ESTIMATION OF EXTREME RAINFALL CHANGES IN THE SERAYU WATERSHED USING A SCENARIO-NEUTRAL APPROACH

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Abstract. Flood disasters are the most frequent and damaging occurrences in Indonesia. They result in destruction, disrupting both economic and community activities. Extreme rainfall serves as one of the triggers for these floods. To mitigate the impact of impending losses, detecting flood disasters is necessary. This research aims to assess the effects of rainfall changes on increased flood risks in the Serayu Watershed using a Scenario-Neutral approach. The data utilised in this study comprise daily rainfall data from 1980-2018, obtained from GPCC, with the research conducted within the Serayu Watershed. The manipulated characteristics of rainfall encompass cumulative annual and monthly rainfall (Jan-Dec), with the upper and lower limits of rainfall changes determined through Mann-Kendall analysis. Daily rainfall data for the 1980-2018 period were generated while preserving the annual and monthly characteristics using an inverse approach, followed by calculating extreme rainfall for various return periods. Based on 132 simulations, the results indicate that excessive rainfall for shorter return periods is more sensitive than more extended return periods. This holds implications for designing flood control structures at both micro and macro scales, necessitating considering climate changes.

Keywords: extreme rainfall, Serayu watershed, flood

1. Introduction

The water resource system is essential for all aspects of human life to fulfil economic, social and environmental well-being. Efforts to meet this can be seen from the many uses of the system, such as for irrigation, drinking water supply, hydroelectric power, flood and drought control. The utilisation of these water resources is controlled by hydrological cycle processes, such as rainfall, evapotranspiration, and infiltration [1-3]. However, climate change can cause water resource systems to experience serious problems [4-6]. Therefore, the impact of climate change is significant to understand so that the capability of this system in the future can be estimated accurately from planning, design, and operation.

Information on hydrology and climate conditions in the future needs to be known precisely to measure the potential impact of climate change on increasing the risk of flooding. One method that can be used to measure the effects of climate change on increased flood risk is the top-down (scenario-led) method. This method has been widely used to assess the impact of climate change on water resources systems in general based on future climate projections generated from global climate models (GCM) and regional climate models (RCM). Using a rainfall-runoff hydrologic model, future hydrological conditions can be estimated by simulating the results of climate projections [7—10]. So that the management of water resources in the future under the threat of climate change and extreme events can be anticipated and carried out appropriately [11-12].

Although measuring climate change's impact on a water resources system is currently dominated by the "scenario-led" approach, this approach has several weaknesses, such as no direct link with practical decision-making in the field [13-15]. Moreover, this method does not consider the special conditions of each water resources system but is generally only based on rainfall and temperature variables (GCM/RCM scenario) for all systems [16-18]. The variables that affect the performance of a water resources system are not only in the form of rainfall and temperature but can also be influenced by other hydro-climatological variables [19]. In addition, the "scenario-led" approach also contains a relatively high element of uncertainty. As a result of the fate of climate change in the future, the management of water resources systems that are adaptive to climate change needs to be implemented so that system performance can be anticipated appropriately [20-24].

Another approach that can be used to assess the performance of a water resources system in flood control due to climate change in the future is scenario-neutral. This method attempts to overcome the shortcomings of the "scenario-led" approach [25]. This approach aims to create logical climate change forecasts that are more comprehensive and focus on assessing the sensitivity of the performance of individual water resources systems regardless of GCM/RCM climate change projections [26]. The performance of water resource systems can experience a sudden decrease in adaptation to climate change depending on a system's vulnerability level [27]. This study aims to measure the impact of changes in extreme rainfall on the Increased Flood Risk in the Serayu Watershed Using Scenario-Neutral.

2. Data and study location

2.1 Study location

The location chosen for the implementation of this research is Serayu Watershed. The Serayu Watershed was chosen as the research location because the watershed is in a critical watershed situation due to the increasing number of agricultural practices that do not heed conservation principles, causing the ratio of maximum discharge and minimum discharge of the river to be very high and sedimentation exceeding the threshold erosion rate. The Serayu Watershed has an area of 3,684.4 km² and is geographically located at the coordinates 07°05' to. 07°04' S and 108°56's.d. 110°05' E. The Serayu Watershed also includes several districts in Central Java, namely parts of Wonosobo, Banjarnegara, Purbalingga, Banyumas and Cilacap Regencies. For an illustration of the Serayu watershed, it can be seen in Figure 1.

Figure 1. Stream of the Serayu watershed

2.2 Input Data

2.1 Rainfall Data Collection

The data used in this study is rainfall data from the Global Daily Precipitation (CPC-Global) observed in the Serayu Watershed. This includes daily rainfall data at eight measurement points in the Serayu Watershed from 1980-2018. The data collection technique uses a quantitative research method of documentation and uses three variables: control, independent, and dependent. The control variable is rainfall data; the independent variable is the Serayu watershed measurement point and the dependent variable results from an analysis of climate change assessments.

The rainfall data is obtained from Global Daily Precipitation (CPC-Global). CPC-Global is the first product to emerge from the CPC Integrated Deposition Project developed by the National Oceanic and Atmospheric Administration (NOAA). CPC-Global is a data source for extreme Rainfall precipitation and future climate analysis. Rainfall data used is daily rainfall for 40 years (1979-2019, in the Serayu watershed, cumulative rainfall data on a monthly scale with a grid resolution of 0.5º x 0.5º. Data is entered in CSV format and summarised using Excel, which is then entered into the Rstudio program.

The rainfall data is summarised before entering the data into the RStudio software. The daily rainfall data obtained by CPC-Global from 1979 to 2019 for the Serayu watershed are summarised in each grid into annual rainfall every month. General information is shown in Figures 2 for Grid-37 and 3 for Grid-38. The results of this summary serve as observation data simulated using a scenario-neutral approach and for comparison data with simulation results.

Figure 2 and Figure 3 are boxplots of annual rainfall data from 1979 to 2019 for the Serayu Watershed on both grids. The horizontal axis shows the months of the year, while the vertical axis shows rainfall (in mm). The figures show that, cumulatively, grid 37 and grid 38 have the most rainfall in January and the least rainfall in August. The box graph also explains that low rain or less than 100 mm usually starts from May to October. Even in July-September, there are years when it does not rain at all (0 mm of precipitation).

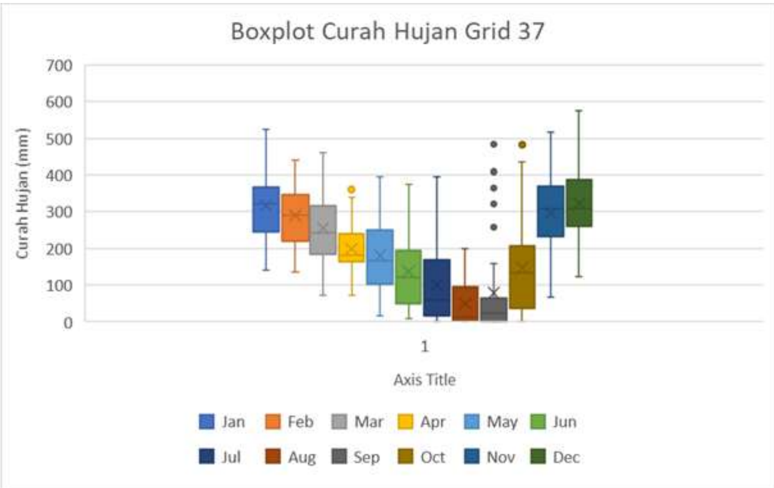

Figure 2. Boxplot of Rainfall Observations on Grid-37

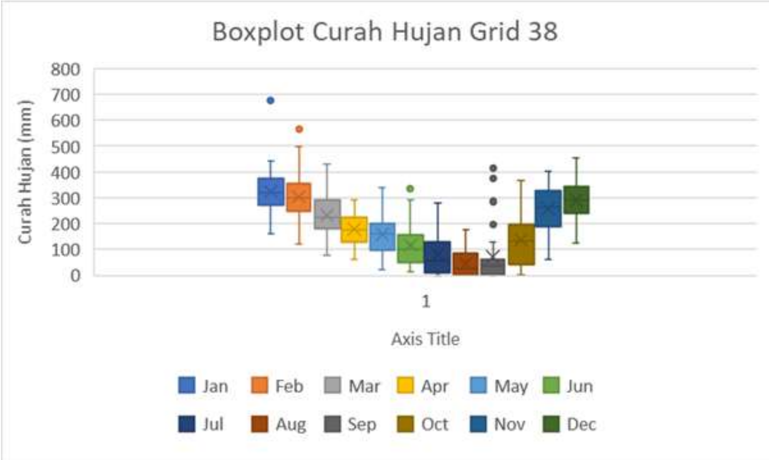

Figure 3. Boxplot of Rain Observations on Grid-38

Figures 4 and 5 show the monthly maximum, average, and minimum rainfall for each grid in January-December, measured from 1 January 1979 to 31 December 2019. The vertical axis shows months 1 to 12, while the vertical axis shows rainfall rain (in mm). The blue line is the maximum rainfall, the orange line is the minimum rainfall, and the grey line is the average rainfall. These two figures explain that the average high rainfall occurs in January-April and November-December. However, it rains a little from May to October.

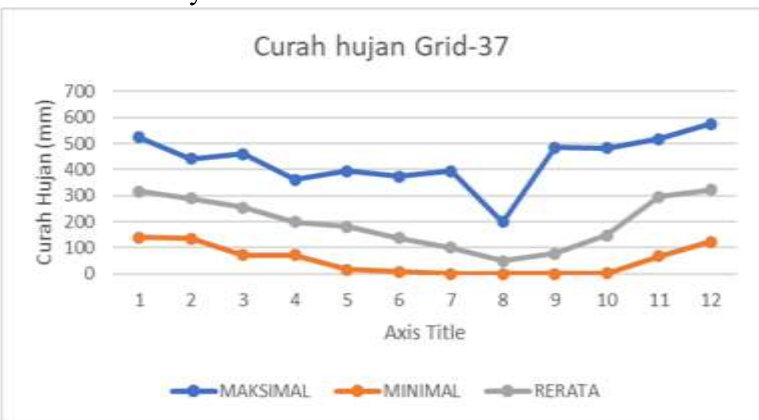

Figure 4. Grid Rainfall 37

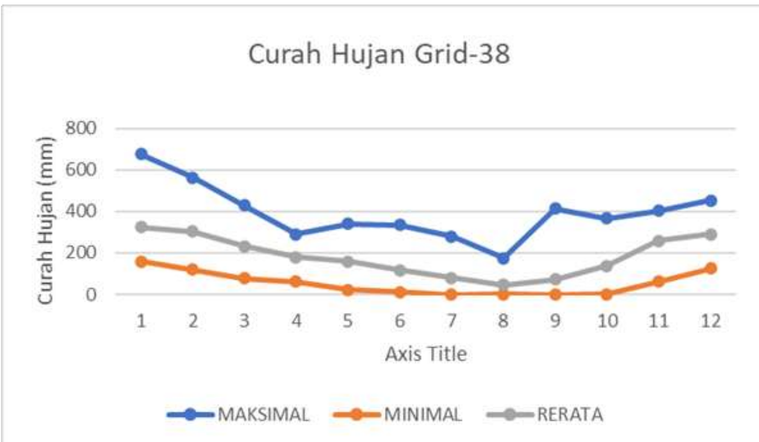

Figure 5. Grid Rainfall 38

3. Method

3.1. Man Kendall Trend Test

Trend analysis is carried out to determine whether time series data consist of trending behaviour, namely increase or decrease with time increase. This analysis is also related to non-stationary characteristics of data. In this research, the Mann-Kendall method is used for trend analysis. If the P-value is less than the significance level (generally used at 1%) to reject the Null hypothesis (No Trend), then the Null hypothesis should be rejected.

3.2. Rainfall Generation Using Iverse Approach

3.2.1 Scenario neutral

The reverse approach to rainfall generation is often used when historical rainfall data are unavailable or incomplete. This can assist in hydrological analysis, water management planning, and developing natural disaster scenarios. A scenario-neutral approach is a way to understand better the complex and sensitive relationship between water resources systems and climate. This approach is increasingly used to assess system performance under climate variability and change [28]. A scenario-neutral approach places the system at the centre of the assessment, explicitly emphasising measuring the climate sensitivity of the system and identifying associated action thresholds or decision boundaries. Neutral scenarios are used as a modelling approach to measure and assess the opportunities and impacts of climate change on water resources systems [29]. A scenario-neutral process needs to consider several steps such as: a) Determine what hydro climatological variables/attributes drive system performance and make changes in hydro climatological variables, b) Generate hydro climatological scenarios that reflect changes in hydro climatological variables, c) System performance simulation in response to changes in hydro climatological variables through a system model, d) Analysis and visualisation of the resulting system performance concerning the attributes of the hydro climatological scenario, and e) Evaluate system options based on simulated system response.

3.2.2 Inverse and stochastic approaches

Using the Stochastic Generator is seen as an alternative to scaling the coefficients on hydrometeorological data to calculate a wider possibility of climate change. This generator's use has been enhanced to produce a realistic time series of meteorological variables [30-33]. The structure of the random time generator may limit the number of properties that can be modified as part of an exhibition space development. A stochastic generator is proposed to broaden the applicability of the scenario-neutral approach to examine the implications of changes on average and hydrometeorological variables. Weather stochastic generator models have sufficient flexibility to broadly simulate future climate change while retaining the statistical features generally associated with time series weather.

The inverse approach creates a hydrometeorological time series that responds to changing climate characteristics. The reverse process allows for a range of future climate conditions to be explored, which can then be used to provide more exhibition space and address the need for a more comprehensive climate impact assessment using a scenario-neutral approach. The reverse process is simplified in two main steps, which are as follows: 1) Identify a set of target levels for each attribute included in the exposure space, and 2) Make a time series hydrometeorology that satisfies each attribute target.

3.3. Rainfall Extreme

Extreme rainfall refers to high and abnormal rainfall events in a particular area or time. This excessive rainfall can be very intense and potentially cause significant impacts, such as flooding, landslides or damage to infrastructure. In this study, the resulting rainfall is the maximum annual daily rainfall, the most significant rainfall that occurs in one day for one year in a particular location or region. It is a measure to gain an understanding of how much of the most extreme rainfall is likely to be in one day of the year. Measuring the maximum annual daily rainfall is vital in hydrological analysis, disaster risk management, drainage planning and water management. By knowing how much extreme rainfall is likely to occur in a given period, planners and scientists can plan infrastructure that can withstand the effects of extreme rainfall, such as flooding caused by heavy rains.

Analysis of maximum annual rainfall involves collecting daily rainfall data from weather stations or rain sensors over several years. From this data, the most significant rainfall in one day in each year is identified. The steps generally taken are: 1) Daily rainfall data from weather stations or other sources over several years are collected. 2) The highest rainfall values in one day each year are identified. 3) Statistical analysis of the maximum annual rainfall's mean, median, and standard deviation are conducted. 4) Statistical modeling, such as distributions of extremes (Gumbel or Frechet), can be used to model the distribution of annual maximum daily rainfall and estimate the likelihood of future occurrence of extreme rainfall. The results of this analysis can be used to plan an effective drainage system, construct flood-resistant infrastructure, and take appropriate disaster risk mitigation measures.

4. Results and discussion

4.1. Man Kendall Test

An evaluation was carried out with the Mann-Kendall test to evaluate the model. The Mann-Kendall test was conducted to assess whether or not there is a trend in the Hydrological period data. The Mann-Kendall test was carried out on grids 37 and 38; Grid-37 can be seen in Table 1, and grid-38 in Table 2.

Table 1. Kendall Man Test Results on Grid 37

STASTIONING 37								
BULAN	OBSERVASI	MAKSIMAL	MINIMAL	RERATA	STANDAR DEVIASI	var(s)	MK.TAU	PVALUE
JANUARI	315	661	152,832	315,344	99,505	9901,285	-0,001	1
FEBRUARI	288	435	147,868	288,485	78,932	6230,296	0,19	0,09
MARET	248	482,298	67,946	248,877	97,686	9542,547	-0,026	0,828
APRIL	202	360,508	70,543	70,543	5230,559	0,08	0,483	0
MEI	177	372,542	14,646	177,364	94,995	9024,064	0,015	0,904
JUNI	133	349,02	6,937	133,383	93,649	8770,192	-0,018	0,885
JULI	94	351,042	0,737	94,16	94,811	8989,038	-0,099	0,384
AGUSTUS	53	213,348	0,411	53,628	64,877	4209,072	-0,134	0,236
SEPTEMBER	78	495,535	0	78,463	124,182	15421,217	-0,042	0,717
OKTOBER	164	482,125	0,908	164,469	132,412	17533,069	0,001	1
NOVEMBER	294	526,757	68,318	294,21	105,908	11216,554	-0,206	0,066
DESEMBER	321	534,055	123,831	321,622	98,864	9774,028	0,066	0,561

Table 2. Kendall Man Test Results on Grid 38

STASTIONING 38								
BULAN	OBSERVASI	MAKSIMAL	MINIMAL	RERATA	STANDAR DEVIASI	var(s)	MK.TAU	PVALUE
JANUARI	327	537	164,670	327,221	97,962	9596,543	-0,069	0,545
FEBRUARI	301	544	214,485	301,271	91,016	8284	0,206	0,066
MARET	224	422,341	224,753	247,139	86,92	7555,059	-0,053	0,646
APRIL	182	289,296	70,493	139,189	3777,622	0,096	0,397	0
MEI	151	340,592	91,252	151,4	74,972	5620,821	0,023	0,847
JUNI	113	316,983	105,467	113,693	81,758	6684,452	-0,009	0,942
JULI	75	253,408	17,862	75,198	72,601	5270,834	-0,139	0,217
AGUSTUS	49	178,518	41,770	49,076	54,937	3018,106	-0,136	0,226
SEPTEMBER	71	428,23	71,809	117,576	104,84	10991,429	0,008	0,952
OKTOBER	148	399,921	9,981	148,201	103,706	10755,015	0,023	0,847
NOVEMBER	260	407,775	260,755	311,017	83,086	6903,349	-0,201	0,073
DESEMBER	287	422,667	262,422	287,603	78,48	6159,056	0,018	0,885

Tables 1 and 2 show that April has the most significant standard deviation value, indicating that rainfall has high variability and diversity. The greater the standard deviation value, the more sloping the probability curve towards the extreme values and the greater the variance of the mean value. So, it can be said that April has the lowest persistence compared to data on the number of rainy days, while August has the smallest standard deviation value, which indicates that rainfall has the highest persistence compared to other months.

MK.tau is Kendall's ranking correlation coefficient to measure the relationship between the two measured quantities. used to calculate the p-value. Interpretation of null hypothesis testing. If the p-value exceeds the significant alpha level of 0.05 or 5%, then the null hypothesis H_0 is accepted. If the p-value is less than the alpha significance level of 0.05 or 5%, rejecting the null hypothesis H_0 and accepting the alternative hypothesis H_1 is impossible. As seen in Tables 4.3 and 4.5, the average for each month can be accepted because it has a value above 0.05 or 5%. The consequences of rejecting the null hypothesis H_0 are justified if it is lower than the 5% alpha significance level.

4.2. Model validation

In Tables 1 and 2, some of the parameters of the Mann-Kendall trend test can also be seen. The S statistic has a significant negative value, which means there is a tendency to fall, and the S statistic has a significant positive value, which means the trend is rising. If you look at Tables 1 and 2, the S value of each month is positive, which means that the rainfall in each month tends to increase. Increase. The level of rainfall trends can be seen in Table 3.

Table 3. Rainfall trend results from the Mann-Kendall test

	Grid 37		Grid 38	
BULAN	cenderung meningkat %	cenderung menurun %	cenderung meningkat %	cenderung menurun %
JANUARI	54	46	100	0
FEBRUARI	6	94	9	91
MARET	64	36	82	18
APRIL	0	100	0	100
MEI	84	16	90	10
JUNI	94	6	88	12
JULI	21	79	38	62
AGUSTUS	22	78	23	77
SEPTEMBER	95	5	71	29
OKTOBER	84	16	100	0
NOVEMBER	7	93	6	94
DESEMBER	88	12	56	44
	=	NO TREND/KECENDURUNGAN		

5. Conclusion

a. Using climate change scenarios, synthetic daily rainfall can be generated in a scenario-neutral approach.
b. The results of synthetic rainfall patterns show an increased risk of flooding in grid-37 and grid-38 of the Serayu Watershed occurring from November to April.
c. Raindall amounts in April have the most significant standard deviation values, indicating that rainfall has high variability and diversity which means the level of persistence is small, while August has the smallest standard deviation value indicating that rainfall has the highest persistence compared to other months.

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