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Spatial Climate Forecasting for Climatology Disaster Mitigation

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Abstract Climate is the average weather conditions over a relatively long time. Climate change is a problem for living things, such as the agricultural sector. It affects the availability of community food reserves, public health, and socio-economics. The impact of climate change causes dramatic changes in agricultural patterns and shifts in planting time. Water availability for agricultural needs is complicated to predict, so the failure rate of agricultural production is getting bigger. Failure is due to a mismatch between the availability of water and the applied cropping pattern. This study aims to analyze and predict the spatial distribution of the Schmidt-Ferguson climate classification on Lombok Island from 2018-2035. This study generated rainfall data using the Thomas Fiering method from 18 rain stations on Lombok Island for 24 years (1994-2017). Determine the dry, moist, and wet months based on the Schmidt-Ferguson classification. From the analysis results, the most significant Q value is at the Geres Daya, Sapit, and Sopak rain stations with the classification "Extraordinarily Dry," and the smallest Q value is at the Sesaot, Perian, and Dasan Cermen rain stations with the "Very Wet" category. The Lombok Island has four dominant climate types based on Schmidt-Ferguson for the years 1994-2017, namely slightly wet (C), moderate (D), slightly dry (E), and dry (F). Meanwhile, for the years 2018-2035, the dominant climates are very wet (A), wet (B), slightly wet (C), and moderate (D). The results obtained can be used for planning in determining cropping patterns based on spatial climatic conditions, and they can be used to mitigate floods and droughts, and regulate water allocation in the irrigation sector. Especially in regional planning, it helps plan drainage systems.

Keywords Climate, Rain, Prediction, Classification, Disasters

1. Introduction

Lombok Island is one of the islands in Eastern Indonesia with the potential for climate changes that are very extreme and sudden. Conditions of climate change tend to spontaneously affect the social conditions of the community, especially economic conditions and agriculture [1,2]. Another impact caused by climate change is the decline in natural ecosystems, forestry, and the environment [3-5]. The failure of agricultural production has become a fundamental problem experienced by the community due to sudden climate changes resulting in a decrease in soil moisture content [6,7]. On a time scale, climate change will form specific patterns or cycles, whether daily, seasonal, annual or several yearly. The El Nino and La Nina phenomena affect climate change [8]. This phenomenon can also cause an increase in temperature and a decrease in rainfall [9-11]. The main problem encountered is related to water availability, be it flow rate or distribution [12]. This condition impacts changes in the planting period and cropping patterns, as well as declining quality and quantity of harvest [13].

Climate change in the agricultural sector has affected the characteristics of the seasons, namely the rainy and dry seasons. A shift at the beginning of the 2–4 week planting season since the last five years, even in the Java North Coast for 1-2 months, increased plant pests and diseases and a decrease in the production of agricultural products. To reduce agricultural production losses on the island of Lombok, it is essential to anticipate actions by forecasting spatial climate events that will occur based on previous occasions. Spatial climate forecasting gets excellent results in determining the incidence of drought and local rainfall events [14]. Forecasting results are beneficial and can be used as an instrument in making adaptations for adaptation to drought events [15]. Forecasting results are beneficial and can be used as an instrument in making adaptations for adaptation to drought events [15].

They [16] carried out a climate classification in agriculture and plantations, specifically in the tropics. The basis for classifying this climate is to use the amount of rainfall that falls each month so that the average wet, humid, and dry months are known. By using the Schmidt-Ferguson method, it is possible to calculate the comparative value (Q) between the average number of dry months (Md) and the average number of wet months (Mw) in the research year. The categories are for dry months (if in one month the amount of rainfall is < 60 mm), humid months (if in one month it has an amount of precipitation of 60 to 100 mm), and wet months (if in one month it has rainfall > 100).

The spatial climate forecasting approach on Lombok Island uses rain data by generating rain data. The Thomas Fiering method is very commonly used to generate hydrological data. Generating flow data produces an excellent flow model with very high sensitivity [17].

2. Materials and Methods

2.1. Study Area

Figure 1. shows the research location is on the island of Lombok, Indonesia, with an area of 4541.87 km^2

2.2. Data

The data used in the analysis is monthly rain data sourced from 18 rain stations spread across Lombok Island. Rainfall data for generation is for 24 years, from 1994-2017. Rain station data used are rain stations spread across Lombok Island, namely: Gunungsari Station, Keru Station, Sesaot Station, Serumbung Station, Santong Station, Sopak Station, Dasan Cermen Station, Kabul Station, Lingkok Lime Station, Loang Make Station, Mangkung Station, Pengadang Station, Rembitan Station, Perian Station, Geres Daya Station, Sepit Station, Pringgabaya Station, Sapit Station.

2.3. Data Forecasting

Thomas Fiering is a method that has long been known to generate discharge data or monthly rainfall data. This method has advantages such as preserving the average, standard deviation, and correlation between months. This method was developed for forecasting by eliminating random components and was carried out semi-monthly. The equations of the Thomas Fiering method:

$$P_{i,j} = \overline{p_j} + B_j.\ (p_{i,j-1} - \overline{p_{j-1}}) + t_{ij}\ .\ s_j\ \sqrt{(1- r_j^2)} \quad (1)$$

$$\overline{p_j} = \frac{\sum_{i=1}^{n} p_{i,j}}{n} \quad (2)$$

$$r_j = \frac{\sum_{i=1}^{n} [(p_{i,j} - \overline{p_j})\ .\ (p_{i,j-1} - \overline{p_{j-1}})]}{\sqrt{[\sum_{i=1}^{n} (p_{i,j} - \overline{p_j})^2\ .\ \sum_{i=1}^{n} (p_{i,j-1} - \overline{p_{j-1}})^2]}} \quad (3)$$

$$B_j = \frac{r_j\ .\ s_j}{s_{j-1}} \quad (4)$$

$$s_j = \sqrt{\frac{\sum_{i=1}^{n} (p_{i,j} - \overline{p_j})}{n-1}} \quad (5)$$

with:

P_{ij}: rainfall data generation (mm)

$p_{ij-1:}$ rainfall of the j month in year i (j = 1,2,......12)

$\overline{p_j}$: rainfall of the jth month in the year i (j = 1,2,......12)

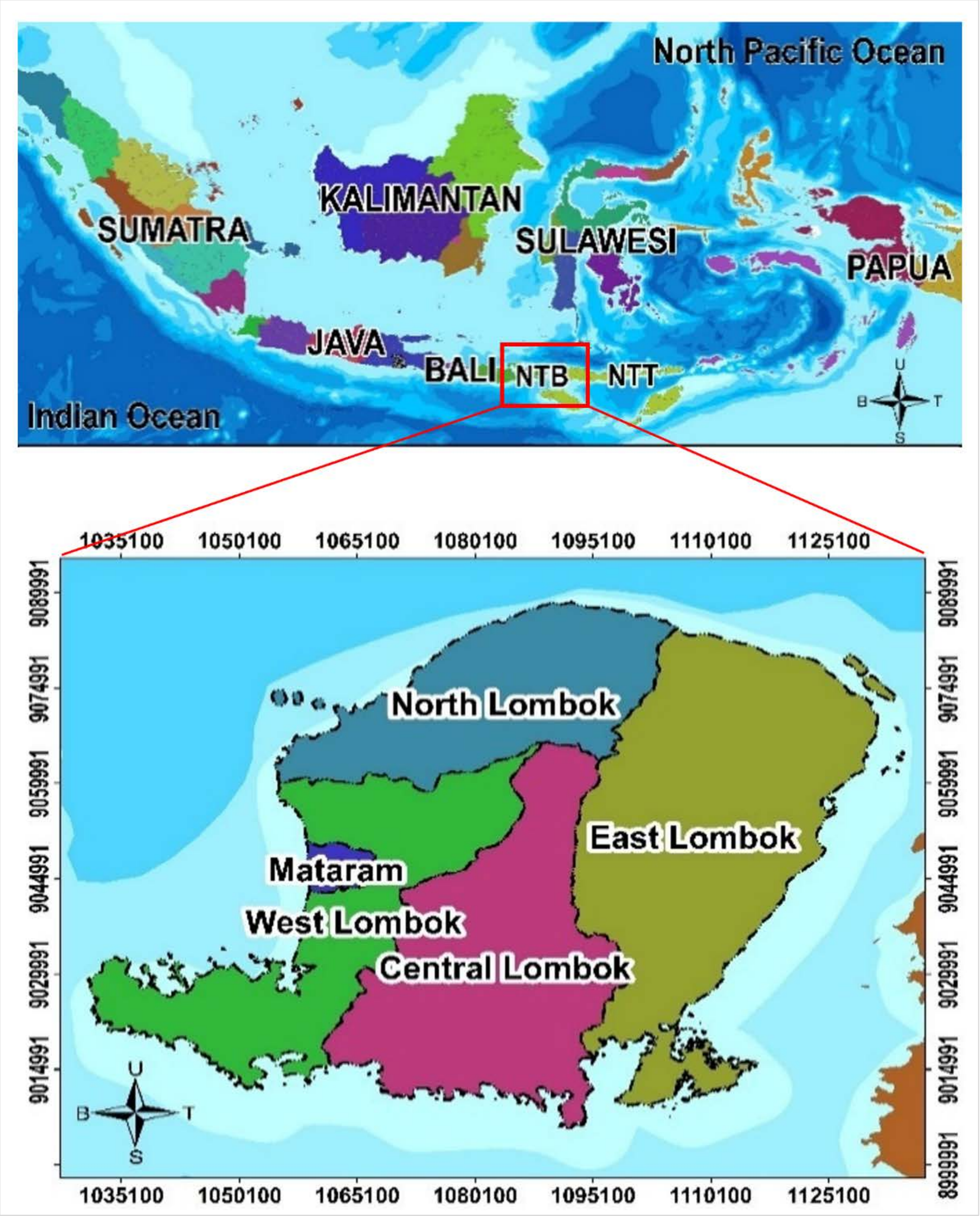
$\overline{p_{j-1}}$: average rainfall for month j-1

Rj: correlation coefficient

B_j: regression coefficient

s_j: standard deviation j

$t_{ij:}$ normal distribution random variable with mean = 0 and standard deviation = 1.0. With a note that for j = 1 (January) then j-1 (December)



Source: Regional Planning Agency (2022)

Figure 1. Research location map

2.4. Classification of Climate Distribution (Schmidt-Ferguson)

Schmidt-Ferguson (1951) used a comparison value (Q) between the average number of dry months (Md) and the average number of wet months (Mw) in a year. This classification does not include the element of temperature because it considers the temperature amplitude in the tropics very small. To determine the dry month and wet month, the categories are as follows:

Average dry months:

$$Md = \frac{\sum fd}{T} \quad (6)$$

Wet month average:

$$Mw = \frac{\sum fw}{T} \quad (7)$$

Comparison value (Q):

$$Q = \frac{Md}{Mw}\, x\, 100\% \quad (8)$$

with:

∑fd: frequency of dry months

∑fw: frequency of wet months

T: number of years of research

Md: average dry month

Mw: Average wet month

Q: Climate type Schmidt-Ferguson

Based on his research, the classification of climate in Indonesia is divided into eight groups which can be seen in table 1, and figure 2 shows a spatial climate map on the island of Lombok.

Table 1. Climate Classification According to Schmidt-Ferguson (Schmidt-Ferguson, 1951)

Climate Type	Climate Criteria	Q (%)
A	Very Wet	0 < Q < 14,3
B	Wet	14,3 < Q < 33,3
C	Slightly Wet	33,3 < Q < 60,0
D	Moderate	60,0 < Q < 100,0
E	A Bit Dry	100,0 < Q < 167,0
F	Dry	167,0 < Q < 300,0
G	Very Dry	300,0 < Q < 700,0
H	Extreme Dry	Q ≥700

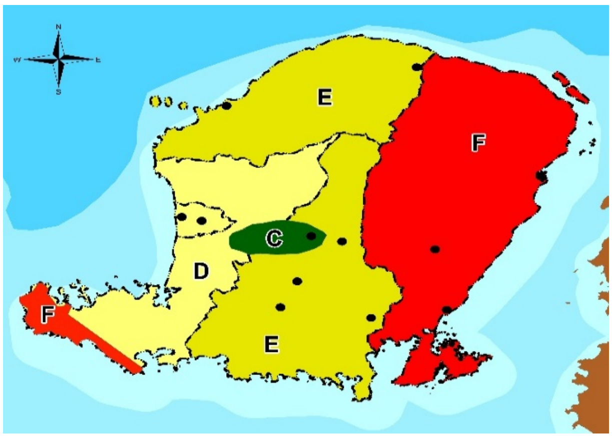


Figure 2. Map climate classification according to Schmidt-Ferguson (Schmidt-Ferguson, 1951)

The types of rain above have certain vegetation characteristics as follows:

1. Type A: very wet area with tropical rain forest vegetation characteristics
2. Type B: wet area with tropical rain vegetation characteristics
3. Type C: slightly wet area with jungle vegetation characteristics
4. Type D: moderate area with seasonal forest vegetation characteristics
5. Type E: slightly dry area with forest vegetation characteristics every time
6. Type G: very dry area with grassland vegetation characteristics
7. Type H: extreme dry area with grassland vegetation characteristics

2.5. Rainfall Depth

Several methods can be used to obtain the depth of the average rainfall in the area, including Arithmetic, Theissen, and Isohyet. In this analysis, the rainfall is calculated using Theissen polygons with the consideration that the area of influence of each station is prominent. The distribution of the influence area of each rain station is shown in Figure 3. Calculation of the average rainfall in the area can be calculated with the following equation [9]

$$\bar{R} = \frac{A1R1+A2R2+\cdots+AnRn}{A1+A2\ldots+An} \quad (9)$$

With:

R: average rainfall (mm)

R_1, R_2, R_n: point rainfall (mm)

n: number of observation points

A_1, A_2, A_n: area of influence of each rain station

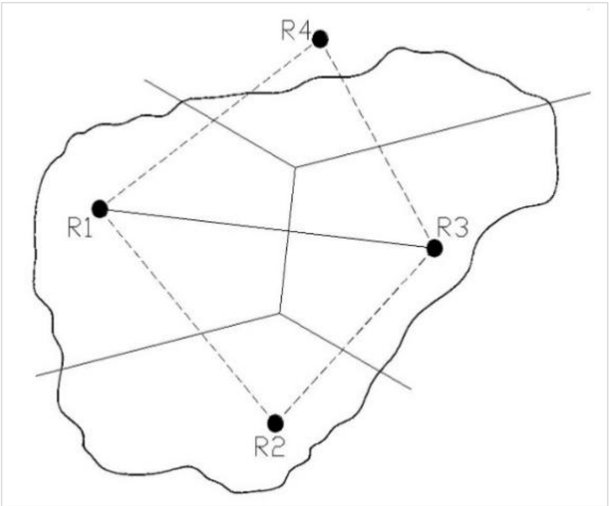


Figure 3. Polygon Theissen

2.6. Climatology Disaster

Climatological disasters can be in the form of temperature rise, storms, droughts, and floods. Drought occurs due to decreased rain intensity, duration, and frequency below normal. Floods occur because the average monthly and yearly rainfall is above regular [18].

3. Results

3.1. Rainfall Generation Using Thomas Fieering Model

The Thomas Fiering method, in this case, is used to predict monthly rainfall data for the next 17 years. The rain data is used to generate data from 1994 to 2017, and the rain data is to be generated monthly rain data starting from 2018 to 2035. The generated rain data will be used to predict spatial season conditions on Lombok Island. By using equations 1 to 5, the results of the generation are shown in the following figure, Figure 4.

Figure 4. Shows that the rain generated from the generation based on historical data from 1994 to 2017 rained on Lombok Island until 2035, namely a significant increase in rainfall depth. The average monthly rain from 1994 to 2017 is 128.230 mm, while the average generation data from 2018 to 2035 is 186.535 mm.

3.2. Climate Classification

Analysis of spatial climate predictions on Lombok Island based on rainfall data generated from generation. To determine the dry month and wet month, the categories are as follows:

1. Dry Month (BK): If in one month the amount of rainfall <60 mm.
2. Humid Month (BL): If in one month the amount of rainfall 60-100 mm.
3. Wet Month (BB): If in one month the amount of rainfall> 100 mm.

Based on the spatial climate classification based on rain data for 1994 - 2017 and rain generation data for 2018 - 2035 shows that there has been a very significant change in spatial climate, as shown in tables 2 to 3.

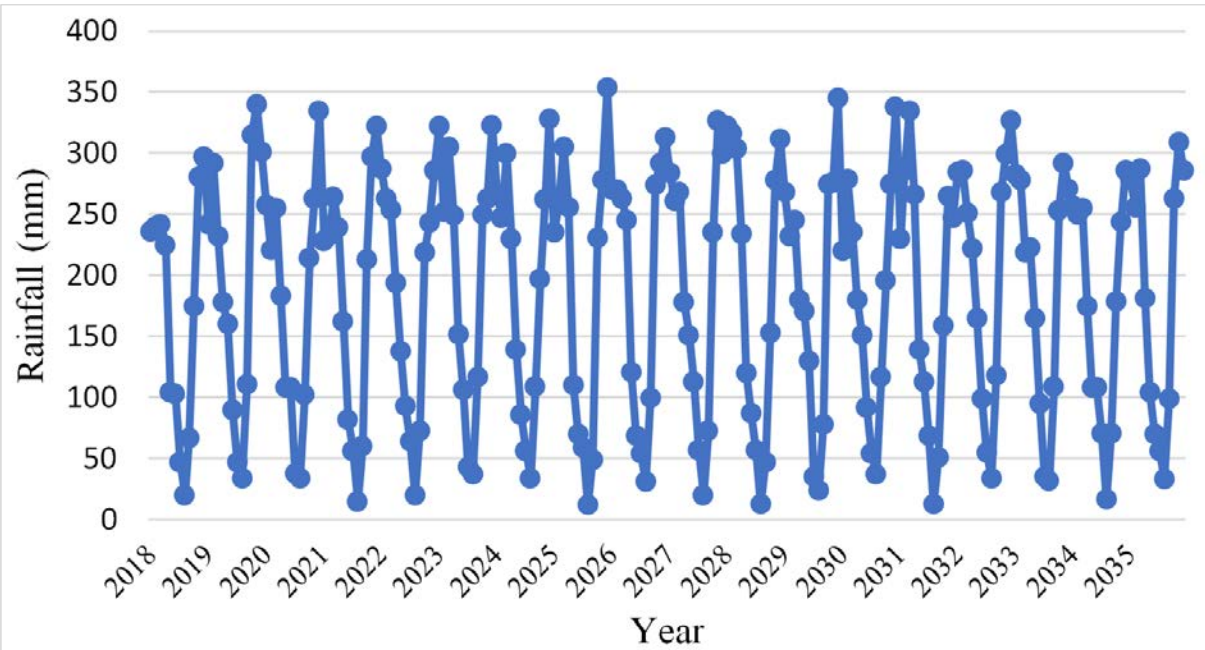


Figure 4. Monthly average rainfall data generated on the island of Lombok

Table 2. Categories of Wet Month, Humid Month and Dry Month on Lombok Island from 1994-2017

Year	Month											
	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Ags	Sep	Okt	Nov	Des
1994	BB	BB	BB	BB	BK	BK	BK	BK	BK	BK	BB	BB
1995	BB	BB	BB	BB	BL	BL	BK	BK	BK	BK	BB	BB
1996	BB	BB	BB	BK	BL	BL	BK	BK	BK	BB	BB	BB
1997	BB	BB	BK	BB	BK	BK	BK	BK	BK	BK	BB	BB
1998	BL	BK	BL	BL	BB	BK	BB	BK	BK	BL	BL	BB
1999	BB	BB	BB	BB	BK	BK	BL	BK	BK	BB	BB	BB
2000	BB	BK	BB	BL	BB	BK	BK	BK	BK	BL	BB	BK
2001	BB	BK	BL	BB	BB	BK	BK	BK	BK	BK	BB	BB
2002	BB	BB	BB	BB	BB	BK	BK	BK	BK	BK	BB	BB
2003	BB	BB	BB	BL	BL	BB	BK	BK	BK	BK	BB	BB
2004	BB	BB	BB	BB	BL	BK	BK	BK	BK	BB	BB	BB
2005	BK	BB	BB	BB	BK	BK	BB	BK	BK	BB	BB	BB
2006	BB	BB	BB	BL	BB	BB	BK	BK	BK	BL	BB	BB
2007	BK	BB	BB	BB	BB	BL	BK	BK	BK	BL	BB	BB
2008	BL	BL	BL	BB	BL	BL	BK	BK	BL	BB	BB	BL
2009	BB	BB	BL	BL	BB	BK	BK	BK	BK	BB	BB	BL
2010	BB	BL	BK	BK	BB	BK	BK	BB	BB	BB	BB	BB
2011	BB	BB	BB	BL	BK	BK	BK	BK	BK	BB	BB	BB
2012	BB	BB	BB	BB	BB	BK	BK	BK	BK	BB	BB	BB
2013	BB	BB	BL	BL	BB	BB	BK	BK	BK	BB	BB	BB
2014	BB	BB	BK	BL	BK	BK	BK	BK	BK	BK	BB	BB
2015	BB	BB	BB	BB	BK	BB	BK	BK	BK	BK	BK	BB
2016	BB	BB	BK	BB	BB	BB	BL	BK	BL	BB	BB	BB
2017	BB	BB	BB	BB	BB	BB	BK	BK	BK	BB	BB	BB

3.3. Regional Climate Change

The climate type of Lombok Island was analyzed using equations 6 to 8. The analysis was carried out on each rain station from 1994 to 2017 and 2018 to 2035 as a result of data generation. Based on these equations and the classification system according to Schmidt Ferguson, the climate type on the island of Lombok in each region represented by the rain station is as shown in Tables 4 and 5 as well as Figures 5 and 6.

Table 3. Categories of Wet Month, Humid Month and Dry Month on Lombok Island from 2018-2035

Year	Month											
	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Ags	Sep	Okt	Nov	Des
2018	BB	BB	BB	BB	BB	BB	BK	BK	BL	BB	BB	BB
2019	BB	BB	BB	BB	BB	BL	BK	BK	BB	BB	BB	BB
2020	BB	BB	BB	BB	BB	BB	BK	BK	BB	BB	BB	BB
2021	BB	BB	BB	BB	BB	BL	BK	BK	BL	BB	BB	BB
2022	BB	BB	BB	BB	BB	BL	BL	BK	BL	BB	BB	BB
2023	BB	BB	BB	BB	BB	BB	BK	BK	BB	BB	BB	BB
2024	BB	BB	BB	BB	BB	BL	BK	BK	BB	BB	BB	BB
2025	BB	BB	BB	BB	BB	BL	BK	BK	BK	BB	BB	BB
2026	BB	BB	BB	BB	BB	BL	BK	BK	BB	BB	BB	BB
2027	BB	BB	BB	BB	BB	BB	BK	BK	BL	BB	BB	BB
2028	BB	BB	BB	BB	BB	BL	BK	BK	BK	BB	BB	BB
2029	BB	BB	BB	BB	BB	BB	BK	BK	BL	BB	BB	BB
2030	BB	BB	BB	BB	BB	BL	BK	BK	BB	BB	BB	BB
2031	BB	BB	BB	BB	BB	BB	BL	BK	BK	BB	BB	BB
2032	BB	BB	BB	BB	BB	BL	BK	BK	BB	BB	BB	BB
2033	BB	BB	BB	BB	BB	BL	BK	BK	BB	BB	BB	BB
2034	BB	BB	BB	BB	BB	BB	BL	BK	BL	BB	BB	BB
2035	BB	BB	BB	BB	BB	BL	BK	BK	BL	BB	BB	BB

Table 4. Average climate type for each area on Lombok Island 1994 - 2017

Area	Q (%)	Climate Classification	Climate Type
Gunung Sari	100,0	Moderate	D
Keru	100,0	Moderate	D
Serumbung	175,0	Dry	F
Sesaot	100,0	Moderate	D
Santong	140,0	A Bit Dry	E
Sopak	200,0	Dry	F
Dasan Cermen	100,0	Moderate	D
Kabul	175,0	Dry	F
Lingkok Lime	140,0	A Bit Dry	E
Loang Make	175,0	Dry	F
Mangkung	200,0	Dry	F
Pengadang	120,0	A Bit Dry	E
Rembitan	200,0	Dry	F
Perian	120,0	A Bit Dry	E
Geres Daya	1100,0	Extreme Dry	H
Sepit	200,0	Dry	F
Pringgabaya	400,0	Very Dry	G
Sapit	175,0	Dry	F

Table 5. Average climate type for each region on Lombok Island from 2018-2035

Area	Q (%)	Climate Classification	Climate Type
Gunung Sari	22,2	Wet	B
Keru	11,1	Very Wet	A
Serumbung	22,2	Wet	B
Sesaot	10,0	Very Wet	A
Santong	25,0	Wet	B
Sopak	42,9	A Bit Wet	C
Dasan Cermen	10,0	Very Wet	A
Kabul	33,3	A Bit Wet	C
Lingkok Lime	10,0	Very Wet	A
Loang Make	83,3	Moderate	D
Mangkung	83,3	Moderate	D
Pengadang	33,3	A Bit Wet	C
Rembitan	50,0	A Bit Wet	C
Perian	9,1	Very Wet	A
Geres Daya	100,0	Moderate	D
Sepit	100,0	Moderate	D
Pringgabaya	150,0	A Bit Dry	E
Sapit	28,6	Wet	B

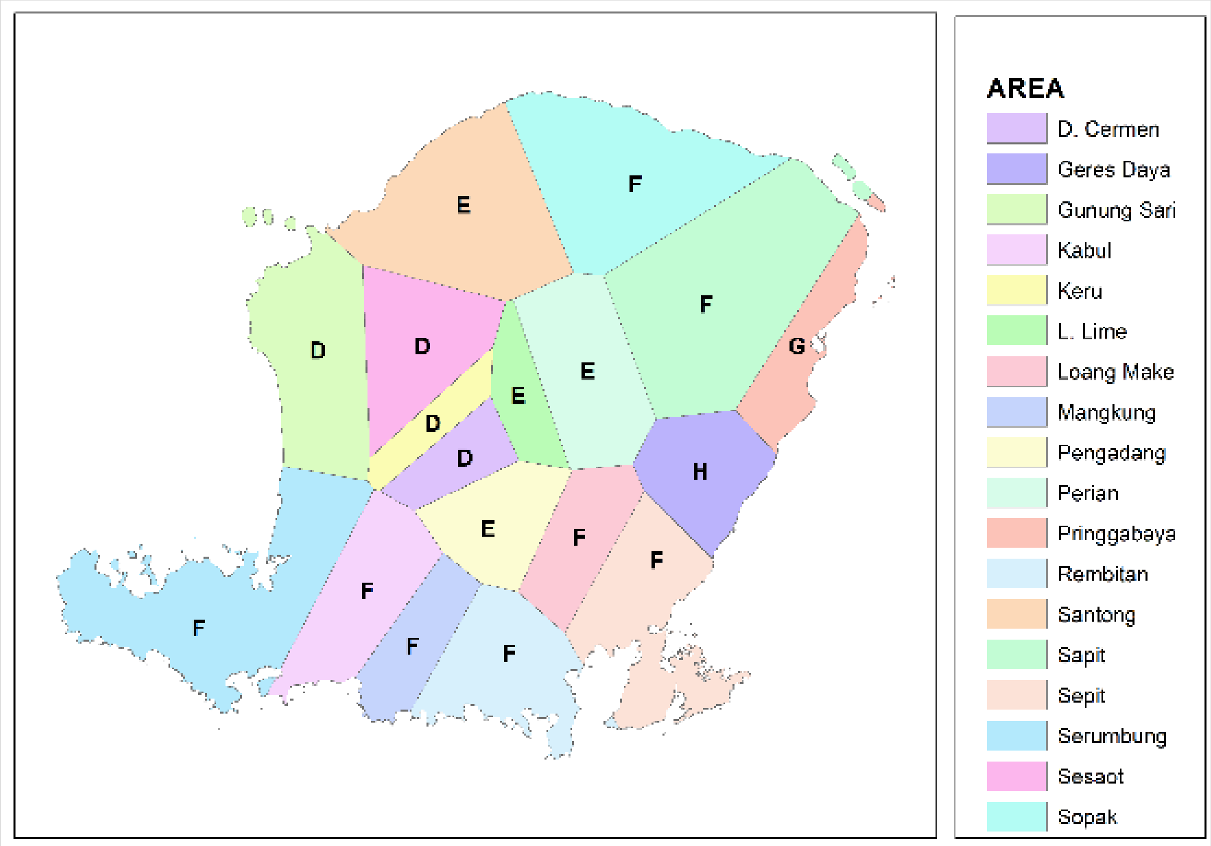


Figure 5. Climate type for each area on Lombok Island 1994 – 2017

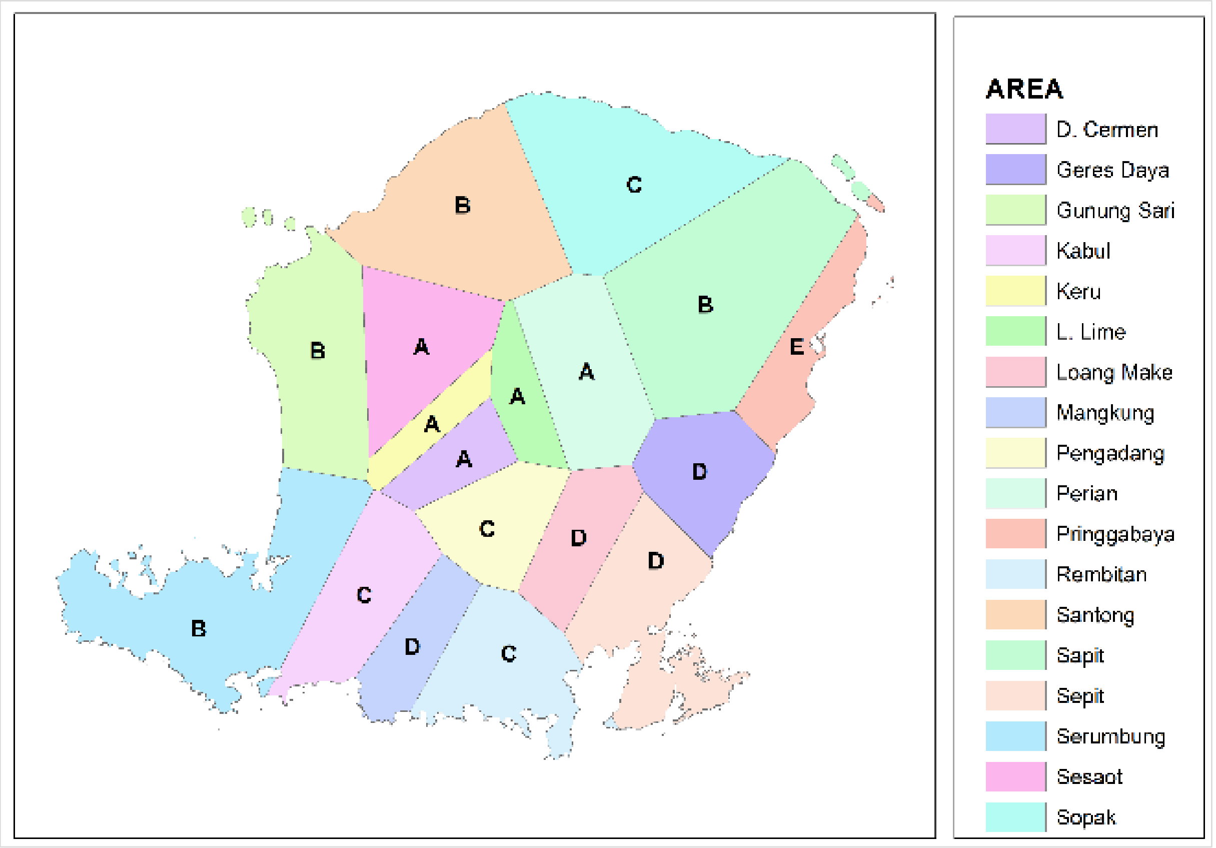


Figure 6. Climate type for each area on Lombok Island 2018-2035

Tables 4, 5, and Figures 4 and 5 show a spatial shift of seasons on Lombok island towards the wet climate type. This indicates that the frequency of rain and into rain has increased significantly.3.4. Prediction of Rainfall Depth

Figures 7 and 8 show spatial climate change is indicated by an increase in wet years from 2018 to 2035. This change causes an increase in the average monthly rainfall depth of the region, reaching 20% from the previous year, 1994-2017.

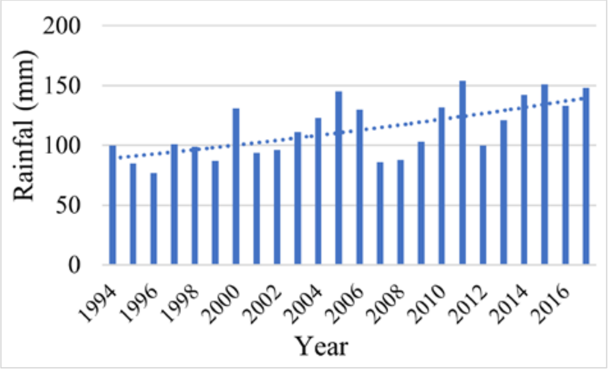


Figure 7. Depth Rainfall From 1994 to 2017

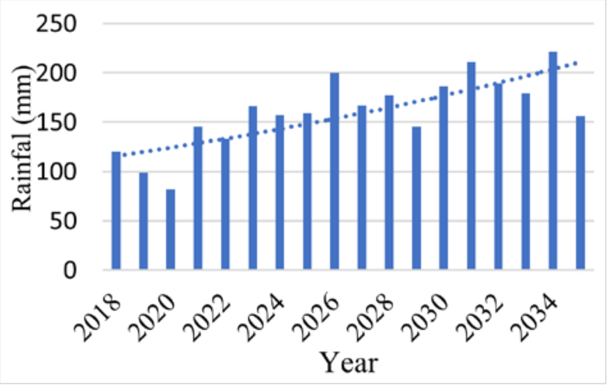


Figure 8. Depth Rainfall From 2018 to 2035

4. Discussion

The results of the generation of rain data from 2018 to 2035 show a significant trend of increasing rain data. The increases in rainfall depth impact spatial climate change, which previously showed a dry climate leading to a wet climate.

Climatology disasters can be in the form of droughts and floods. Drought occurs due to decreased rain intensity, duration, and frequency below normal. Floods occur because the average monthly or yearly rainfall is above normal. (Vinod Thomas and Ramón López, 2015). Figure 5 shows spatial climate changes from 2018 to 2035, which offer an increase in the wet climate that will impact several disasters, such as floods and landslides. Based on the prediction of spatial climate change, it is very necessary to immediately take anticipatory steps to adapt to flood and landslide disasters.

5. Conclusion and Suggestions

From the results of the analysis, several conclusions can be drawn as follows:

1. Results of spatial climate analysis using the Schmidt-Ferguson method in 1994-2017, the largest number of dry months (fd) with a period of 1 year, namely at Geres Daya, Sapit, and Sopak stations as many as 12 months, and the number of wet months (fw) the largest was at Sesaot and Perian stations for 12 months.
2. The comparison value of the average dry month and wet month (Q) produced in the one-year period from 1994-2017 is the largest at the Geres Daya, Sapit, and Sopak rain stations of 1,200.0 ($Q > 700$) with the classification extreme dry. The smallest Q value is at the Sesaot, Perian, and Dasan Cermen rain stations of 0 ($0 < Q < 14.3$) with the classification "Very Wet". For the years 2018-2035 produced in a one-year period, the largest was at the Pringgabaya rain station of 233.3 ($167 < Q < 300$) with the "Dry" classification. The smallest Q value is at the Sesaot and Perian rain stations of 0 ($0 < Q < 14.3$) with the classification "Very Wet".
3. The distribution of climate that occurred on Lombok Island from 1994-2017 was divided into four conditions with the dominating classification level, namely Slightly Wet (C), Moderate (D), A Bit Dry (E), and Dry (F). For the years 2018-2035, it is also divided into four conditions with the dominating classification level, namely Very Wet (A), Wet (B), A Bit Wet (C), and Moderat (D).
4. Climate spatial changes from 2018 to 2035, which show an increase in the wet climate, will impact several disasters, such as floods and landslides. Based on the spatial climate change prediction, it is necessary to immediately take anticipatory steps to adapt to flood and landslide disasters.
5. Because there is an increase in the depth of rain, it is essential to take anticipatory steps in the form of mitigation and early adaptation to the possibility of floods and landslides.

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