GIS Application for Mapping Monthly Rainfall for the Period 1995-2004 Using the Isohyet Method

(Case Study: Buleleng Regency)

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Abstract. Rain is one of the important meteorological elements in tropical areas such as Indonesia and especially Buleleng Regency which uses a lot of land, namely as agricultural land and plantation land. This is because rainfall greatly affects the level of water availability for agricultural and plantation irrigation. The observation method by utilizing rainfall measuring posts to obtain rain data cannot describe the level of rainfall in a certain area. So that the purpose of this study is the need for a special method to obtain information or a spatial picture of rainfall, so in this study what is felt to be very representative is the isohyet method to obtain an overview of the average monthly rainfall in an area as a whole. Using the isohyet method, the spatially average monthly rainfall in the period 1995-2004 has the highest rainfall spatially in December, January and February (DJF), where the highest rainfall is in February, which ranges from 203 mm to 697 mm and the highest area is in Gitgit District. Whereas spatially the lowest rainfall is in July, August and September (JAS), where in August it has quite extreme rainfall, ranging from 4.5 mm to 44 mm and the lowest area is in the District Gerokgak (Pejarakan Village) and Tejakula District. Based on the average monthly rainfall, it can be concluded that Buleleng Regency has an average monthly rainfall that is not evenly distributed because in one region and the other there is very high inequality.

Keywords: Rainfall, Isohyet, Buleleng Regency.

1. Introduction

Indonesia is a country that is on the equator, so countries on this line have a climate system that always repeats itself every year. The most dominant systems are warm, wet, warm, and dry. The equator is always characterized by humid areas. Because Indonesia is on the equator, the climate is divided into two seasons: rainy (wet) and dry (dry) [13].

Indonesia's climate is strongly influenced by the monsoon system, which is driven by the presence of high-pressure and low-pressure systems on the Asian and Australian continents. During the Northern Hemisphere winter, which occurs in December, January, and February, high-pressure systems dominate the Asian continent. In contrast, the Southern Hemisphere experiences its summer during this time, leading to the formation of low-pressure systems over the Australian continent. The contrast in air pressure between these two continents results in the movement of wind from Asia towards Australia. This wind pattern is a key driver of Indonesia's weather and climate.

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During the Northern Hemisphere winter, which aligns with the rainy season in many parts of Indonesia, particularly those south of the equator, the prevailing wind direction is from west to east. In contrast, during the Northern Hemisphere summer, the situation is reversed. The wind flows from the Australian continent towards the Asian continent, causing the winds in the Indonesian region to blow from east to west. This wind pattern coincides with the dry season, which typically occurs in June, July, and August in Indonesia.

Rainfall holds great significance as a meteorological factor in tropical regions like the maritime continent of Indonesia. Observers at each weather observation station diligently record rainfall data on a daily basis. This practice is essential because rainfall information is vital for a wide range of human activities, including agriculture, plantations, fisheries, transportation (land, sea, air), and numerous others [15]. Rainfall is one of the most extensively researched climatic elements in Indonesia due to its substantial temporal (time) and spatial (location) variability [12]. The interaction between the atmosphere and the surrounding sea in Indonesia plays a pivotal role in shaping the diversity of rainfall patterns in the country. Events like the El Niño-Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) have a profound impact on Indonesia's rainfall, contributing to the intricate and dynamic nature of its weather patterns [2].

Rain is defined as hydrometeor elements that fall to the Earth’s surface with a diameter of 0.5 mm or more. If the hydrometeor element falls from the cloud but evaporates before reaching the Earth’s surface, it is called a virga. The form of the hydrometeor element itself is in the form of virga, drizzle, rain, hail, fog, dew, and so on [3].

Rainfall of 1 mm is defined as the height of rainwater in an area of one square meter on a flat place, where one liter of water is accommodated where the water does not evaporate, does not seep, and does not flow. Rainfall measurements were performed using a rain gauge or rain gauge [4]. There are several types of rain gauges, including ordinary (conventional) and automatic rain gauges. The collected rain was measured every 07.00 local time using a measuring cup that was adjusted to the cross-sectional area of the rain gauge. In general, rainfall is recorded in millimeters or inches. One inch is equal to 25.4 mm. In Indonesia, rainfall is measured in millimeters (mm).

Geographic information system (GIS) is a computerized system created for the function of input, storage, management, and analysis of data for mapping studies [14]. Another definition of GIS is a system that can be used as an additional reference in making decisions from a spatial perspective and can be integrated into a description of a place based on its characteristics and phenomena [9]. The GIS subsystem consists of input data which is tasked with collecting spatial and attribute data from various sources, output data representing partial and whole databases in the form of soft copy or hard copy, data management which includes spatial data and attributes in an organized database so that updating, input and deletion operations can be carried out, and the GIS subsystem, the last one is data processing and analysis which determines all data that can be generated by GIS and performs data modeling to produce the expected data [16]. The GIS application in this study serves to carry out spatial analysis of monthly average rainfall by entering, manipulating, analyzing and displaying rainfall data from BMKG using the Isohyet (IDW) method [10].

Hydrological analysis is required to obtain the average rainfall in an area. One method that can be used to obtain the average rainfall in an area is the arithmetic, Polygon Thiessen, and isohyet methods [6]. The Isohyet method is an interpolation method that connects points with the same rainfall value. This method is considered the most accurate when compared to other rainfall interpolation methods.

The Isohyet method can also be used to obtain rainfall mapping patterns in an area. The Isohyet method uses the Inverse Distance Weighted (IDW) tool in ArcGIS. ArcGIS is an application based on the Geographic Information System (GIS) created by the Environment Science & Research Institute (ESRI) [8]. This research applied the Isohyet method to calculate rainfall mapping for the Buleleng Regency area. The Isohyet method was selected because it is the most accurate average rainfall calculation method. The Isohyet method considers each rain gauge station [1].

This study aims to obtain information or a spatial description of rainfall using the Geographic Information System application with the Isohyet method. Which was used to obtain an overview of the average monthly rainfall in an area as a whole.

2. Methods

2.1 Study Area

Buleleng Regency is situated in the northern hemisphere of Bali Island and spans from approximately 8º 03' 40" S to 8º 23' 00" S in latitude and 114º 25' 55" E to 115º 27' 28" E in longitude (as depicted in Figure 1). This regency boasts a coastline that stretches 157.05 kilometers along with a land area covering 136,588 hectares, accounting for 24.25% of the total land area of Bali Province. Buleleng Regency shares its borders with the Java Sea to the north, Jembrana Regency to the west, Karangasem Regency to the east, and Bangli, Tabanan, and Badung Regencies to the south.

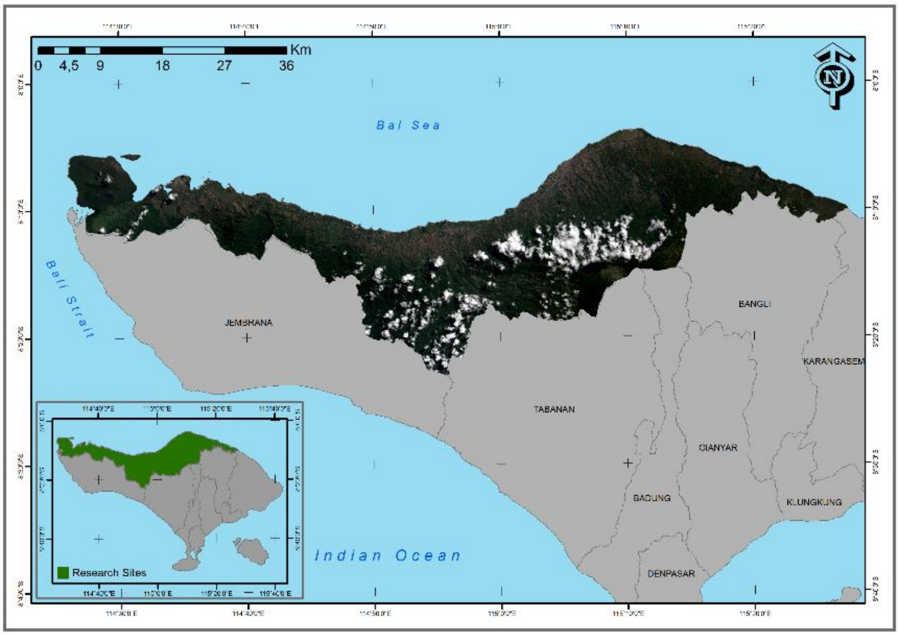


Fig 1. Study Map Area (Buleleng Regency)

In this study, the population comprised all the rainfall collection stations in the Buleleng Regency. Rainfall collection stations in the Buleleng Regency were spread over nine sub-districts, namely Kec. Gerokgak, Seririt, Busungbiu, Banjar, Buleleng, Sawan, Additional Strongholds, Sukasada, and Kec. Tejakula. The rainfall collection stations are spread unevenly in each sub-district depending on the area or coverage to be represented and the distribution of rainfall collection stations along with their coordinates (Table 1).

Table 1. District Rainfall Catcher Station Buleleng Regency

No	Location	Coordinate	
		Latitude (LS)	Longitude (BT)
1	Sumber Klampok	-8.178611111	114.4847222
2	Pejarakan	-8.143888889	114.59
3	Banyupoh	-8.149722222	114.6947222
4	Gerokgak	-8.188333333	114.7966667
5	Tukad Mungga	-8.141388889	115.0569444
6	Kubutambahan	-8.082222222	115.2069444
7	Patas	-8.212222222	114.7880556
8	Sukasada	-8.136111111	115.1011111
9	Bengkala	-8.11	115.1813889
10	Tejakula	-8.126388889	115.3419444
11	Wanagiri	-8.237222222	115.1388889
12	Munduk	-8.264167	115.050556
13	Tangguwisia	-8.191389	114.951389
14	Busungbiu	-8.260278	114.970278
15	Tegalasih	-8.315556	114.946667
16	Gitgit	-8.200833	115.137778

Source: Office of the Meteorology, Climatology and Geophysics Region III Denpasar

Target population research was used, and the population was the rainfall control post, which totaled 16 stations, so the entire population was used as the respondent. The population study was chosen because there are 16 overall rainfall control posts in the Buleleng Regency, so population research is needed.

2.2 Observational Rainfall Data Processing

Rain data from each rain post is made the average monthly rainfall for the 1995-2004 period, using ordinary arithmetic, namely:

$$X_r = \frac{\sum X_i}{n} \quad \text{.......(1)}$$

where : Xr = Average value

Xi = Data (i)

n = amount of data

2.3 Monthly Rainfall Interpolation Method (Isohyet)

The isohyet method is a method for spatial modeling that is widely used for spatial modeling of rainfall, where the line connects points with the same rainfall. The isohyet method, explains if the rain in an area between the two isohyet lines is evenly distributed and equal to the average value of the two isohyet lines [7]. The isohyet is obtained by interpolating local rainfall values using the following equation [17]:

$$R = \frac{\sum_{i=1}^{n} \frac{d_{i=1} + d_i}{2} * A}{\sum_{i=1}^{n} A_i} \quad \text{.......(2)}$$

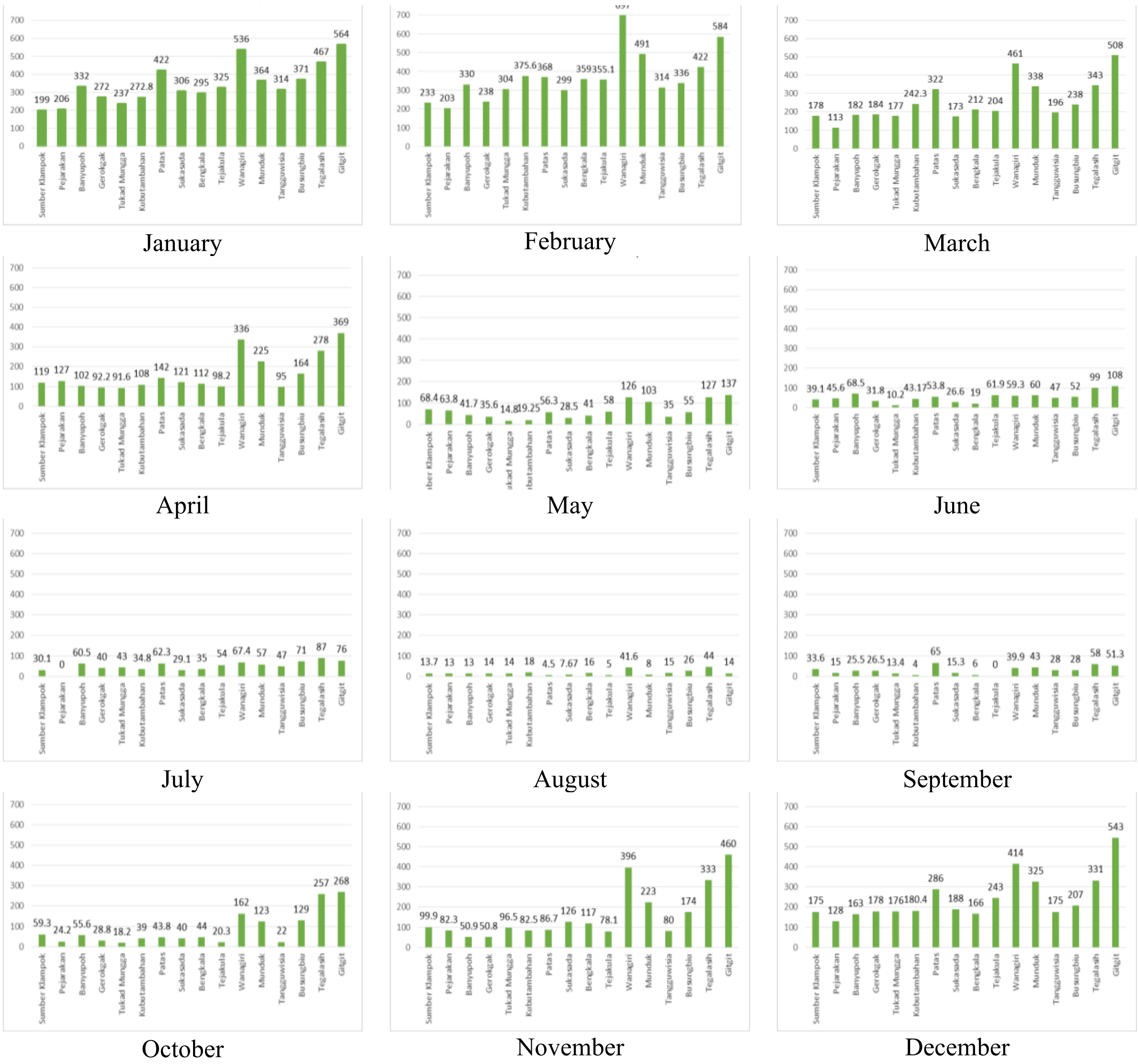
Where:

R	: Regional rainfall
A1,A2..An	: The area of the isohyet rainfall area adjacent (km2)
d1,d2..dn	: Rainfall on isohyet line (mm)

3. Result and Discussion

3.1 Spatial analysis of average monthly rainfall in Buleleng Regency

Following are the results of the spatial analysis of average monthly rainfall in Buleleng Regency from January to December for the period 1995 to 2004 (Graph 1 and Figure 2).



Graph 1. Graph of average monthly rainfall in January-December in North Bali for the period 1995 to 2004. (Source: BMKG Region III Denpasar, 2016 with processing)

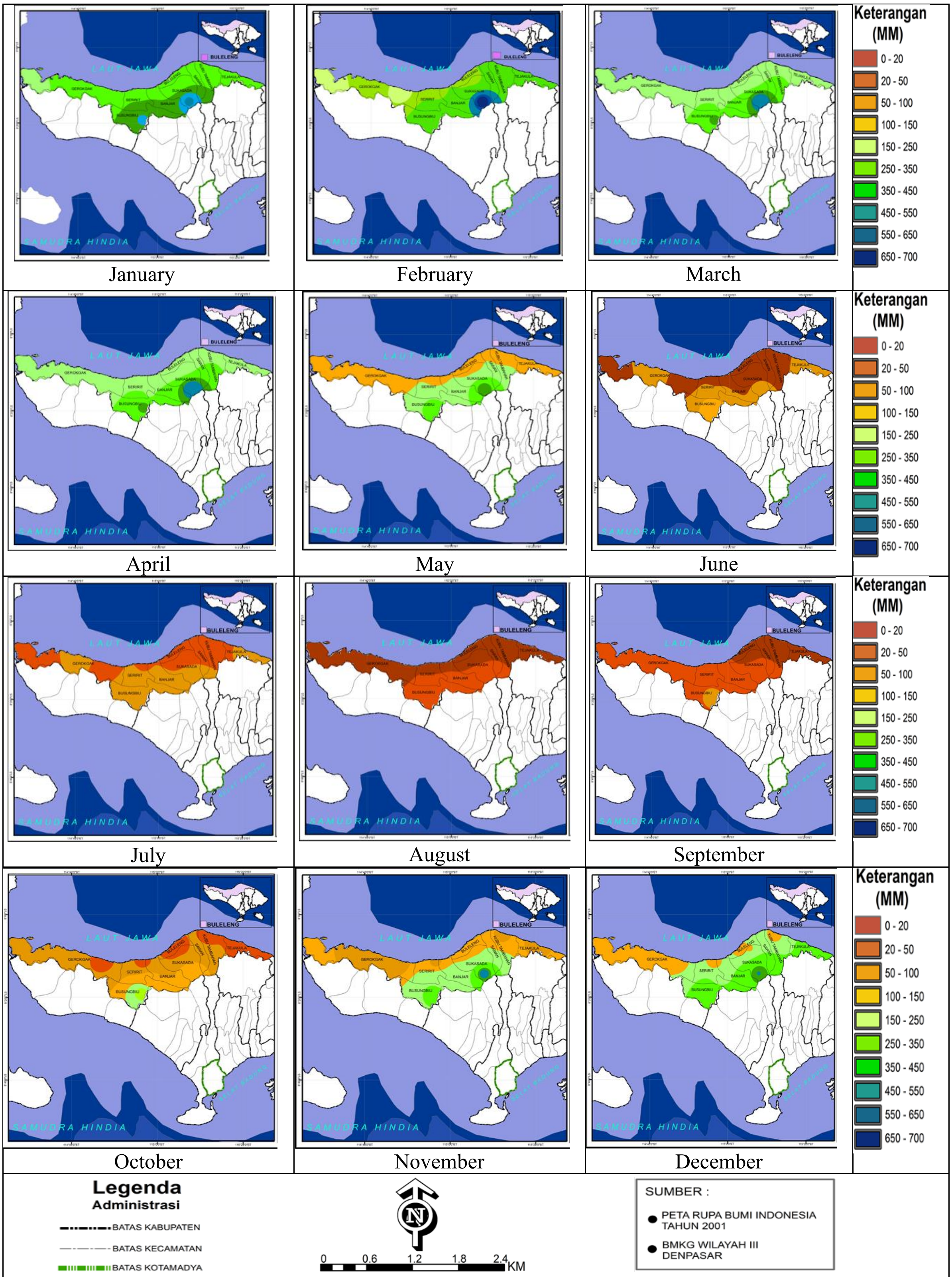


Fig 2. Map of average monthly rainfall in December in North Bali for the period 1995 to 2004. (Source: BMKG Region III Denpasar, 2016 with processing)

The results of the 10-year monthly rainfall spatial analysis for the period 1994–2005 in the Buleleng Regency are still influenced by global and local phenomena, namely the monsoon phenomenon and the topographical conditions of the Buleleng Regency. The characteristic of the rainy season pattern is monsoonal, which in a period of one year has one maximum rainfall peak which generally occurs in December, January, February (DJF). In December, the areas with the highest average rainfall were Gitgit 543 mm and Wanagiri (414 mm), both in Sukasada District, and the area with the lowest average rainfall was the Pejarakan area (128 mm). Furthermore, in January, the areas with the highest average rainfall were Gitgit 564 and Wanagiri 536, both in Sukasada District, as well as the areas with the lowest average rainfall, namely the Sumber Kelampok area and Gerokgak District with 199 mm. In February, the areas with the highest average rainfall were Wanagiri 697 mm and Gitgit (584 mm), which were both in Sukasada District, and the area with the lowest average rainfall was the Pejarakan area Gerokgak District (203 mm).

March, April, and May (MAM) is a transitional period from the rainy season to the dry season, a minimum rainfall peak generally occurs in June, July, and August (JJA), and September, October, and November (SON) is a transitional period from the dry season to the rainy season. In March, the areas with the highest average rainfall were Gitgit 508 mm and Wanagiri 461 mm, both in the Sukasada District, and the area with the lowest average rainfall was the Pejarakan area (113 mm). Furthermore, in April, the areas with the highest average rainfall were Gitgit 369 mm and Wanagiri (336 mm), both in Sukasada District, and the area with the lowest average rainfall was Tangguwisia, Seritit District (95 mm). In May, the areas with the highest average rainfall were Wanagiri 137 mm and Gitgit (126 mm), both in Sukasada District, and the area with the lowest average rainfall was the Tukad Mungga area, Buleleng District (14.8 mm.

In June, the area with the highest average rainfall, namely Gitgit 108 mm, was in Sukasada District, and the area with the lowest average rainfall, namely the Tukad Mungga area, Buleleng District, had a rainfall of 10.2 mm. Furthermore, in July, the area with the highest average rainfall was Tegalasih, Busung Biu District, with 87 mm, and the area with the lowest average rainfall was the Pejarakan area, Gerokgak District, with 0 mm. In August, the area with the highest average rainfall was Tegalasih, Busung Biu Sub-District, with 44 mm, and the area with the lowest average rainfall was the Patas area, Gerokgak District, with 4.5 mm.

In September, the area with the highest average rainfall was Patas, Gerokgak District, with 65 mm, and the area with the lowest average rainfall was Tejakula District, with 0 mm. Furthermore, in October the areas with the highest average rainfall were Gitgit, Sukasada District, 268 mm and Tegalasih, Busung Biu District, 257 mm and the area with the lowest average rainfall, namely the Tukad Mungga, Buleleng District, with 18.2 mm. In November, the area with the highest average rainfall was Gitgit Sukasada District (460 mm), and the area with the lowest average rainfall was Gerokgak District (50.8 mm).

The peak of maximum rainfall in the Buleleng Regency area occurred during the west monsoon season (westerly wind), which in the 1994-2005 period occurred in February with the highest average rainfall area in Gitgit, Sukasada District with an average of 697 mm, followed by January, namely Gitgit Sukasada District with an average of 564 mm, whereas the minimum rainfall peak occurred during the eastern monsoon season (eastern wind) which in the 1994-2005 period occurred in August, with the highest average of only 44 mm.

This is reinforced by previous research, namely, that rainfall on the island of Bali is generally included in the monsoonal rainfall pattern and rainfall in Buleleng Regency is directly influenced by global factors, namely the sea surface temperature anomaly in the Central Pacific (Nino 3.4) known as El Nino which results in a decrease in rainfall intensity [11]. This monsoonal rainfall pattern is characterized by a peak in the rainy season (unimodial), namely, between December, January, and February, and has a clear difference between the rainy season and the dry season [5]. In general, the occurrence of rain in the rainy season in Bali depends on atmospheric phenomena, both globally and regionally. However, when global and regional phenomena are weak, rain events tend to be dominated by local factors only.

4. Conclusion

In the highlands of Buleleng, the rainfall is relatively higher than in other areas. Where in the Gitgit and Wanagiri areas, Sukasada District, which is a highland area in Buleleng Regency, had the highest average rainfall during the 1995-2004 period. The highest rainfall pattern in North Bali is in December-January-February (DJF), and the lowest is in June-July-August (JJA), with the Patas area of Gerokgak and Tangguwisia Districts of Seririt District having the lowest average rainfall area, which is incidentally found in lowland areas even near the coast.

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