeman, Log Pearson III, and HSS Nakayasu. The data used is daily rainfall data for 29 years (1993-2021) from Bangga Atas and Bangga Bawah stations. The results of this study are: the rain pattern for the last 10 years(2012-2021) remains the same as the previous 19 years (1993-2011), namely Pattern B or Equatorial Pattern. Rainfall characteristics and climate change show an upward trend for the last 10 years compared to the previous 19 years. The design flood discharge for the last 10 years is greater than the previous 19 years for the 1.01 return period; 2; 5 years. Meanwhile, at other times the results are smaller. It can be concluded, that although there has been an increasing trend of rainfall in the last 10 years, it has not caused an increase in the design flood discharge for all return periods.

Keywords: *Climate change, Mann-Kendall, rain characteristics, floods, Bangga watershed*

I. INTRODUCTION

Climate change is a long-term change in weather patterns over decades to millions of years. High climate variability, changes in seasonal patterns, and the occurrence of extreme climate phenomena are indicators of climate change [1]. Climate change can be measured from changes in the main components of the climate, such as temperature, humidity, wind, rain, and rainy and dry seasons. Of these variables, the most dominant influence on climate change is rainfall [2].

Climate change causes changes in rain patterns, wind patterns, humidity, sunlight, river discharge, and seasonal dynamics. In general, the impact is very simple, namely, the higher the rainfall will produce a larger river discharge, on the other hand, a decrease in rainfall will reduce the river flow rate [3]. Climate change has brought changes to the characteristics of rain and rain patterns. The duration of the rainy season is getting shorter but with high intensity and the duration of the dry season is getting longer which results in drought. The number of rainy days tends to decrease, and the maximum daily rainfall and rainfall intensity trends to increase [4]. A phenomenon like this affects the flow of water in the river.

The results of research by Mahawan Karuniasa and Priyaji Agung Pambudi (2022) in East Nusa Tenggara Province, Indonesia East Nusa Tenggara Province, Indonesia found that there was a decrease in total cumulative rainfall in El Nio years. The annual rainfall for the last six El Nio events was lower than the annual rainfall for the first six El Nio events. The dry day series is dominated by extreme drought (>60 days) which generally occurs from July to October. This drought is having a major impact on livelihoods and causing difficulties in agriculture and access to freshwater [5]. N'Da Jean Claude Konin et al. (2022) in their research in Agnéby watershed, it was found that although rainfall generally decreased, extreme rainfall often occurred, causing flooding in watersheds [6]. Eshetu Ararso Heyi (2022) in his research on the upper Awash River sub-basin resulted that water sources in the upstream Awash watershed are expected to be highly affected by climate change. Therefore, different adaptation options should be made to reduce the possible impacts and ensure water security in the sub-watershed [7].

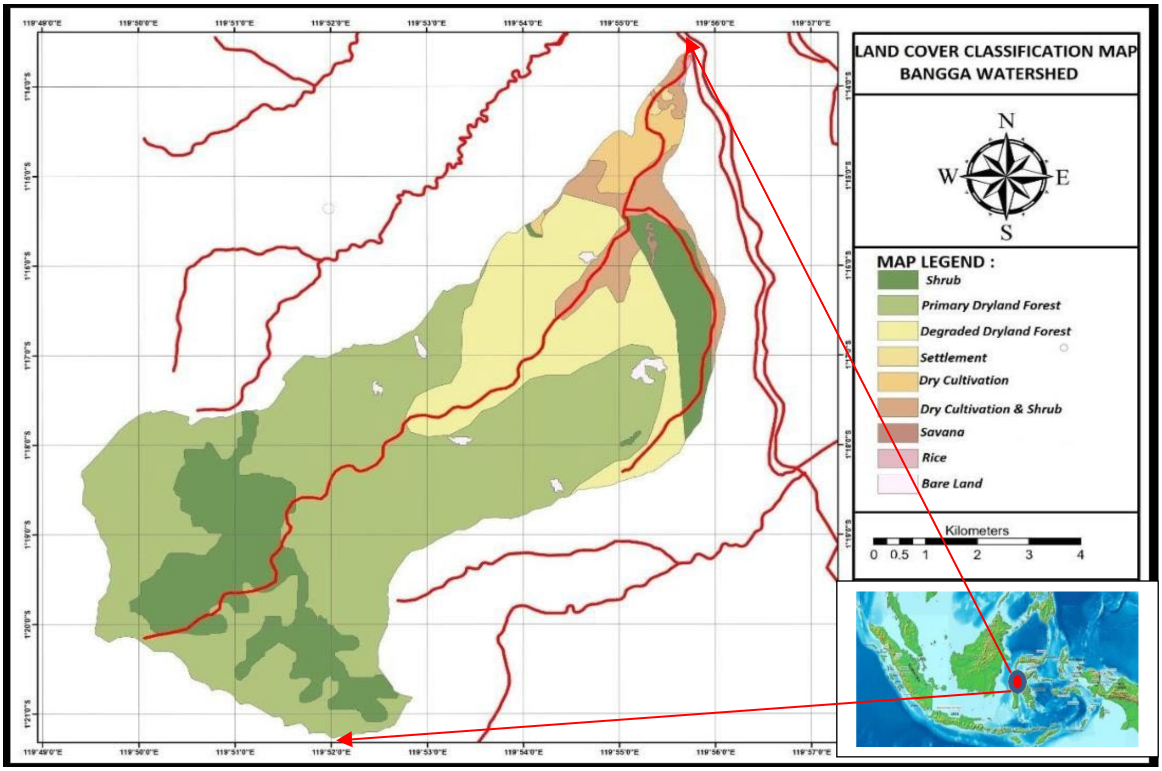
This study aims to determine the effect of climate change on river flood discharge by paying attention to rain patterns and rain characteristics. The rain series data for the last 10 years is assumed to be affected by climate change compared to the data for the previous 20 years, then analyzed.

II. MATERIAL AND METHODS

A. Description of study

The location of this research is in the Bangga watershed, Sigi Regency, Central Sulawesi, Indonesia with a watershed area of 65.90 km^2. The research location is presented in the following figure:

N. Edy et al. (eds.), *Proceedings of the 2nd International Interdisciplinary Conference on Environmental Sciences and Sustainable Developments 2022 Environment and Sustainable Development (IICESSD-ESD 2022)*, Advances in Biological Sciences Research 36,
https://doi.org/10.2991/978-94-6463-334-4_20



a). Bangga watershed b). Indonesian map

Fig. 1. Location of research

The rainfall data used in this study is the Bangga Atas and Bangga Bawah Station with coordinates: 1° 17' 14" south latitude 119° 54' 01" east longitude and 1° 14' 35" south latitude 119° 54' 35" east longitude.

B. Literature review

B.1. Mann-Kendall test

Detection of climate change uses the Mann-Kendall method [3], [8], [9], [10], [11], [12], [13], [14], [15], [16]:

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

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

$$Z = \begin{cases} (S - 1)/\sigma s & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ (S + 1)/\sigma s & \text{if } S < 0 \end{cases} \quad (3)$$

Where Xj and Xk are the data values for "j" and "k", j> k. After detecting whether there is an increase or decrease trend with the Mann Kendall test, then to determine the magnitude of the trend non-parametric Sen's method is used with the assumption that the trend is linear. The procedure starts from equations 1 to 3. The two methods are combined so they are called the Makesens method.

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

where: Q is the slope and B is a constant. To obtain the estimated slope Q in equation (4), it is first necessary to calculate the slope for all data with the equation:

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

where is j > k. If there is an "n" value of "Xj" in the time series, then N = n (n-1) / 2 slope of Qi estimation is obtained. Slope Sens estimation is the median of N Qi values. The N value of Qi is ranked from small to large, with the estimated Sens being:

Q = Q[(N+1)/2] if N is odd or

Q=0,5(Q(N/2)+Q((N+2)/2))if N is even (6)

To obtain estimation B in equation (4), then data values of the difference (Xi - Q.ti) are calculated. The median of this value is estimate B.

B.2. Rainfall characteristics

a) Rainfall patterns

There are three rainfall patterns in Indonesia, namely [17]: 1). Pattern A or Monsoon Pattern, influenced by monsoon winds with the characteristic of monthly distribution forming the letter (V); 2). Pattern B or equatorial pattern, the distribution of rainfall with two maximums, around April and October; 3). Pattern C or local pattern, where the distribution of monthly rainfall is opposite to pattern A.

b) The nature of rain

The evaluation of rainfall characteristic can be calculated using the standard deviation equation that divided into five characteristics of rain, namely [15], [18]:

1. Far below normal (JBN)
   $$JBN = x \leq X - 1{,}5\ SD \quad (7)$$
2. Under normal (BN)
   $$BN = X - 1{,}5\ SD < x \leq X - 0{,}5\ SD \quad (8)$$
3. Normal (N)
   $$N = X - 0{,}5\ SD < x \leq X + 0{,}5\ SD \quad (9)$$
4. Above normal (AN)
   $$AN = X+0{,}5\ SD < x \leq X+1{,}5\ SD \quad (10)$$
5. Far above normal (JAN)
   $$JAN = x > X + 1{,}5\ SD \quad (11)$$

Standard deviations are calculated using the equation [19], [20], [21], [22]:

$$SD = \sqrt{\frac{\sum_{i=1}^{n} Xi^2 - \frac{(\sum Xi)^2}{n}}{n-1}} \quad (12)$$

Where: X = average rainfall (mm); x = Xi = monthly rainfall (mm); SD = deviation standard; Xi = monthly rainfall; n = the number of years of observation

The nature of rain according to Oldeman in Wahid (2017) is presented in the following table [23]:

TABLE I. Classification nature rainfall according to Oldeman

No	Rainfall	Nature Rainfall
1	> 200 mm	Wet month (WM)
2	100 – 200 mm	Humid month (HM)
3	< 100 mm	Dry month (DM)

B.3. Frequency analysis

Rain frequency analysis is very necessary for calculating the design flood event if at the planned location there is no recording of the maximum long-term and continuous discharge. Some of the methods that are often used include normal distribution, log-normal distribution, Pearson type III distribution, and

Gumbell distribution. The choice of the method depends on the statistical parameters except for the

Pearson type III log distribution which is not implied. Therefore, in this study, the Log Pearson type III method was used [21], [24]:

The calculation steps are as follows:

1. Change the rainfall data for n pieces from x1, x2, x3,...,xn into logarithmic form, namely log x1, log x2, log x3,..., log xn (13)
2. Calculate the average value, from the rainfall data that has been converted into logarithmic form with the equation:
   $$\log x_o = \frac{1}{n} \sum_{i=1}^{n} \log x_i \quad (14)$$
3. Calculate the standard deviation, using the equation:
   $$S \log x = \sqrt{\frac{\sum_{i=1}^{n} (\log x_i - \log x_o)^2}{n-1}} \quad (15)$$
4. Calculate the coefficient of deviation, with the equation:
   $$Cs = \frac{\sum_{i=1}^{n} (\log x_i - \log x_o)^3}{(n-1)(n-2)(n-3)} \quad (16)$$
5. Calculating the logarithm of rainfall with the equation:
   $$\log XT = \log x_o + K_{Tr}.\ S\log x \quad (17)$$
   The value of KTr is obtained from the table of the relationship between Cs and the return period.
6. Calculate the anti-log value of XT, to get the design rainfall with a T year return period.

B.4. Design flood

The design flood was determined based on an analysis of the maximum daily rainfall recorded. The maximum discharge frequency is rarely applied because of the limited observation period. So the analysis is carried out by using empirical equations by taking into account the related natural parameters. To determine the design of flood discharge, an analysis of the peak flood discharge was carried out using the HSS Nakayasu method. Nakayasu has researched flood hydrographs on several rivers in Japan. Some equations to analyse HSS Nakayasu are [4], [25], [26], [27], [28], [29], [30], [31].

a) Analysis of unit rain and effective rain / Net Hourly

The equation to get the hourly rainfall distribution value is:

The hourly net rainfall analysis can be expressed as follows:

b) Synthetic Unit Hydrograph Nakayasu

Nakayasu has made the formula for a synthetic unit hydrograph from the results of his investigations as follows:

$$Qp = \frac{C \times A \times R_0}{3,6 \times \left(0,3Tp + T_{0,3}\right)} \quad (21)$$

where : Qp = peak flood discharge (m3/second); ro = unit rain (mm); tp = time lag from the beginning of the rain to the peak of the flood (hours); tp = tg + 0.8 tr; tg = concentration time (hours), grace period from the center of rain to the center of gravity of the hydrograph (time lag).

in this case, if:

$L < 15$ km, $tg = 0,21 \cdot L^{0,7}$ (22)

$L > 15$ km, $tg = 0,4 + 0,058 \cdot L$ (23)

tr = time base of hidrograf

= 0,5 sampai 1 tg

$t_{0,3} = \alpha . tg$ (24)

$$\alpha = \frac{0,47 \times \left(A \cdot L\right)^{0,25}}{tg} \quad (25)$$

Based on observations in Indonesia, the concentrated rain is not more than 7 hours, for the calculation the equation is used:

$$R_T = \frac{R_{24}}{t}\left(\frac{t}{T}\right)^{\frac{2}{3}} \quad (18)$$

$$Rt = t.R_T - [t-1].R_{(T-1)} \quad (19)$$

$$Rn = C \cdot R \cdot R_t \quad (20)$$

For ordinary drainage area α=2; the slow ascending part of the hydrograph and the fast descending part α =1.5; the fast-ascending part of the hydrograph and the slow descending part α =3

The rising limb of the unit hydrograph is calculated using the formula:

$$Qa = Q_p \times \left(\frac{t}{T_p}\right)^{2.4} \quad (26)$$

The decreasing limb of the unit hydrograph is calculated using the formula:

$$q_{d1} = Qp \times 0,3^{\frac{t-Tp}{T_{0,3}}} \quad (27)$$

$$q_{d2} = Qp \times 0,3^{\frac{t-Tp+0,5T_{0,3}}{1,5T_{0,3}}} \quad (28)$$

$$q_{d3} = Qp \times 0.3^{\frac{t-Tp+1,5T_{0,3}}{2T_{0,3}}} \quad (29)$$

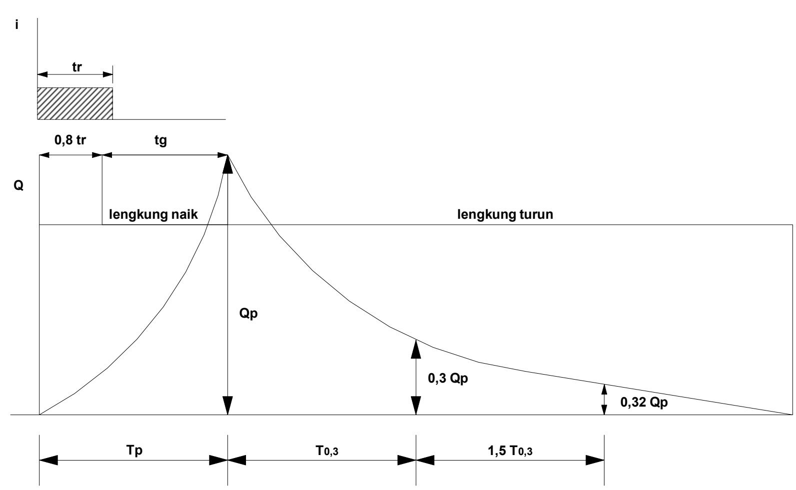


Fig. 2. Nakayasu synthetic unit hydrograph curve

B. Framework

These are the necessary steps to complete this research: 1). Climate change detection, 2). Rain characteristics, 3). The nature of rain, 4). The frequency analysis, and 5). Design flood discharge analysis. The flow chart is presented in the following figure:

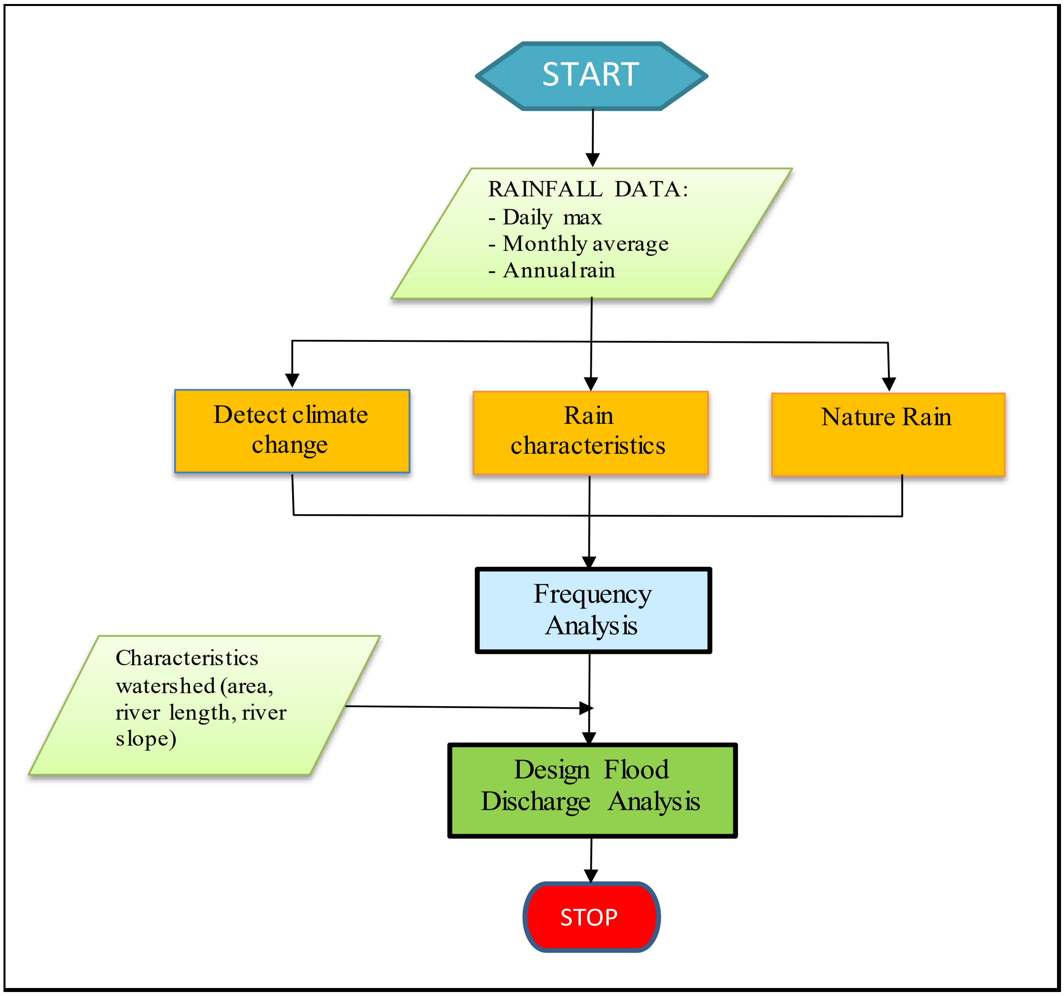


Fig. 3. Flowchart of research

III. RESULTS AND DISCUSSION

A. Rainfall pattern

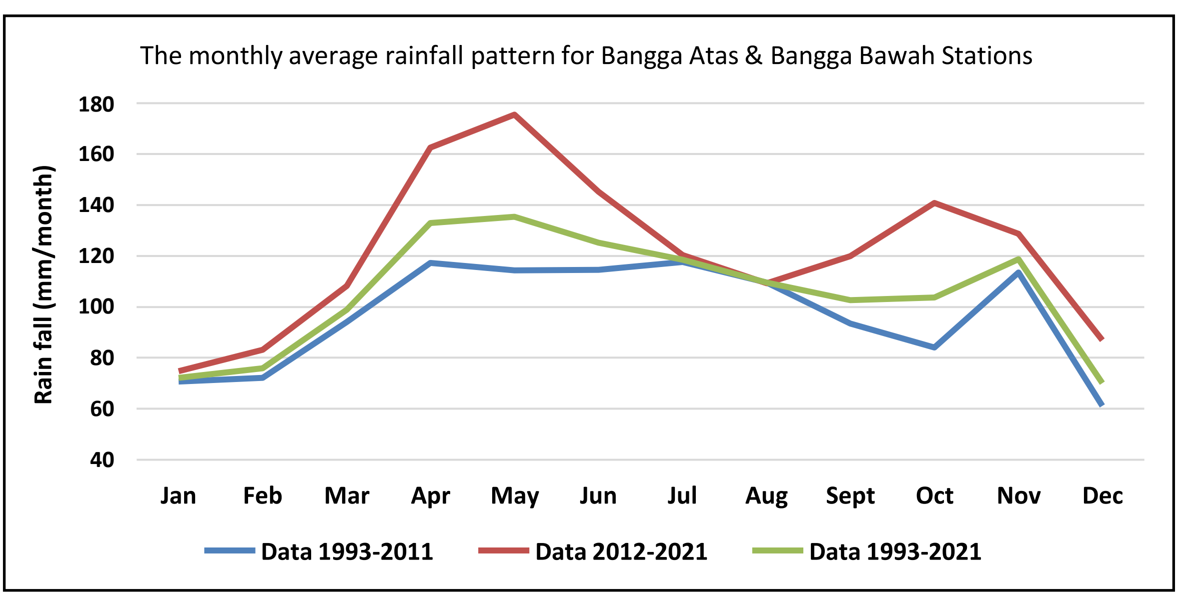


Fig. 4. Rainfall pattern at Bangga Atas and Bangga Bawah Stations

Based on Figure 4, it can be seen that the rain pattern is almost the same for the three periods of rain data. The peak of rain occurs in April-May and October-November. With this condition, it is classified as Pattern B or Equatorial Pattern. The average monthly rainfall for the last 10 years (2012-2021) is greater than that for the 1993-2011 and 1993-2021 rainy periods. This shows that the incidence of rain is quite large in the last 10 years (2012-2021).

B. Annual rain trend

The annual rain trend for the 1993-2011, 2012-2021 and 2012-2021 periods is presented in Figures 5 to 7. From the figure, it can be seen that the annual rainfall for the 1993-2011 period has a downward trend with the linear equation y = -26.831x + 54878, R^2 = 0.1441. In the period 2012-2021 there was an uptrend with the linear equation y = 70.771x - 141254, R^2 = 0.2985. In the period 1993-2021 there was an uptrend with the linear equation y = 9.0877x - 16976, R^2 = 0.035. The three periods of annual rainfall show a low correlation. This is due to fluctuations in the value of annual rainfall. However, this does not affect the research because what we want to compare is the annual rainfall trend for the 1993-2011 period against the 2012-2021 period as one of the determinants of climate change. By paying attention to the annual rain trend, it can be said that the annual rain in the last 10 years (2012-2021) has increased quite significantly.

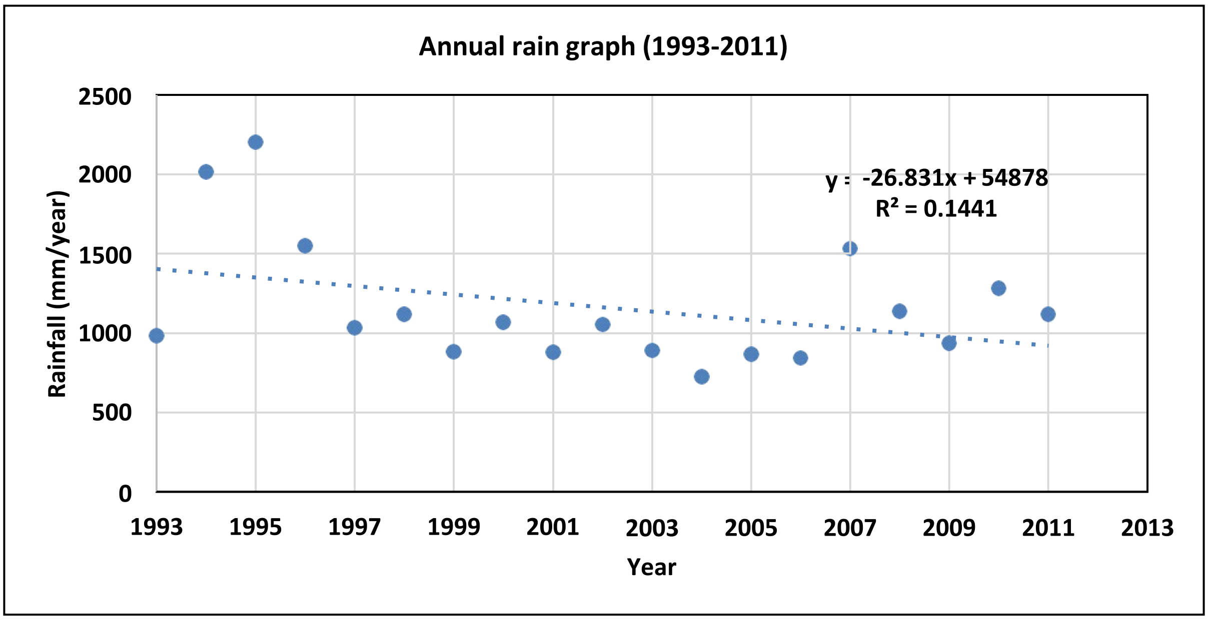


Fig. 5. Annual rain graph (1993-2011)

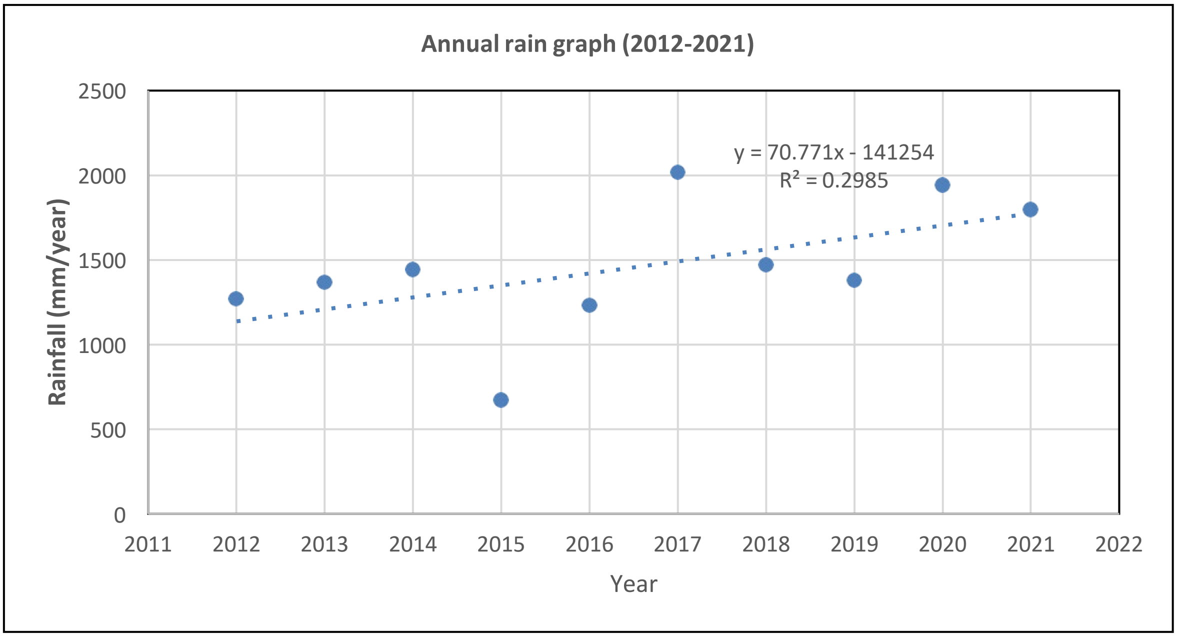


Fig. 6. Annual rain graph (2012-2021)

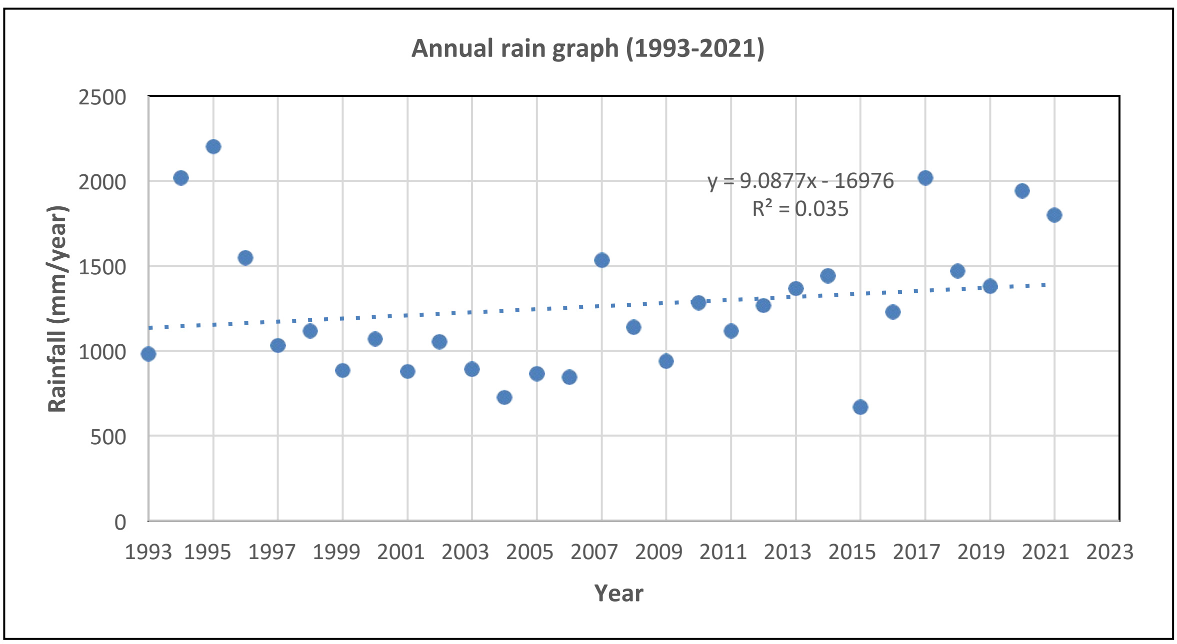


Fig. 7. Annual rain graph (1993-2021)

C. *Number of rainy days*

The trend in the number of annual rainy days for the 1993-2011, 2012-2021 and 2012-2021 periods is presented in Figures 8 to 10. From the figure, it can be seen that the number of annual rainy days for the 1993-2011 period has a downward trend with the linear equation $y = -0.4965x + 1147.3$, $R^2 = 0.005$. During the period 2012-2021 there was an uptrend with the linear equation $y = 2.3879x - 4656.4$, $R^2 = 0.1097$. In the period 1993-2021 there was an uptrend with the linear equation $y = 0.2118x - 269.89$, $R^2 = 0.0028$. The three periods of annual number of rainy days showed a low correlation. This is due to fluctuations in the number of annual rainy days. However, this has no effect in the study because what we want to compare is the trend of the number of annual rainy days for the 1993-2011 period against the 2012-2021 period as one of the determinants of climate change. Taking into account the trend in the number of annual rainy days, it can be said that the number of annual rainy days in the last 10 years (2012-2021) has increased significantly.

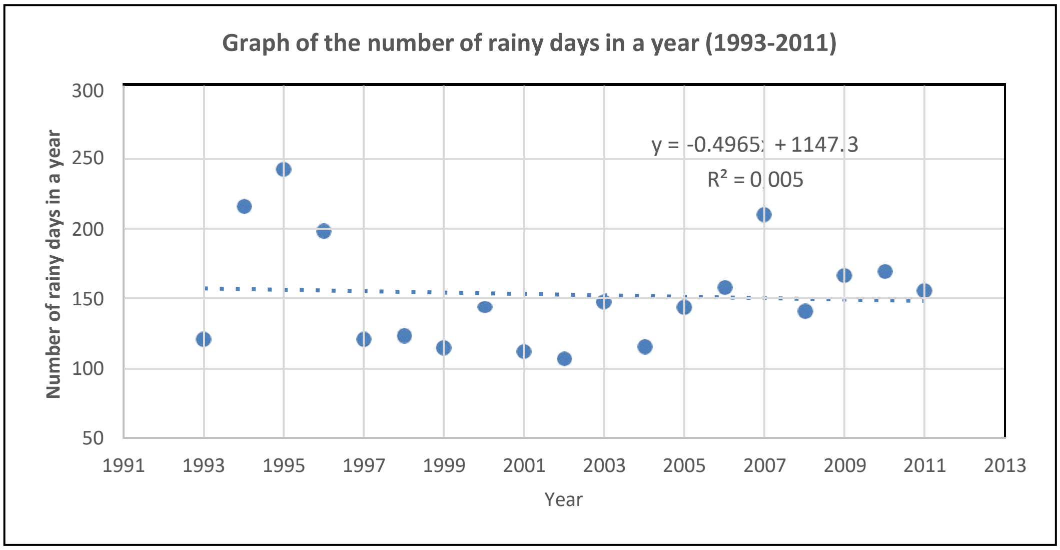


Fig. 8. Graph of the number of rainy days in a year (1993-2011)

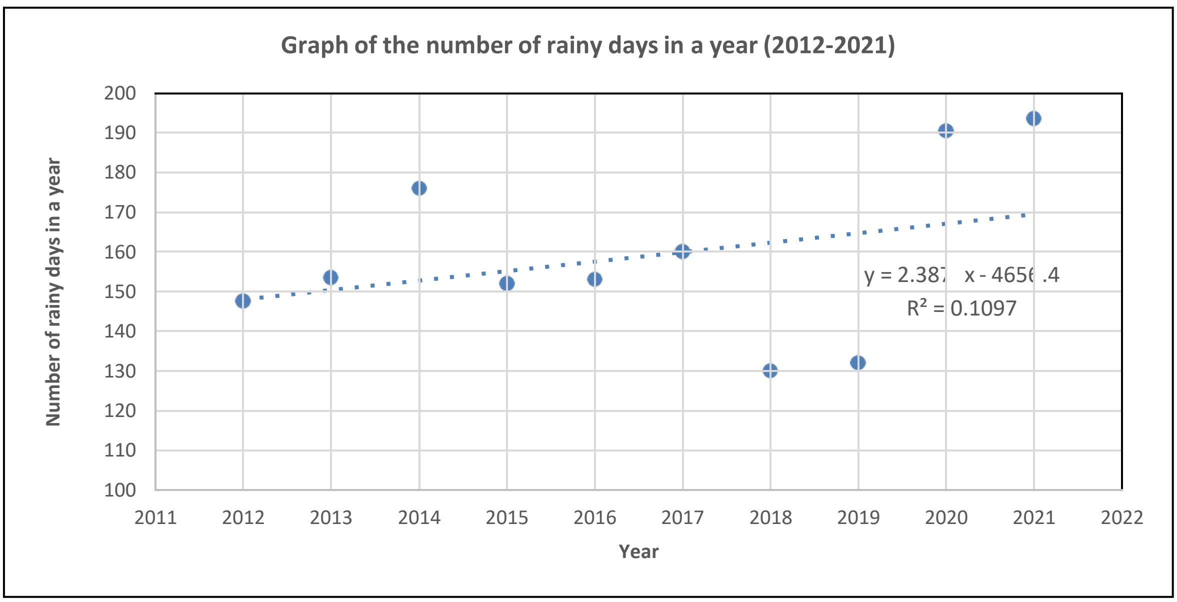


Fig. 9. Graph of the number of rainy days in a year (2012-2021)

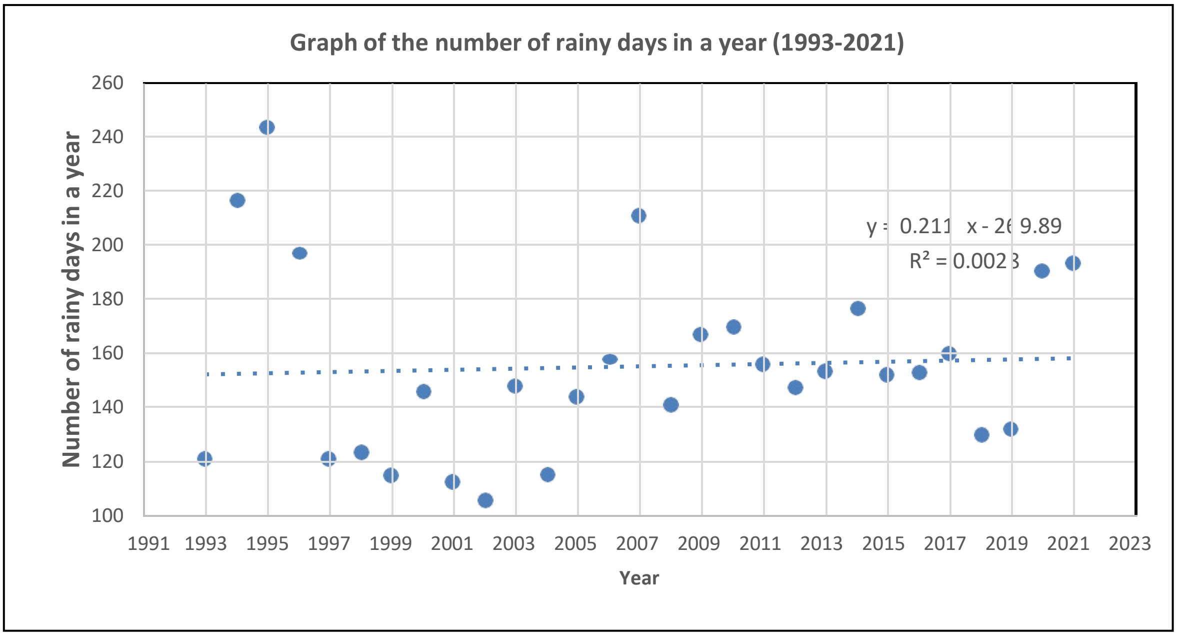


Fig. 10. Graph of the number of rainy days in a year (1993-2021)

D. *Detection of climate change*

By using the Mann-Kendall method from formulas 1 to 3, the Z value can be calculated as a guide to determine the detection of climate change. The results are presented in the following table:

TABLE II. Detection of climate change with Mann Kendall method

Description	From	To	n	Trend											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nop	Dec
Rainfall (mm)															
Test Z, Daily Max	1993	2011	19	-0.35											
				NNS											
	2012	2021	10	2.33											
				PYS											
	1993	2021	29	1.11											
				PNS											
Test Z, Monthly Ave.	1993	2011	19	0.00	-0.53	-0.42	-0.95	-0.77	-0.98	-0.42	0.14	-0.98	-2.31	-0.56	1.40
				NT	NNS	NNS	NNS	NNS	NNS	NNS	PNS	NNS	NYS	NNS	PNS
	2012	2021	10	1.07	0.89	1.43	0.54	1.07	1.61	1.25	0.54	1.25	1.43	0.00	-1.43
				PNS	PNS	PNS	PNS	PNS	PNS	PNS	PNS	PNS	PNS	NT	NNS
	1993	2021	29	0.62	0.98	1.18	0.19	0.77	0.96	-0.06	0.58	0.32	0.21	0.21	0.81
				PNS	PNS	PNS	PNS	PNS	PNS	NNS	PNS	PNS	PNS	PNS	PNS
Test Z, Annual	1993	2011	19	-1.02											
				NNS											
	2012	2021	10	1.61											
				PNS											
	1993	2021	29	1.43											
				PNS											

where:

P	= Positif or increasing trend;	$Z_{cal} > Z\alpha$ ...Yes significant (YS)	Table Z for normal standard distribution
N	= Negatif or decreasing trend;		$Z_{0,001}$ = 3,292 .... α = 0,1%
YS	= Yes significant;	$Z_{cal} < Z\alpha$ ... No significant (NS)	$Z_{0,01}$ = 2,576 .... α = 1 %
NS	= No significant;		$Z_{0,05}$ = 1,96 .... α = 5%
NT	= No trend;	Z = 0 ...No trend (NT)	$Z_{0,1}$ = 1,645 .... α = 10%

Based on Table II, it can be explained that for the maximum daily rainfall for the 1993-2011 period, climate change occurred with a decreasing but not significant trend, in the 2012-2021 period there was climate change with an up and significant trend, the 1993-2021 period there was a climate change with an upward trend but not significant. This shows that in the last 10 years (2012-2021) there has been an increase in maximum daily rainfall and the amount is quite significant. The average monthly rainfall for the 1993-2011 period experienced a downward trend in climate change, except that in January there was no climate change and in August and December there was an upward trend. During the period 2012-2021 climate change occurred with an upward trend, except in November there was no climate change and in December there was a downward trend. In the period 1993-2021 climate change occurred with an upward trend, except in July with a downward trend. The annual rains for the 1993-2011 period saw climate change with a downward trend but not significant, for the 2012-2021 and 1993-2021 climate changes there was an upward trend. This shows that for the last 10 years (2012-2021) there has been a change in climate with an upward trend for maximum daily rain, monthly average rain, and annual rain.

There is an alignment of the rain pattern with the annual rain trend, the number of annual rainy days and the Z value of the annual rain from the Mann-Kendall calculation, where the 1993-2011 period has a downward trend, the 2012-2021 period has an upward trend and the 1993-2021 period has an upward trend. The results are presented in table 3.

TABLE III. Trend rainfall

Description	Period		
	1993-2011	2012-2021	1993-2021
Annual rain trend	decrease	increase	increase
Trend of annual number of rainy days	decrease	increase	increase
Test Z, annual rain	decrease	increase	increase

E. The nature of rain

Yearly rainfall data from 1993 to 2021 can be classified by the nature of the rain by calculating the standard deviation and classification according to Oldeman as presented in the following table and figure:

TABLE IV. Classification of nature rainfall according to deviation standard and Oldeman

No	Year	Month												Yearly	Average	Rain	Natur
		Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec			Clasification	of rain
1	1993	0	0	0	0	9	137	257	83	97	127	170	101	981	82	BN	DM
2	1994	108	152	308	154	368	178	65	202	47	129	179	126	2015	168	JAN	HM
3	1995	155	249	266	98	135	183	169	232	287	205	192	28	2199	183	JAN	HM
4	1996	113	212	99	149	156	163	91	179	151	112	81	42	1546	129	AN	HM
5	1997	37	95	101	171	41	60	166	6	14	23	267	51	1030	86	BN	DM
6	1998	10	15	69	164	97	136	264	87	140	71	41	22	1115	93	N	DM
7	1999	9	61	108	135	103	21	60	94	94	147	36	14	883	74	BN	DM
8	2000	208	23	27	102	111	172	72	67	88	69	100	28	1067	89	N	DM
9	2001	110	51	60	147	132	113	24	16	91	66	21	48	877	73	BN	DM
10	2002	70	11	53	129	56	203	89	25	106	55	186	68	1051	88	BN	DM
11	2003	37	61	76	150	105	36	60	77	28	122	107	28	888	74	BN	DM
12	2004	88	12	41	118	165	51	100	1	75	17	39	14	722	60	BN	DM
13	2005	12	22	102	91	116	42	64	81	116	123	52	45	865	72	BN	DM
14	2006	47	69	9	140	93	56	97	66	86	9	98	72	842	70	BN	DM
15	2007	74	167	115	153	240	103	43	242	79	116	90	111	1531	128	AN	HM
16	2008	43	24	138	157	121	144	222	55	9	10	151	64	1136	95	N	DM
17	2009	54	0	102	104	78	58	74	108	44	94	88	131	935	78	BN	DM
18	2010	97	82	39	0	0	273	241	264	100	57	49	79	1281	107	N	HM
19	2011	73	66	75	64	45	48	77	198	123	46	210	91	1115	93	N	DM
20	2012	34	89	23	136	98	78	29	123	64	100	237	254	1265	105	N	HM
21	2013	61	108	92	120	119	119	131	90	174	102	119	129	1363	114	N	HM
22	2014	94	22	91	83	531	109	109	84	23	46	98	148	1439	120	N	HM
23	2015	67	58	121	104	38	57	24	15	11	47	122	4	668	56	BN	DM
24	2016	41	49	124	345	95	204	55	99	121	59	29	7	1228	102	N	HM
25	2017	114	122	121	153	142	94	329	131	189	385	163	75	2015	168	JAN	HM
26	2018	31	95	137	125	129	203	67	153	101	166	140	125	1468	122	N	HM
27	2019	122	80	102	204	109	198	75	54	31	144	163	97	1378	115	N	HM
28	2020	107	114	88	267	306	174	227	82	271	234	65	5	1939	162	JAN	HM
29	2021	77	97	185	91	189	218	157	263	216	124	150	28	1795	150	AN	HM
	Average	72	76	99	133	135	125	119	109	103	104	119	70	1263	105	N	HM
												Deviation standard			34		

Where:

JBN	=	Far below normal	WM	=	Wet month for rainfall > 100 mm/month
BN	=	Below normal	HM	=	Humidity month for rainfall 100 - 200 mm/month
N	=	Normal	DM	=	Dry month for rainfall < 100 mm/month
AN	=	Above normal			
JAN	=	Far above normal			

Based on Table IV, it can be explained that the monthly average rainfall characteristics for the 1993-2011 period are dominated by the below normal rain category. While the period 2012-2021 is dominated by rain with the normal category even far above normal. Likewise, for the nature of rain by Oldeman, the 1993-

2011 rainy period was dominated by dry rain while the 2012-2021 period was dominated by moist rain. The nature of below normal rain and dry month rain indicates a low amount of rain while the nature of normal rain, above normal and rainy month rain indicates a high amount of rain. This event is in accordance with the results of the calculations in Table 3 (rainfall trend). This shows that in the last 10 years (2012-2021) there has been a significant increase in the amount of rain as a sign of climate change.

F. Frequency analysis

The results of the frequency analysis calculations using the Pearson Log III Method are presented in Figure 11 and Table IV. From the figures and tables, it can be seen that the design rainfall for the 2012-2021 period is greater than the 1993-2011 and 1993-2021 periods for return periods of 1.01, 2, and 5 years. As for the other repeat times, the results are smaller. If it is related to the amount of annual rain, the number of annual rainy days, the results of the Mann-Kendall calculation and the nature of the rain, then the period 1993-2011 the amount of rain is smaller, the trend of rain is decreasing and the rainy month is dry so that the results of the calculation of design rain with frequency analysis of the Pearson Log Method III smaller than the period 2012-2021. Table 4 also shows that the higher the return period, the greater the difference in design rainfall between the 2012-2021 period and the 1993-2011 and 1993-2021 periods. This may be due to differences in the use of rain data series which are 10 years and 19 years.

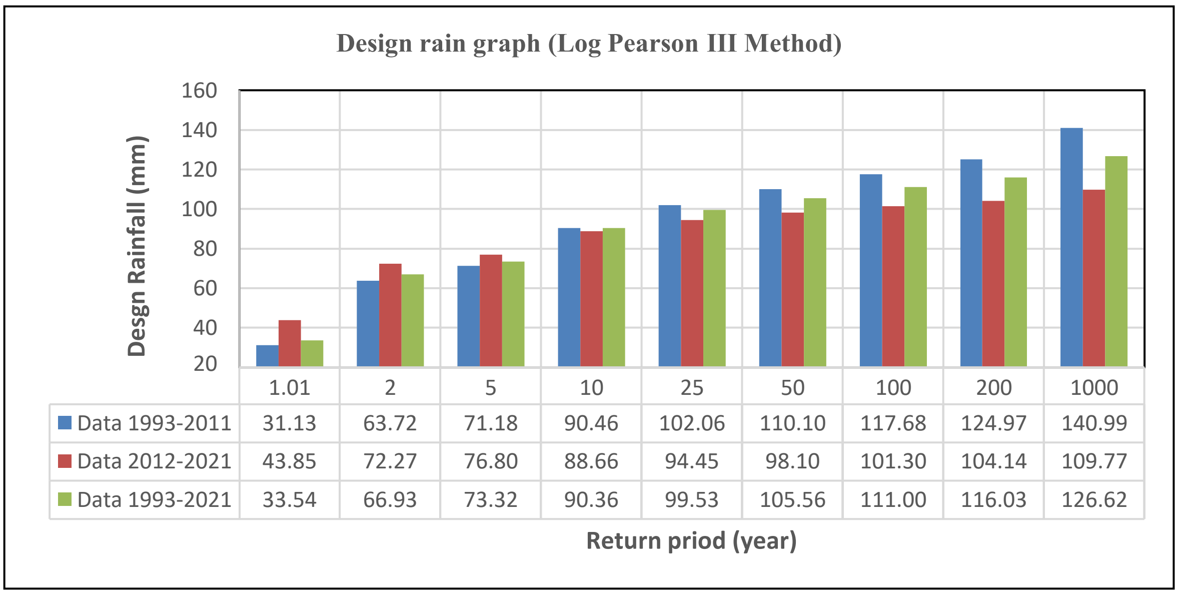


Fig. 11. Design rain graph (Log Pearson III Method)

TABLE V. Percentage difference in design rain

Return period (year)	Period 1993-2011 (mm), (a)	Period 2012-2021 (mm), (b)	Period 1993-2021 (mm), (c)	Percentage difference	
				(b) - (a)	(b) - (c)
1.01	31.13	43.85	33.54	29.00%	23.52%
2	63.72	72.27	66.93	11.82%	7.39%
5	71.18	76.80	73.32	7.31%	4.53%
10	90.46	88.66	90.36	-2.03%	-1.93%
25	102.06	94.45	99.53	-8.05%	-5.38%
50	110.10	98.10	105.56	-12.23%	-7.60%
100	117.68	101.30	111.00	-16.17%	-9.57%
200	124.97	104.14	116.03	-20.00%	-11.42%
1000	140.99	109.77	126.62	-28.44%	-15.35%

G. *Design flood*

The results of the calculation of the design flood discharge using the HSS Nakayasu method are presented in Figure 12 and Table 6. From the figure and table, it can be seen that the design flood discharge for the 2012-2021 period is greater than the 1993-2011 and 1993-2021 periods for the return period of 1.01; 2; and 5 years. As for the other return period, the results are smaller. If it is related to the amount of annual rain, the number of annual rainy days, the results of the Mann-Kendall calculation and the nature of the rain, the period 1993-2011 the amount of rain is smaller, the trend of rain is decreasing, rainy months are dry and the results of frequency analysis are also smaller so that the results of the calculation of flood discharge the design is smaller than the period 2012-2021. Table 5 also shows that the higher the return period, the greater the difference in design flood discharge between the 2012-2021 period and the 1993-2011 and 1993-2021 periods. This may be due to differences in the use of rain data series which are 10 years and 19 years.

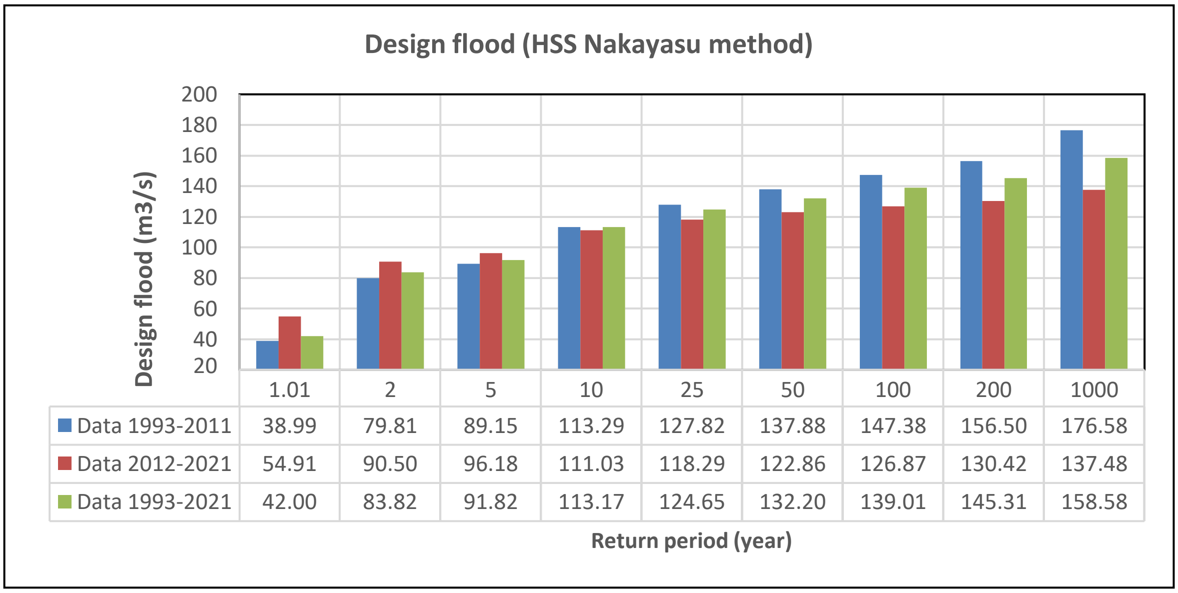


Fig. 12. Design flood (HSS Nakayasu method)

TABLE VI. Percentage difference in design flood discharge

Return period (year)	Period 1993-2011 (m3/s), (a)	Period 2012-2021 (m3/s), (b)	Period 1993-2021 (m3/s), (c)	Percentage difference	
				(b) - (a)	(b) - (c)
1.01	38.99	54.91	42.00	29.00%	23.52%
2	79.81	90.50	83.82	11.82%	7.39%
5	89.15	96.18	91.82	7.31%	4.53%
10	113.29	111.03	113.17	-2.03%	-1.93%
25	127.82	118.29	124.65	-8.05%	-5.38%
50	137.88	122.86	132.20	-12.23%	-7.60%
100	147.38	126.87	139.01	-16.17%	-9.57%
200	156.50	130.42	145.31	-20.00%	-11.42%
1000	176.58	137.48	158.58	-28.44%	-15.35%

IV. CONCLUSIONS

Based on the results of calculations and discussions that have been carried out, several conclusions can be drawn, namely:

1. The rain pattern for the last 10 years (2012-2021) remains the same as the previous 19 years period (1993-2011), namely Pattern B or Equatorial Pattern.
2. There is an alignment of rain patterns with the annual rain trend, the number of annual rainy days and the Z value of the annual rain from the Mann-Kendall calculation, where the 1993-2011 period has a downward trend, the 2012-2021 and 1993-2021 periods have an upward trend.
3. There has been a change in the nature of the rain from below normal to far above normal, as well as

an increase in the category of rain from dry month to wet month rain for the last 10 years (2012-2021) compared to the previous 19 years (1993-2011)

4. The relationship between the amount of annual rain, the number of annual rainy days, the results of the Mann-Kendall calculation and the nature of the rain, then the period 1993-2011 the amount of rain is smaller, the trend of rain is decreasing and the rainy month is dry so that the calculation results of the design rain for the period 1993-2011 are smaller from the period 2012-2021. The same thing happened in the calculation of the design flood discharge. Thus, it can be concluded that there has been a significant change in climate in the last 10 years (2012-2021) so that it affects the magnitude of the design flood discharge. Therefore, climate change needs to be considered in designing water structures on rivers

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