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Climate change in south Kalimantan (Borneo): assessment for rainfall and temperature

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ABSTRACT

A severe flood hit South Kalimantan in 2021. The flood inundated several cities and regions, including Banjamasin City and its surrounding areas in the Martapura Basin. According to data from the National Disaster Management Agency (BNPB), over 20,000 houses were flooded, and over 100,000 people were forced to relocate. Many flood causes are being debated these days, including climate change issues which are triggered by many factors. However, the significant factor indicating its existence is the increase in temperatures. Rising temperature will result in the intensity of the extreme rainfall and the change of its pattern. Due to this background, this study aims to evaluate rainfall and temperature variability as an indicator of climate change in the study area. The Man-Kendall Test is used in this study to analyze a trend analysis and its relationship to rainfall. The results show a temperature trend of 0.2 to 0.3 degrees Celsius over the last two decades. It indicates that climate change has occurred on a local scale. Further, the trend of rainfall and temperature have increased in all selected locations. The annual rainfall over the last 20 years has also increased by roughly 25 mm per annum.

Keywords: climate change; flood; rainfall; south Kalimantan; temperature; trend analysis

1 Introduction

Currently, climate change issues are resonating widely over the world and were done by many journal authors [1]. Inter-Governmental Panel on Climate Change (IPCC) defined climate change as the change in the state of the climate that can be identified by the change in the mean and/or variability of its properties and lasts for a long time, typically in a decade or longer time period [2]. According to The Fourth report of IPCC's Assessment, the global average temperature is expected to rise by 1.8 to 4.0 degrees Celsius by 2100 [3]. Extreme weather or climate events have greater potential to trigger disastrous impacts on society and the environment than gradual climate changes [4]. The rise in global average temperature has resulted in the increased frequency and severity of drought and rainfall events [5].

Rainfall is the most critical component of the environment and human life but it also can be turned into a dangerous disaster if not well managed. The change in the rainfall patterns will add more challenging issues to water management. The extensive rainfall amount can be a disaster for society, such as a flood. Increased rainfall trends can result in an increased frequency of flood occurrence [6]. Otherwise, the decreasing rainfall trends will affect the availability of water and tend to be drought events. The increasing rainfall trends (positive trends) are indicated in several regional scale studies such as Northern Australia, India, and other regions [7] including Indonesia. From 1998 to 2010, the TRMM rainfall dataset shows the increasing rainfall over Indonesia in several areas such as Java, Kalimantan (Borneo), Sumatra, and Papua [8].

South Kalimantan province is located on Kalimantan Island and has the main basin named Martapura River Basin (MRB). In early 2021, this province was hit by a severe flood, resulting in inundation in several cities and regencies [9]. There were 2 cities and 8 regencies flooded in the list, named Banjarmasin City, Banjarbaru City, Banjar Regency, Tanah Laut Regency, Tapin Regency, Barito Kuala Regency, Hulu Sungai Utara Regency, Balangan Regency, Tabalong Regency, Hulu Sungai Tengah Regency, and Hulu Sungai Selatan Regency. In total, there were approximately 633.732 people affected [10] and 15 people killed during the flood event [11]. The maximum flood depth was reached 200 cm in several locations and the flood duration was more than one week [10]. The flood events was become one of the severe floods in several decades since 1928 [12].

According to the several potential indications of the flood causes, climate change is one of the possible causes of the South Kalimantan 2021 flood. However, there have little numbers of climate change research in the Kalimantan Region, especially in South Kalimantan. The aim of this study is to do a preliminary analysis to know the existence of climate change in study area by using the common main indication, such as rainfall and temperature variability. Rainfall and temperature are two of the most important variables in climate sciences and hydrology, and they are regularly used to determine the extent and amount of climate change and fluctuation [13]. Climatic variability can be studied using statistical approach though long-term climatic data analysis. The climatic data can be analyzed by using parametric and non-parametric statistical method.

2 Data and Methods

2.1 Study Location

Flood in South Kalimantan located in the Martapura River Basin (MRB) which stretched over an area of 435.88 km^2 within elevations ranged from 0 to 1878 masl (meters above sea level)[14]. Most MRB area is under the administrative of Banjar Regency, South Kalimantan Province, Indonesia (114^{0}30'20'' – 115^{0}35'37'' E and 2^{0}49'55'' – 3^{0}43'38'' S). For detail of study location can be seen on Figure 1.

Topographical condition is consisted of low land area, hilly area and mountainous area. Following the slope classification of Van Zuidam [15] which adopted by Statical Agency of South Borneo Province, slope classes divided by 5 categories there are Category 1 (flat area, 0 – 2%), Category 2 (Gentle slope, 2% - 8%), Category 3 (Moderate slope, 8% to 15%), Category 4 (Strong slope, 15% - 25%), and Category 5 (Very strong slope, 25% - 40%) [16]. Climatic situation is categorized as tropical-humid with a temperature range of 20 ^{0}C to 36.3 ^{0}C. Annual averaged rainfall ranged from 2000 mm to 2500 mm.

MRB has main river named Martapura River with total length approximately about 36.5 km. In the upstream there are two tributary rivers called Riam Kanan River and Riam Kiwa River which are led to Martapura River in downstream. Riam Kanan acts as important position for South Kalimantan electricity source by operating hydropower plant since 1973 [17].

2.2 Data Acquisition

The Long-term data series of rainfall and temperature is provided from NASA Global Modeling and Assimilation Office (GMAO) called MERRA-(Modern-Era Retrospective Analysis for Research and Application version 2 [18]. MERRA is a contemporary re-analysis systems using latest V5 Goddard Earth Observing Systems Model (GOES) that combined with ground observation readings from many sources using advance numerical models and assimilation schemes [19].

MEERA precipitation product use three-dimensional variation (3D-Var) data assimilation based on the grid to point interpolation [20]. MERRA was released in 2009 based on the version of GEOS-5 atmospheric data assimilation systems which was frozen in 2008. Data span of MERRA product is ranged from 1979 to 2016 and replaced by MERRA-2 in near present [17]. Geographical resolution of MERRA-2 is approximately about 50 km x 50 km and the publishing latency is a few weeks (similar with MERRA) [21]. The atmospheric analysis uses a Gaussian grid with the same resolution (50 km x 50

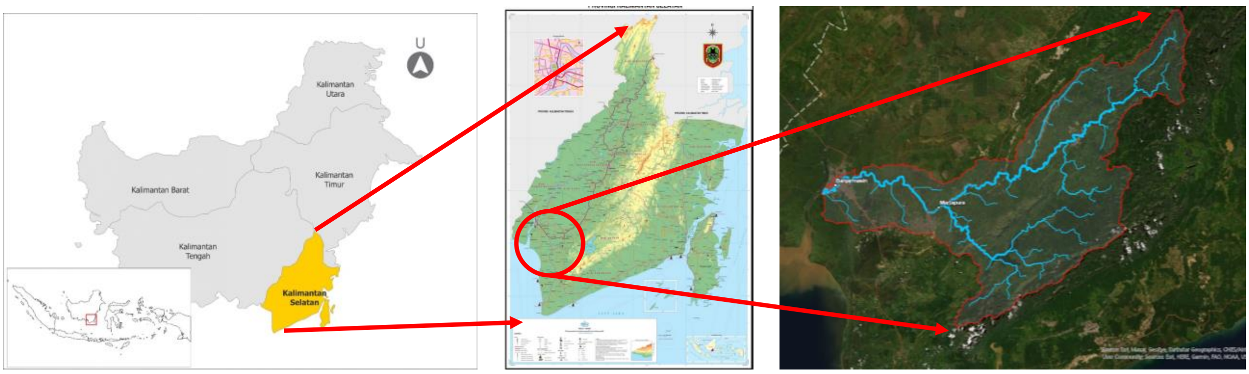

Figure 1. Map of Study Location, Martapura River Basin

km) and the output fields are interpolated to regular latitude-longitude grid of 0.5⁰ x 0.65⁰. MERRA has updated and advanced assimilation systems and resulting a best alternative for hydrological application in sparse and ungauged regions.

This study was applied daily precipitation and temperature data for a period of 20 years, ranging from year 2000 to 2020 which can be downloaded from NASA – Prediction of Worldwide Energy Resources" (NASA-POWER) website (https://power.larc.nasa.gov/). NASA-POWER is an initiative to improve the present renewable energy data collection and create new datasets using new satellite systems that are targeted to 3 user communities such as Renewable Energy, Sustainable Building, and Agro-climatology. All daily temperature data also averaged annually to obtain the trend of changing temperature in the study period.

In this study we selected 3 different locations in our study location than can be shown in Figure 2, such as Loc1-downstream area (yellow triangle), Loc2-middle area (red triangle), and Loc3-upper area (blue triangle). The coordinate of the selected locations are:

- Downstream area, 3⁰19'7.68" and 114⁰35'26.88"
- Middle area, 3⁰26'42.72" and 114⁰50'45.24"
- Upper area, 3⁰2'56.76" S and 115⁰29'40.56"

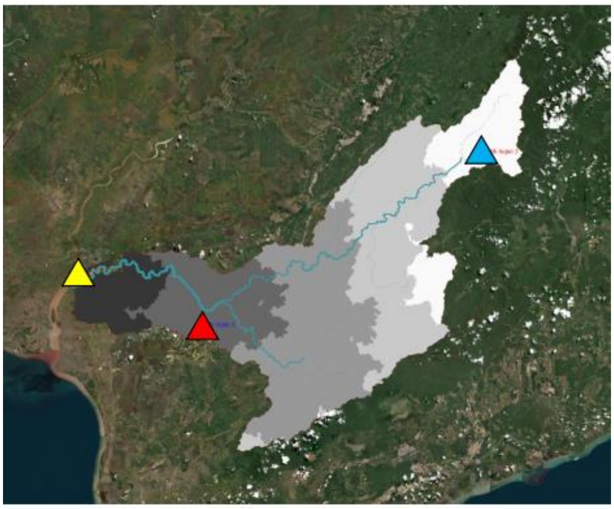

Figure 2. Selected location for Rainfall Data

2.3 Methods

In this study, we were selected a non-parametric Mann-Kendall test (MK) and the magnitude of linear trends analyzed by Sen's Slope test. Mann Kendall and Sen's Slop test are the most widely used for non-parametric method analysis. These methods were widely used in many different countries around the globe such as Italy, Iraq, China, and India, and the methods effectiveness have been proven by many journal authors [1].

The Mann-Kendall test was found to be the most often employed approach in the previous studies [5]. The rainfall trend of the selected area was analyzed by checking the trend on an annual and daily basis to know if the trend is decreasing, increasing, or no-trends. After checking the trends, we used the Sen's Slope test to estimate the magnitude of the trends.

Man-Kendall Test

Rainfall and temperature data from NASA-POWER were analyzed using Mann-Kendall Test. The Mann-Kendall test, often known as Kendall's statistic, has been frequently used to test for randomness in hydrology and climatology [22]. This approach was used to find statistically significant trends in variable such as rainfall, temperature, and stream flow [23]. Following equations calculate the Mann-Kendall test:

$$S = \sum_{i=1}^{n=1} \sum_{j=i+1}^{n} \operatorname{sign}\left(x_j - x_i\right) \quad (1)$$

Where n is number of data points, x_i and x_j are the i_{th} and j_{th} data value in the time series $(j > i)$, respectively, and $\operatorname{sign}(x_j - x_i)$ is the function determined below:

$$\operatorname{sign}\left(x_j - x_i\right) = \begin{cases} +1, \text{ if } x_j - x_i > 0 \\ 0, \text{ if } x_j - x_i = 0 \\ -1, \text{ if } x_j - x_i < 0 \end{cases}$$

An upward (increasing) or downward (decreasing) trend is indicated by a positive or negative value of S. If the number of data more than 10, the mean $(\mu(S))$ and variance $Var(S)$ are given by following equations:

$$\mu(S) = 0 \quad (2)$$

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i - 1)(2t_i + 5)}{18} \quad (3)$$

Where m is the number of tier groups and t_i is the number of ties of extent i. A tied group is a set of sample data with the same value. The variance is determined using following equation in the absence of links between the observations:

$$Var(S) = \frac{n(n-1)(2n+5)}{18} \quad (4)$$

Then standardized statistical test is computed as follows:

$$Z_s = \begin{cases} \dfrac{S-1}{\sqrt{\sigma^2(S)}}, \text{ if } S>0 \\ 0, \text{ if } S=0 \\ \dfrac{S+1}{\sqrt{\sigma^2(S)}}, \text{ if } S<0 \end{cases} \quad \text{.......(5)}$$

In this analysis, we used the significant level of $\alpha = 0.05$. If the Z_s value is positive, it indicated increasing trend, otherwise it represented a decreasing trend. The trend is categorized as significant if Z_s is greater than standard normal variate $Z_{a/2}$, where $a\%$ is the significant level. For significant level of 5%, a trend is significant when $Z_s > 1.96$ [24].

Sen's Slope Estimator

Sen's Slope Estimator is a non-parametric approach to estimating the magnitude of the trend by calculating the linear rate of the change (slope) and intercept. For given time series $X_i = x_1, x_2, x_3, \ldots, x_n$ with N pairs of data, the slope (T_i) is computed using following equation:

$$T_i = \frac{x_j - x_k}{j-k} \text{ for } i = 1,2,3,\ldots,n \quad \text{.......(6)}$$

Where x_j and x_k are data value at the time j and k, respectively. The median of n-values of T_i represent by the Sen's slope estimation is calculated by Equation (8) below:

$$Q_i = \begin{cases} T_{\frac{n+1}{2}} \\ \dfrac{1}{2}\left(T_{\frac{n}{2}} + T_{\frac{n+2}{2}}\right) \end{cases} \text{ for } i = 1,2,3,\ldots,n \quad \text{.......(7)}$$

A positive value of Q_i indicates an increasing trend and a negative value indicates a decreasing trend in the time series.

3 Results and Discussion

The rainfall characteristic of the selected area was analyzed based on the daily and annual rainfall pattern. The variation of monthly rainfall showed that the intensity of rainfall gradually increasing from September to March and then decrease significantly by April (see **Figure 3**). The highest rainfall is recorded on December for all selected location. By following the monthly rainfall amount, the downstream area has slightly higher than middle and upper area.

For more detailed analysis of mean monthly rainfall distribution, the monthly data of each selected location were divided into two periods, i.e., before and after 2010 as shown in the Figure (4, 5, and 6). Partitioning data series into two separate periods provides in-depth variations of the mean monthly rainfall amount before and after 2010. By this, we can analyze the shifting of dry and wet patterns and vice versa. The increasing rainfall shift in the downstream area (Loc1) occurs in all months both in wet and dry season. The significant shifting showed on March and May. In the middle area (Loc2), increasing shift also in all months and the highest shift is on March and June. The smallest shift is showed in November. The Upper zone (Loc3) is slightly different compared to downstream and middle area. The increasing shift showed on November to May and swift to decreasing shift from June to October. The significant increase and decrease are on December and July, respectively.

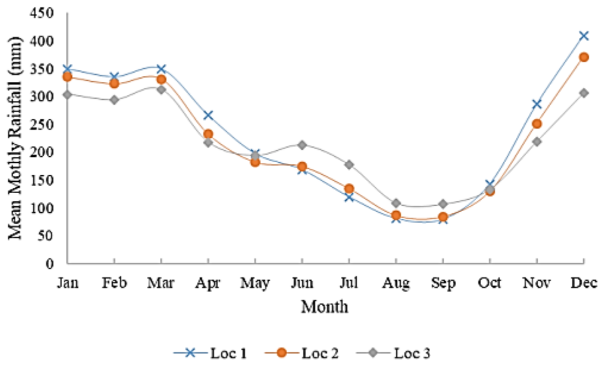

Figure 3. Mean monthly rainfall distribution. Grey line is upper area; Orange line is middle area, and Blue line is downstream area.

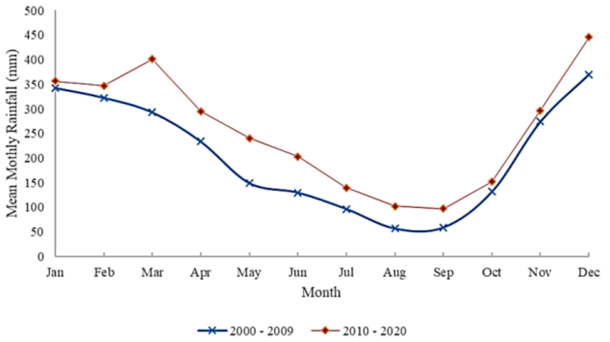

Figure 4. Mean monthly rainfall shift in Downstream Area.

3.1 Daily Rainfall Trend Analysis

According to the statistical information that shown in **Table 1**, the rainfall amount in the upper area is higher than downstream area. It can be resulted the different behavior of the stream flow fluctuation in the downstream area during rainy seasons.

The variation of the daily calculated using Mann-Kendall Test and the magnitude of slope is calculated by using Sen's Slope estimator as represent in Figure (7, 8, 9). Based on the calculation, the result of P-Value is smaller than significant level ($a = 5\%$), then the H_0 hypothesis is rejected and accept H_a . The rejected of null hypothesis indicates there is a trend in data series. The positive values of the Sen's Slope Estimator for all selected locations from 2000 to 2020 indicate the trend is going upward that means the increasing trends are occurred.

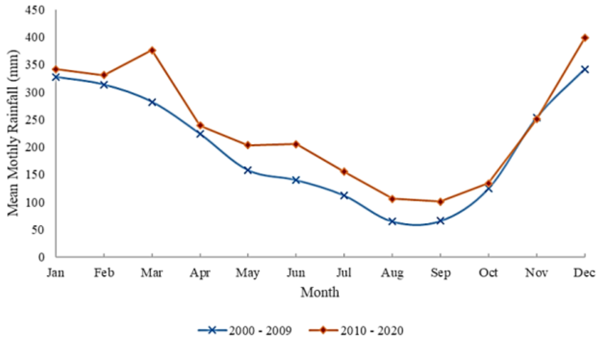

Figure 5. Mean monthly rainfall shift in Middle Area.

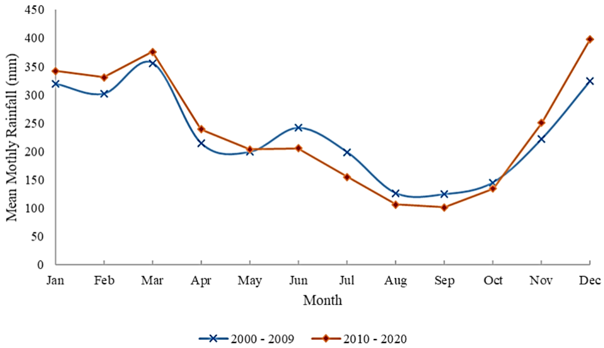

Figure 6. Mean monthly rainfall shift in Upper Area.

Table 1. Statistical information of Daily Rainfall Data

	Loc 1	Loc 2	Loc 3
Min	0	0	0
Max	171.9	357.62	242.61
Mean	7.62	7.21	7.07
SDev	11.65	11.09	9.90

Table 2. Mann-Kendall trend analysis (daily)

	Loc 1	Loc 2	Loc 3
Kendall's Tau	0.10	0.08	0.05
S	2854952	2198893	1351597
P-Value	0.0001	0.0001	0.0001
Sen's Slope	0.000187	0.000108	0.000071

Generally, these daily rainfall time series data give a slightly significant trend. As shown in **Table 2**, both of Mann-Kendall trend and Sen's Slope Magnitude and all selected locations have increasing trends (Positive).

3.2 Annual Rainfall Trend Analysis

The trend of total annual rainfall of 20 years data is represent in Figure (10, 11, and 12) which highlighted that the maximum annual rainfall is about 4457.32 mm in 2020 and occurred in downstream area. The minimum annual rainfall occurs in middle area and the amount is about 1849.33 mm.

According to the analysis result, the non-parametric Mann-Kendall test show the significant monotonic upward trend in all selected locations. The increased trend line for annual rainfall is roughly showed that difference between years 2000 to 2020 is about 500 mm.

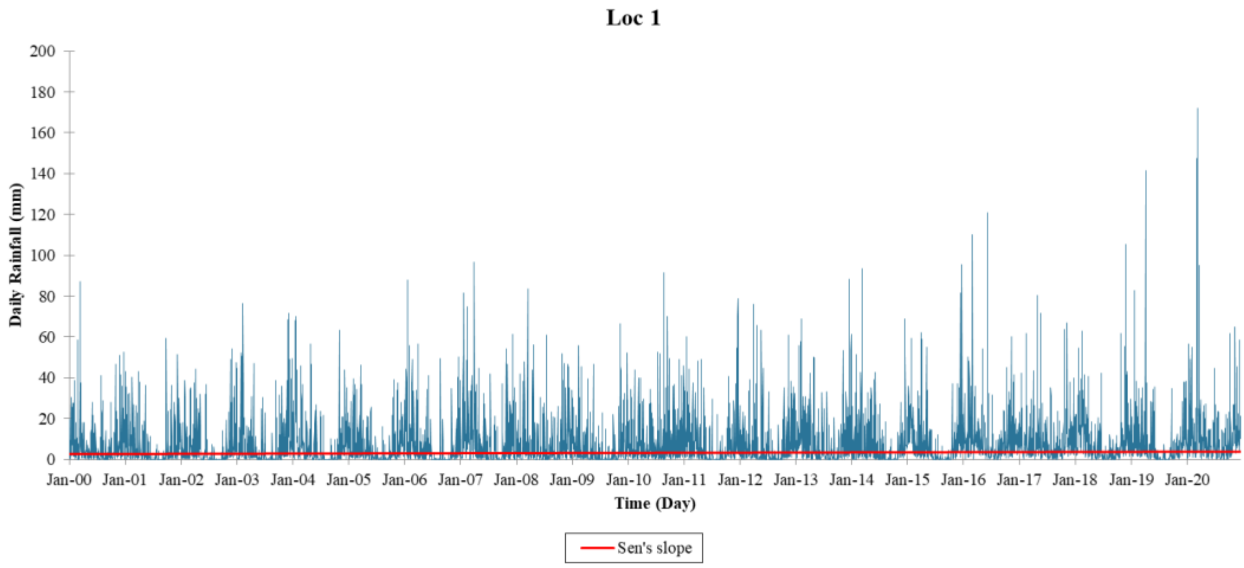

Figure 7. Daily rainfall trend in the Downstream area

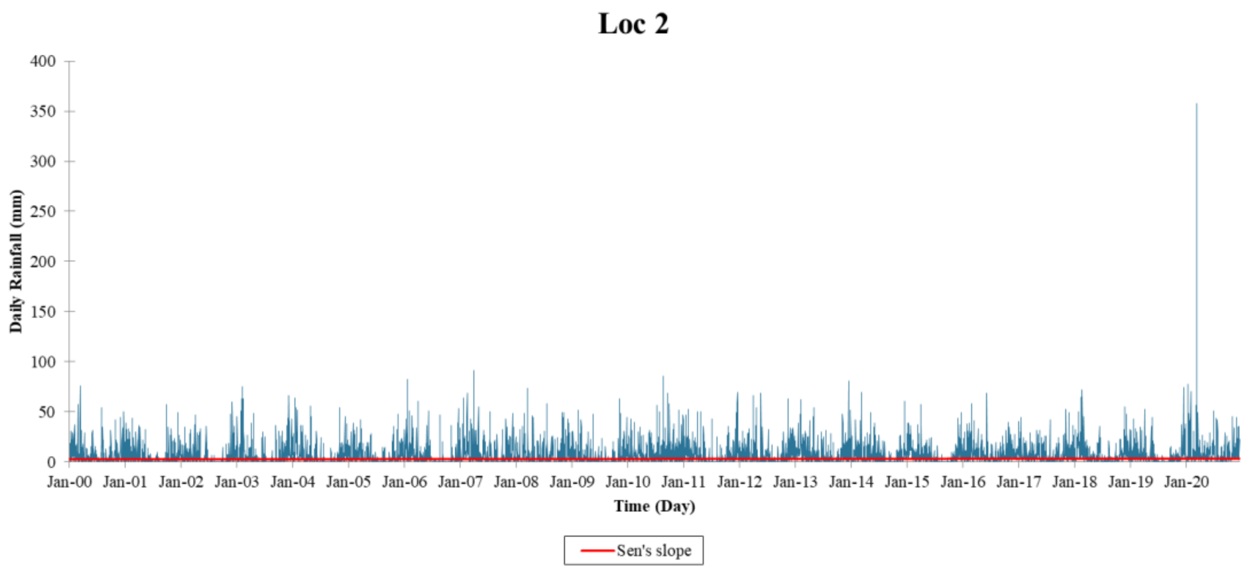

Figure 8. Daily rainfall trend in the Middle area

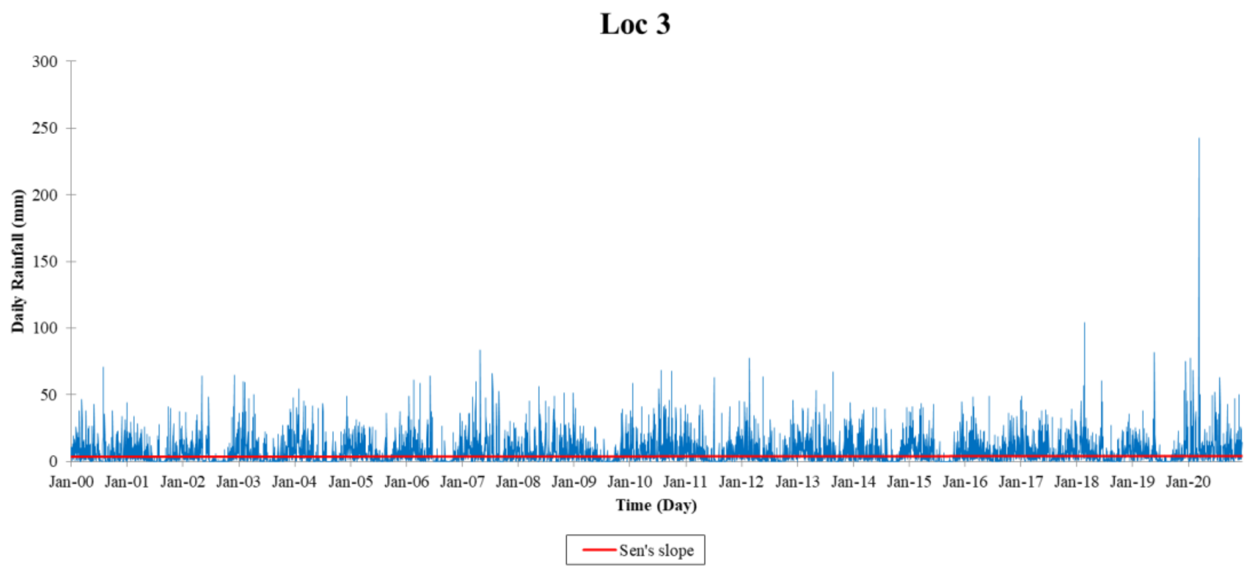

Figure 9. Daily rainfall trend in the Upper area

Sen's Slope Estimator results show that all selected locations have significant trend with high positive values (see **Table 4**). Figure (10, 11, and 12) shows the annual rainfall distribution of the study area. All selected locations showed an annual precipitation frequency of more than 1500 mm. Table 3 shows the differences of minimum and maximum annual rainfall amount is roughly reach double amount.

Table 4 explains the Mann-Kendall test summary with the 5% significant level. The computed Mann-Kendall Test indicates a trend in the annual rainfall series. Computed annual P-value for all selected locations from downstream area to upper area are 0.01, 0.11, and 0.16, respectively. Lower P-value than significant level ($a = 5\%$) is ensure to reject the null hypothesis and accept alternative hypothesis.

The magnitude of statistically increasing trend was determined by Sen's Slope. The result of long-term rainfall data indicates the trends were more rapid with high slope at all selected locations which positive incline roughly reaching 25mm/year.

This signifies that in the last 20 years, annual rainfall has constantly increased, and the observed trend implies increased wetness and possible risk to flood due to increasing potential amount runoff.

Additionally, **Table 3** shows the considerable difference in rainfall may have an impact on the quantity, quality, and accessibility of surface water [25] and it could have a positive or negative impact. For the upstream area, the amount of rainfall might be impacting Hydropower production. For downstream area, the positive impact of huge rainfall amounts is good for securing fresh water supply but it also can result the negative impact such as flooding issues if it not well managed.

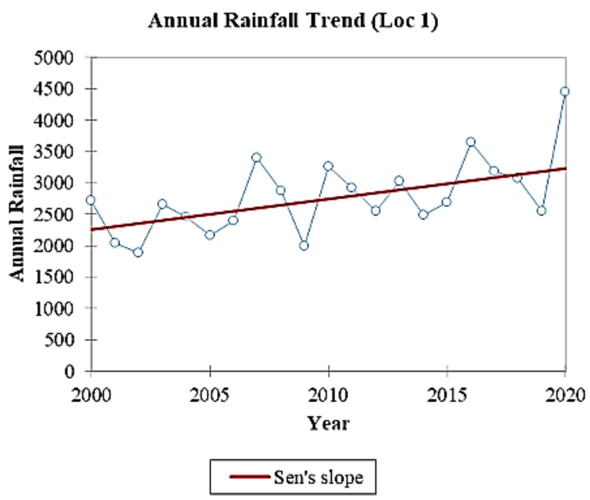

Figure 10. Annual rainfall trend in Downstream Area

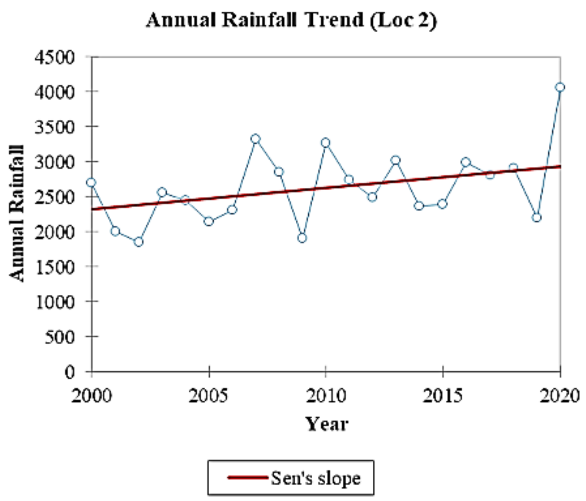

Figure 11. Annual rainfall trend in Middle Area

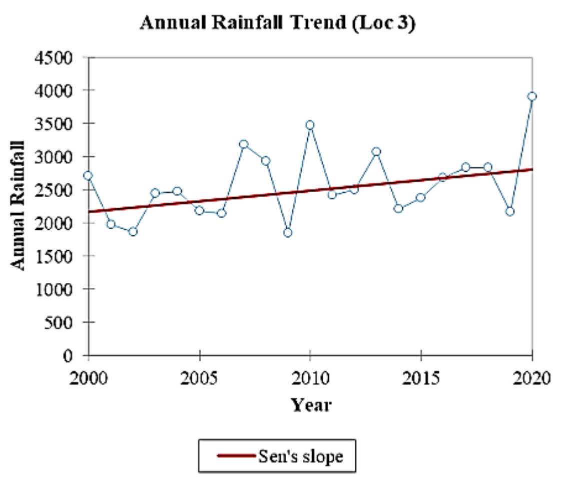

Figure 12. Annual rainfall trend in Upper Area

Table 3. Statistical information of Annual Rainfall Data

	Loc 1	Loc 2	Loc 3
Min	1878.55	1849.22	1855.76
Max	4457.32	4053.74	3909.31
Mean	2782.32	2635.14	2584.1
SDev	605.85	529.93	529.96

Table 4. Mann-Kendall trend analysis (annual)

	Loc 1	Loc 2	Loc 3
Kendall's Tau	0.39	0.26	0.23
S	82.00	54.00	48.00
P-Value	0.01	0.11	0.16
Sen's Slope	48.71	30.44	31.55

3.3 Annual Temperature Trend Analysis

In the same way as rainfall data, the Mann-Kendall and Sen's Slope estimator was used to assess the trends for average annual temperature. **Figure (13, 14, and 15)** displays the results of the average annual temperature for all selected locations.

From the analyzed locations, the most notable observation based on the results is the average temperature at annual have positive (upward) trend for all selected locations. According to the statistical data, the temperature is warmer year by year. According to the statistical data, the quite high differences in mean temperature between upstream and downstream areas reaching approximately 2.95 degrees Celsius and comparing all selected locations, the lowest temperature was recorded in the upstream area and the highest temperature recorded in the downstream area with temperatures of 24.19 ^{0}C and 28.10 ^{0}C, respectively (see **Table 4**).

Upper area has lower temperature than other locations due to the high elevation and the land cover mostly covered by natural cover such as forest. In other side, the downstream area is an industrial and urban area which the urban activity will generate more heat than upper area.

Table 5. Statistical information of Average Annual Temperaturel Data

	Loc 1	Loc 2	Loc 3
Min	27.15	25.91	24.19
Max	28.10	27.10	25.24
Mean	27.65	26.10	24.70
SDev	0.24	0.30	0.29

Table 6. Mann-Kendall trend analysis (average annual temperture)

	Loc 1	Loc 2	Loc 3
Kendall's Tau	0.305	0.438	0.390
S	64.00	92.00	82.00
P-Value	0.057	0.006	0.014
Sen's Slope	0.02	0.026	0.024

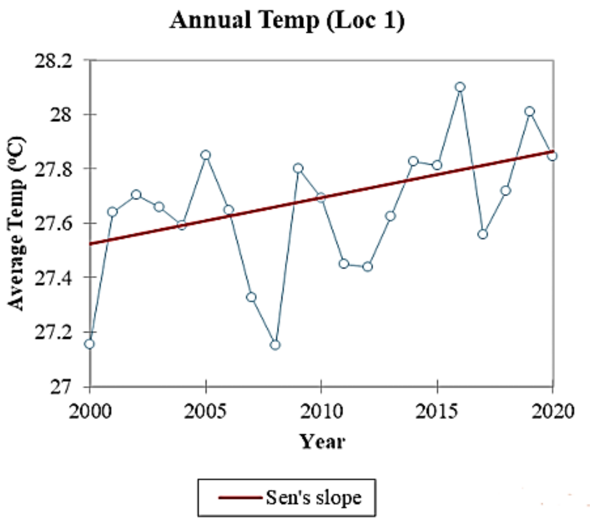

Figure 13. Average annual temperature trend in Downstream Area

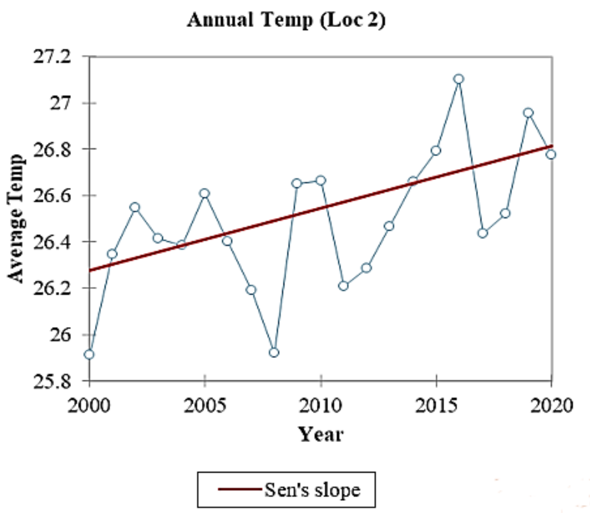

Figure 14. Average annual temperature trend in Middle Area

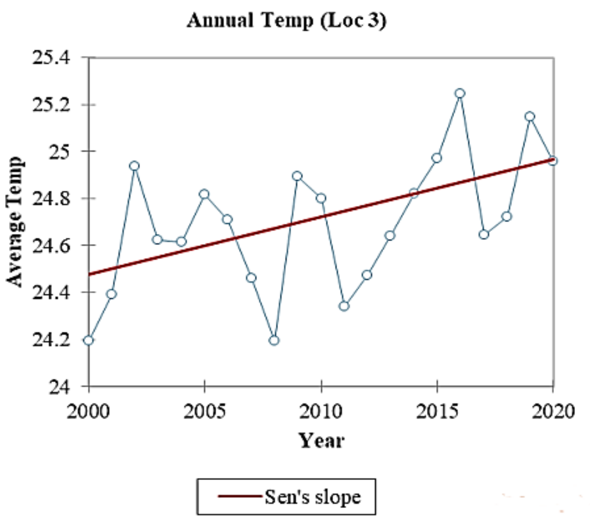

Figure 14. Average annual temperature trend in Upper Area

3.4 Discussion

According to the result of Mann-Kendall and Sen's Slope trend analysis, all selected areas show a monotonic upward trend for the last 20 years. Annual rainfall has increased significantly at the approximate rate reaching 25 mm per annum. The trend has increased over time and will possibly continue in the future. Whereas unpredictability and fluctuation in rainfall can lead to various natural disasters such as floods and landslides [26]. The local topography, altitude, and slope are correlated significantly with annual rainfall. Geographical characteristic such as variation of topography, elevation and mountain probably can be play as the main factor affecting the rainfall variation in this study location.

A rising trend in rainfall will almost certainly result in an increase in runoff volume. If the capacity of the river and drainage system is not sufficient for the current condition, it will seriously high risk to be flooding. Human activities such as deforestation or mining activities can be a multiplier factor for the natural sedimentation process which will directly decrease river capacity..

Trough the recorded meteorological data analysis of the average annual temperature, this study reveals that local climate change occurs in Martapura River Basin. It is showed by increasing (positive) trend of the average annual temperature. The temperature has become warmer year by year for the last 20 years. The increasing temperature will increase the rate of evaporation and the cloud formation, which will increase the amount of rainfall sequentially [27] and has possibility of increasing the amount of runoff.

4 Conclusion

The study reveals the local scale of the climate change occurrence. The statistical result of the Mann-Kendall test and Sen's Slope estimator highlighted that all of the selected locations presented increasing trends for both rainfall and temperature trends on a daily and annual basis.

The trend in 20 years of climatic data does confirm climate change (local scale) is occurring in the South Kalimantan. The average annual temperature trends showed an increase of roughly 0.2 to 0.3 per annum and impacted the study location which become warmer year by year. The rainfall trend showed the rainfall was increase roughly 25 mm per annum. Trend analysis proved to be the qualitative description of the impact of climatic factors on the number of runoff changes that can trigger a flood event.

Therefore, the rainfall and temperature trend analysis of this preliminary study could provide information for developing strategic action and adaptation measures to climate variability in anticipated climate change in South Kalimantan.

Based on our analysis we highly recommend a further deep investigation to establish the cause of the high increase of rainfall shifting and trends in the Martapura River Basin, South Kalimantan Indonesia.

Acknowledgement

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