RAINFALL ANALYSIS IN EAST KALIMANTAN PROVINCE BASED ON THORNTHWAITE METHOD

ABSTRACT

Climate change has brought changes to the characteristics of the rainfall, in general, there is a dynamic monthly rainfall cumulative annual rainfall[Ma1]. This study aims to detect[Ma2] the climate change presence or absence, identify the relationship of climate change to the nature of rainfall to wet (rainy), humid and dry months. This research was conducted in the East Kalimantan province[Ma3]. This study aims to detect the climate change presence or absence, identify the relationship of climate change to the nature of rainfall, rainy, humid and dry months.[Ma4] The research object [Ma5]observed was the condition and extent of forest cover along with the condition of climate elements "in situ" from 1977 to 2020. East Kalimantan Province experienced dry months in 1981-1985 and 1991-1995.[Ma6]

Keywords: *rainfall, wet month, humid month, dry month, climate change*

1. INTRODUCTION

Rainfall is the estimated rainfall that falls from a given height on a flat site and is expected to be unaffected by evaporation, infiltration and run-off. [Ma7]1 mm of rainfall is 1 mm of rainwater falling on a 1 m^2 flat surface using estimates of evaporation, flow rate and infiltration. The rain data used is daily rain or cumulative rainfall for 24 hours. Monthly rain is obtained from cumulative daily rain during a 1-month period. Rain duration (t) and rain intensity (R) are the two main rain variables that are almost always observed for various analytical, predictive and planning purposes.

Climate change has brought changes to the characteristics of rain. In the rainy season, the duration is shorter, however in the dry season is getting longer. The number of rainy days tends to decrease, and the maximum daily rain and rain intensity increases. Since the last decade, the application of various methods for interpolation and spatial variability studies of hydro-climatological data has intensified in many parts of the World. The simplest analysis is to summarise statistical values of a data series or in the context of spatial data is to summarise[Ma8] attributes or grid values. Analyses in graphical form generally take the form of: histograms, pie charts, box plots and/or scatter plots.

Changes in annual average rainfall have occurred in many countries, especially in the tropics. Over much of Indonesia average rainfall has fallen significantly in all seasons, at an average rate of 7.8 mm per month (3.6%) per decade since 1970. Until 2000 the rainfall decline varied between 7.5-8.9 mm or 3.3-3.6% per month per decade. However, using simulations of various climate models in the 21st century it is estimated that Indonesia as a whole will experience changes in rainfall varying between (-28) to (+53) mm or -12% to +20% per month (Ellias, 2012). [Ma9]For this reason, an assessment was carried out to determine climate variability, especially rainfall in this case shifting wet, humid and dry months.

2. MATERIALS AND METHODS

The research object observed was the condition and extent of forest cover along with the condition of climate elements "in situ" from 1977 to 2020 from 76 Meteorological Stations in East Kalimantan Province. Rainfall data collected both primary and secondary data related to the research. Rainfall is made exclusive period can be statistically known according to the maximum annual daily rainfall data (maximum annual series data) Long-term more than 20 years using frequency distribution analysis (Wood et al, 2021). Before processing the precipitation data, it is necessary to assess the reliability and quality of the observations available and then to correct for unreliable data. If there are missing data, they can be filled in from observations by considering at least three stations close to the target station (Wood et al, 2021[Ma10]; Sipayung, 2009)

Annual rainfall is calculated from the cumulative daily rainfall during the current year. Furthermore, for the purposes of spatial analysis, the data used is the average monthly rainfall data at each location (station). Furthermore, the number of wet, humid and dry months in one year for one period was calculated. The number of wet, humid and dry months for one period were summed up and a value was calculated to determine the number of wet, humid and dry months for one period

Variations in the length of the rainfall data recording period between one station and another were ignored. It is assumed that the length of the recording period does not significantly affect the determination of the average monthly rainfall value.

In this study, the Wet Month (WM) and Dry Month (DM) were determined using the Oldeman climate classification method. The basis for determining wet months, humid months, and dry months according to the Oldeman method, is as follows:

a. Wet month, if the rainfall is > 200 mm/month.
b. Humid month, if the rainfall is 100 - 200 mm/month.
c. Dry month, when the rainfall is < 100 mm/month

3. RESULTS AND DISCUSSION

Wetness Level (Q): the Q value of an area or region is determined based on the ratio between the number of wet months (WM) and the number of dry months. Based on the data in Appendix1, [Ma11]it can be obtained the number of WM and DM throughout the period, as can seen in Table 3[Ma12]. Based on the American Climate Prediction Center (Climate Prediction Center) noted that since 1950, there have been 22 El-Nino phenomena that caused world attention to global climate anomalies. Strengthening the El-Nino phenomenon, 6 of which took place with strong intensity, namely 1957/1958, 1965/1966, 1972/1973, 1982/1983, 1987/1988, 1991/1992 dan 1997/1998. Most El Niño events start at the end of the wet season or early to mid dry season in May, June and July[Ma13]. The El Niño of 1982/1983 and were two of the most severe El Niño events that have occurred in the modern era with impacts felt globally. These natural phenomena had a direct impact on the existence of forest cover in East Kalimantan Province, because they triggered large-scale forest and land fires. Therefore, the conditions in these years are directly related to changes in climate elements, especially rainfall.

Large-scale simulations include parameterizations of convection, which may not adequately represent links between the land surface and atmosphere (Fu et al, 2021) Models with a horizontal resolution of less than ∼4 km are capable of permitting convection, and they show some substantial improvements in the representation of convective rainfall and representation of the impacts of LCC. Recent advances in computational power have allowed larger domain simulations to be conducted at these resolutions. Over West Africa, initiation of convection occurs preferentially over tree-grass boundaries in a convection-permitting simulation. Treatment of LCC is often too simplistic and does not represent the complex reality of tropical LCC. Conversion of tropical forest to bare soil causes reductions in regional precipitation of 460±100 mm year−1, substantially more than the reduction of 220±260 mm year−1 when tropical forest is converted to pasture Cheng et al, 2017).

Based on annual data, it can be obtained information on the number of dry months each year is highest in the period 1981-1985 which reached 242 months (43%), although the number of dry months in the period 1986-1990 is higher (371 months) than the period 1981-1985 (242 months) but lower in the percentage of dry months occurrence, the high percentage of dry months indicates the strong influence of El Nino in that period.

From data above, it can be obtained that the strengthening of the El-Nino natural phenomenon that triggers forest fires has reduced rainfall for several months in each period. Long droughts in the periods 1981/1982, 1987/1988, 1992/1993 and 1997/1998 have increased the number of dry months many times compared to the period 1977-1980. In the 1981-1982 period, there were many climate stations that did not provide data, especially those that were established during the TAD programme, and at the same time there were several newly established climate stations. The data do not indicate a strong disturbance to rainfall due to changes in forest cover in East Kalimantan province but are more related to the El Niño phenomenon.

However, when using the annual average data in each period as can be seen in Table 4[Ma14], be obtained information that for 33 years the province of East Kalimantan only experienced dry months in the period 1991-1995 which occurred in August-September. Humid months occurred in the period 1981-2010, and never occurred in the period 1977-1980 which all experienced wet months.

Tabel 1. Wet Month (WM), Humid Month (HM) and Dry Month (DM) in 1 Year[Ma15]

Periode	Jan	Feb.	Marc	April	May	June	July	Augs	Sept	Oct	Nov	Dec
1977-1980	**WM**	**WM**	**WM**	**WM**	**WM**	**WM**	**WM**	**WM**	**WM**	**WM**	**WM**	**WM**
1981-1985	**WM**	**WM**	**WM**	**WM**	**WM**	**HM**	**HM**	**DM**	**HM**	**HM**	**HM**	**WM**
1986-1990	**WM**	**WM**	**WM**	**WM**	**HM**	**HM**	**HM**	**HM**	**HM**	**WM**	**WM**	**WM**
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2011-2015	**WM**	**WM**	**WM**	**WM**	**WM**	**WM**	**HM**	**HM**	**HM**	**WM**	**WM**	**WM**
2016-2020	**WM**	**WM**	**WM**	**WM**	**WM**	**WM**	**HM**	**HM**	**HM**	**HM**	**WM**	**WM**
Average	**WM**	**WM**	**WM**	**WM**	**WM**	**HM**	**HM**	**HM**	**HM**	**HM**	**WM**	**WM**

This occurs due to changes in atmospheric circulation, namely a more active hydrological cycle, and an increase in the capacity of the atmosphere to hold water vapour, theoretically every 1°C increase in air temperature will increase the water vapour holding capacity by 7%. These conditions then in the climate system directly affect the characteristics of rainfall, including amount, frequency, intensity, duration, type and extreme values. In weather systems, the accumulation of water vapour in the atmosphere will make rainfall heavier in a short time but decrease in duration and frequency, so that cumulatively there is not much change (Pendergrass, et al 2017).

Such conditions also occur in India, according to the results of Meher's research (1999) changes in forest cover in some parts of India are followed by changes in normal year rainfall patterns and tend to decrease almost throughout lowland India. The area of forest cover in India decreased from about 65% in 1944, 50% in 1961 and 43% in 1984. Corresponding to this change, normal rainfall years decreased from 47% in the earlier period to 36% in 1984. The average rainfall and number of rainy days for the period of 20 consecutive years, as well as the 20-year moving average, showed a downward trend, the lowest rainfall record being 800 mm in 1982 (Meher-Homji, 1984). The average annual rainfall decreased from 1415 mm in 1902-1921 to 1200 mm in the period 1965-1984, as did the number of rainy days from 106 to 89, a decrease of about 16%. In contrast, the frequency of dry years (years with below normal rainfall levels) increased from 8 years between 1902-1922 to 12 years between 1954 and 1964.

According to MINEPDED (Ministry of the Environment, Nature Protection and Sustainable Development) et al. (2015), in Cameroon, observations of climate change indicate a decrease in rainfall in four of the five agro-ecological zones in the country (high Guinean savannahs, Sudano-Sahelian, high plateaus, and bimodal rainfall), with the exception of the monomodal rainfall zone, where rainfall has increased. Servat et al. (1999) mention that, in Cameroon, during the period of disruption from 1969 to 1971, the average rainfall deficit observed was 16%; and this rainfall deficit was already being felt and would even seem to have increased over more than two decades from the 1970s to 1980.
Based on the wetness index data (Q) in Table 2, the Rain Type Distribution of East Kalimantan Province can be determined, which shows the level of wetness in an area based on monthly rainfall data, using the method developed by Anonymous (1996a), as can be seen in Table 2 below.

Table 2. Distribution of Rain Type in East Kalimantan Province

Periode	Wet month	Humid month	Dry month	Q	Rain Type
1977-1980	12	0	0	0	A
1981-1985	6	5	1	0.9	A
1986-1990	7	5	0	0	A
1991-1995	5	5	2	2.0	F
1996-2000	4	8	0	0	A
2001-2005	7	5	0	0	A
2006-2010	10	2	0	0	A
2011-2015	9	3	0	0	A
2016-2020	8	4	0	0	A

Based on the results of the Wetness Index (Q) Analysis, it shows that East Kalimantan Province in the period 1977-1990 and the period 1996-2010 has Rain Type A, except for the period 1991-1995 with Rain Type F. The results of the analysis are closely related to the condition of average air temperature show the same trend, the increase of humid months in the period 1981-1985 occurred when the average air temperature in Balikpapan and Samarinda also increased. The same condition also occurs in the period 1991-1995, 1996-2000 and 2001-2005 which in the same period there is a surge in air temperature in Balikpapan regency, Samarinda rgency and West Kutai regency (Melak).

In a study by Hulme and Nicola (1999) of average historical data, temperatures in Indonesia have increased by 0.3°C per year since 1900. The 1990s were the warmest decade and 1998 was the warmest year, 1°C above the 1961-1990 average, with temperature increases occurring throughout the seasons. Rainfall decreased by 2% to 3% especially in December - February. In most parts of Indonesia changes in rainfall are influenced by El-Nino, major droughts occurred in the El-Nino years 1982/1983, 1986/987, 1991/1992 and 1997/1998. Various other studies of historical data also found the same thing in increasing air temperature, although with different rates of increase, but not linear for changes in rainfall. According to the analysis of Hidayati, et al. (1999), the temperature in most parts of Indonesia, especially during the day, increased. Although the rate of change is small, it is significant according to statistical tests (Spearman rank). Rainfall did not show the same pattern of change and although the climate data of all meteorological stations did not show any significant change.

According to Asfaw et al (2018) the modification of vegetation cover due to massive area deforestation inevitably affects rainfall. The results of Avissar et al (2002) and Spraklen and Gracia (2015) showed that in 1990 and in the future rainfall increased most prominently in August, during the transition from the dry to the wet season. Tropical deforestation has a double impact on the climate, causing changes in humidity and airflow, leading to changes in fluctuations in rainfall patterns and consequently an increase in temperature on earth. Deforestation, for example, will cause a 10-15% decrease in rainfall in the surrounding area (Youba, 2022)

Forest vegetation affects cloud formation by emitting carbon-based chemicals called volatile organic compounds (VOCs) into the atmosphere. Some of these compounds are deposited on small airborne particles such as dust, bacteria, pollen and mould spores. As the particles grow with the deposition of VOCs, they drive the condensation process and collect the resulting moisture, accelerating cloud formation.

The model predictions in this study show that the location of deforestation will greatly impact temperature and rainfall. Deforestation in the Congo Basin of West Africa would reduce rainfall across the region by 40-50% and increase temperatures by 3°C. Deforestation in the Amazon basin by 40% would reduce the rainy season by 12% (Nicholson et al, 2018)

4. CONCLUSION

Based on 43 years of rainfall data, Kalimantan Province received an average rainfall of 2752 mm $year^{-1}$. The lowest rainfall occurred in 1982 at 2090 mm $year^{-1}$, while the highest rainfall occurred in 1978 at 3482 mm $year^{-1}$. East Kalimantan Province experienced dry months in 1981-1985 and 1991-1995, which are likely correlated with the occurrence of severe forest fires. In addition, it is known that on average East Kalimantan province has 7 wet months and 5 humid months.[Ma16]

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1. INTRODUCTION

Rainfall is the estimated rainfall that falls from a given height on a flat site and is expected to be unaffected by evaporation, infiltration and run-off. 1 mm of rainfall is 1 mm of rainwater falling on a 1 m^2 flat surface using estimates of evaporation, flow rate and infiltration. The rain data used is daily rain or cumulative rainfall for 24 hours. Monthly rain is obtained from cumulative daily rain during a 1-month period. Rain duration (t) and rain intensity (R) are the two main rain variables that are almost always observed for various analytical, predictive and planning purposes.

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2. MATERIALS AND METHODS

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3. RESULTS AND DISCUSSION

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Table 2. Distribution of Rain Type in East Kalimantan Province

Periode	Wet month	Humid month	Dry month	Q	Rain Type
1977-1980	12	0	0	0	A
1981-1985	6	5	1	0.9	A
1986-1990	7	5	0	0	A
1991-1995	5	5	2	2.0	F
1996-2000	4	8	0	0	A
2001-2005	7	5	0	0	A
2006-2010	10	2	0	0	A
2011-2015	9	3	0	0	A
2016-2020	8	4	0	0	A

Based on the results of the Wetness Index (Q) Analysis, it shows that East Kalimantan Province in the period 1977-1990 and the period 1996-2010 has Rain Type A, except for the period 1991-1995 with Rain Type F. The results of the analysis are closely related to the condition of average air temperature show the same trend, the increase of humid months in the period 1981-1985 occurred when the average air temperature in Balikpapan and Samarinda also increased. The same condition also occurs in the period 1991-1995, 1996-2000 and 2001-2005 which in the same period there is a surge in air temperature in Balikpapan regency, Samarinda rgency and West Kutai regency (Melak).

In a study by Hulme and Nicola (1999) of average historical data, temperatures in Indonesia have increased by 0.3°C per year since 1900. The 1990s were the warmest decade and 1998 was the warmest year, 1°C above the 1961-1990 average, with temperature increases occurring throughout the seasons. Rainfall decreased by 2% to 3% especially in December - February. In most parts of Indonesia changes in rainfall are influenced by El-Nino, major droughts occurred in the El-Nino years 1982/1983, 1986/987, 1991/1992 and 1997/1998. Various other studies of historical data also found the same thing in increasing air temperature, although with different rates of increase, but not linear for changes in rainfall. According to the analysis of Hidayati, et al. (1999), the temperature in most parts of Indonesia, especially during the day, increased. Although the rate of change is small, it is significant according to statistical tests (Spearman rank). Rainfall did not show the same pattern of change and although the climate data of all meteorological stations did not show any significant change.

According to Asfaw et al (2018) the modification of vegetation cover due to massive area deforestation inevitably affects rainfall. The results of Avissar et al (2002) and Spraklen and Gracia (2015) showed that in 1990 and in the future rainfall increased most prominently in August, during the transition from the dry to the wet season. Tropical deforestation has a double impact on the climate, causing changes in humidity and airflow, leading to changes in fluctuations in rainfall patterns and consequently an increase in temperature on earth. Deforestation, for example, will cause a 10-15% decrease in rainfall in the surrounding area (Youba, 2022)

Forest vegetation affects cloud formation by emitting carbon-based chemicals called volatile organic compounds (VOCs) into the atmosphere. Some of these compounds are deposited on small airborne particles such as dust, bacteria, pollen and mould spores. As the particles grow with the deposition of VOCs, they drive the condensation process and collect the resulting moisture, accelerating cloud formation.

The model predictions in this study show that the location of deforestation will greatly impact temperature and rainfall. Deforestation in the Congo Basin of West Africa would reduce rainfall across the region by 40-50% and increase temperatures by 3°C. Deforestation in the Amazon basin by 40% would reduce the rainy season by 12% (Nicholson et al, 2018)

4. CONCLUSION

Based on 43 years of rainfall data, Kalimantan Province received an average rainfall of 2752 mm year^{-1}. The lowest rainfall occurred in 1982 at 2090 mm year^{-1}, while the highest rainfall occurred in 1978 at 3482 mm year^{-1}. East Kalimantan Province experienced dry months in 1981-1985 and 1991-1995, which are likely correlated with the occurrence of severe forest fires. In addition, it is known that on average East Kalimantan province has 7 wet months and 5 humid months.

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