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Impact of Extreme Drought Climate on Water Security of Machap Dam

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Abstract : Due to climate change, severe changes throughout the rainy season and protracted dry seasons offer issues. Drought is harmful to human health and productivity. Extremely dry weather caused by severe drought can induce serious imbalances in water cycles, affecting rainfall patterns and evaporation, atmospheric water vapour circulation, and soil moisture content, resulting in decreased volumes in streams, rivers, and reservoirs. In September 2019, Johor began to feel the impact of the extended heat and lack of rain. As a result, the water level at Machap Dam has reached critical levels. This study intends to calculate yearly rainfall intensities and identify year or month droughts events between 2011 and 2020. The information was collected from the Water Resources and Hydrology Management (SPRHiN) website. Monthly rainfall, yearly rainfall, mean annual rainfall, variance, and percentage deviation were determined using collected rainfall data. The percentage deviation was used to identify extreme drought periods. According to the statistics, the wettest year was 2018. The most precipitation fell in 2018, with a total of 2333.50 mm, while the least fell in 2019, with a total of 1699 mm. Base on obtained result the average annual rainfall is 2050.373 mm. As a conclusion, the study's goal of determining annual rainfall intensities and year or month droughts was effectively accomplished. In future study, it is suggested that the data given be expanded so that it is easier to spot missing data.

Keywords: Rainfall, Intensity, Drought, Climate Change, Hydrology

1. Introduction

Water resources are a natural environment in which climate change will have a direct impact, as unfavourable weather conditions can lead to water shortages. Climate change causes severe changes throughout the rainy season and protracted dry seasons, posing problems to local people in managing their water demands. Drought caused water shortages and has severe consequences for human health

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and productivity. Extremely dry weather caused by severe drought can induce serious imbalances in water cycles, affecting rainfall patterns and evaporation, atmospheric water vapour circulation, and soil moisture content, resulting in decreased volumes in streams, rivers, and reservoirs [1].

At the same time, due to over-discharge from human activities, present demand for water exceeds availability. Climate change has also had an impact on the groundwater recharge system, resulting in anomalous rainfall and rising temperatures, which influence the amount of water in the ground. Water scarcity and low periodic rainfall caused by climate change, particularly drought episodes, impose extra strain on groundwater supplies [2].

Climate change may pose an extra challenge to groundwater resources in particular, as well as outside groundwater, as it impacts many political borders, perhaps leading to intervention and conflict over water boundaries. However, its waters cross borders in several nations, which implies that numerous political parties share water resources in difficult climatic circumstances. As a result, water disputes and disagreements are frequently addressed emotionally, with cooperation and conversation amongst provinces. However, none of these cross-border water agreements have included shared groundwater necklaces [3].

According to news stated that Johor started to be affected by the prolonged hot weather and lack of rain in September 2019. This is due to the fact that the water level at Machap Dam has reached critical levels. Furthermore, the water level at Lebam Dam, Upper Layam Dam, and Pulai Dam are all in a dangerous state. This circumstance prompted the government and Ranhill SAJ to implement a month-long water rationing programme while also continuing to monitor the water levels in the dams. As a result, 150,000 water consumers have been impacted, with some having to live without water for a few days [4] [5]. The objectives of this study are; (1) to determine the annual rainfall intensities from 10 years back from 2011 to 2020, and (2) to identify year or month drought that happened within 10 years from 2011 to 2020. This study focus on observations at the Machap Dam. As rainfall water drop in dams occurs annually, this study focus on the Machap Dam region to obtain accurate final findings. with the use of data obtained from Water Resources and Hydrology Management (SPRHiN). From the data obtained, calculations will be made for the rainfall that occurs for 10 years to record the phenomenon of drought and to detect in which month the drought is experienced [6].

2. Results and Discussion

The data and analysis from the study are presented in the findings and discussion section. This part can be ordered in accordance with the stated objectives, the historical chronology, different case groupings, different experimental setups, or any other logical sequence thought acceptable.

2.1 Site Description

The research area is located in Johore, Malaysia's central state, 110 km North of Johore Bahru, east-southeast of Batu Pahat, West of Mersing, and South of Segamat. The bearing of the Machap Dam is 1.8880680977673796, 103.27121013960743 .The Machap dam is operated by the Department of Irrigation and Drainage and is located near Simpang Renggam in Johor. The dam holds back a portion of the Sungai Benut flood discharge, reducing the intensity of the downstream flood. It was built to withstand a 25-year flood with a maximum downstream flow of 540 cusecs, the capacity of the downstream channel. The reservoir's stored water is used to control Sungai Machap flows to the Syarikat Air Johor intake, which is farther downstream for residential water supply. Syarikat Air Johor was digged around 2 metres from Sungai Machap. The hydroelectric turbine provision was not used since it was costly. The dam is made up of three distinct components: an earthfill saddle dam, a service spillway structure, and radial gates as shown in **Figure 1.**

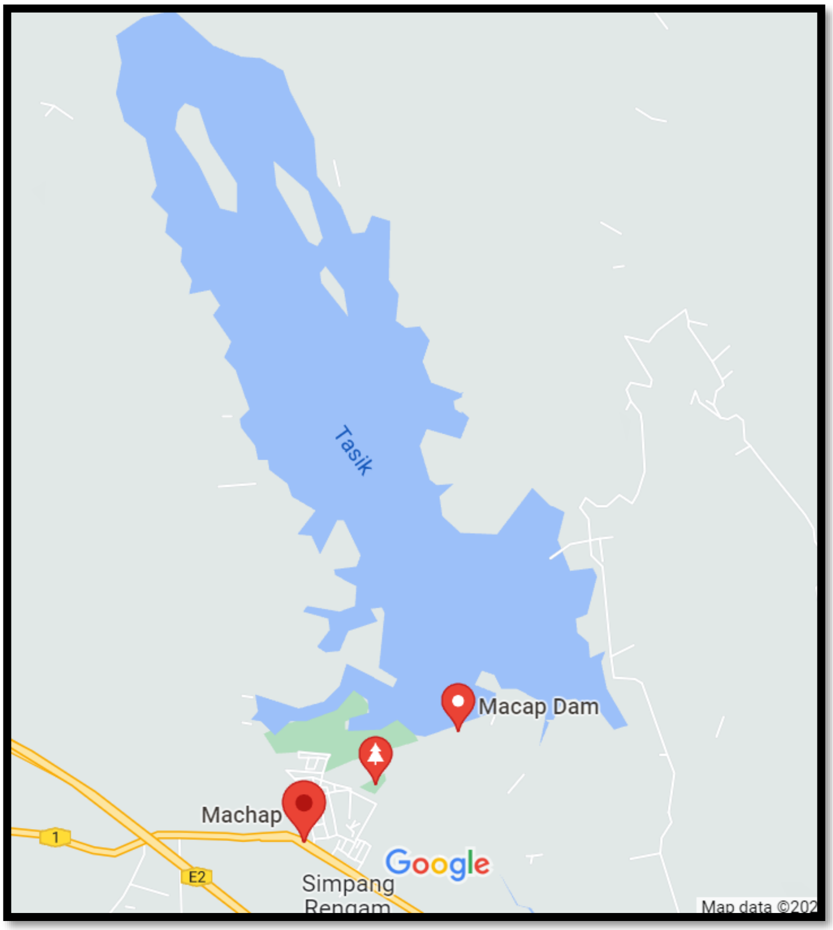

Figure1: Location of Machap Dam

2.2 Composite Drought Index (CDI) and Customized Composite Drought Index (CCDI)

The composite drought index (CDI) is a metric that collects various forms of earth observation data to estimate the level of drought over a certain time period. Key component analysis (PCA) is used to determine which variables from the obtained data set will contribute the most to the index in order to construct one variable. The data values for the CDI and CCDI are distinct. This is because CCDI only utilises 5 of the 10 variables found in CDI. This can show that this study has the potential to employ tactics to improve the region's monitoring system as well as drought prediction [7].

Drought is assessed using methods such as the standardised evapotranspiration index (SPEI) and the standardised precipitation index (SPI). SPEI will calculate the amount of drought that happens on agricultural land by calculating the index between precipitation, temperature, and firing time. SPI will monitor and identify drought-affected regions by developing an index that is divided into a single relevant component or a combination of many factors. SPI has presented a drought monitoring system based on pre-precipitation [8].

2.3 Dam Water Leveling and Rainfall Analysis

Better criteria that are clear, practical, and effective are needed to define atypical drought periods utilising limited data, such as rainfall data. As a result, this is the primary goal of this study, and the extensive work on drought management and damshave been done, primarily focusing on groundwater and long-term impacts, which involved the use of many databases as well as the complex and technical application of conceptual modelling and visualisation approaches such as Geographic Information and remote sensing. These may be the most severe constraints for some places that lack datasets, lack historical data for long-term research and comparison, or have database and information accessibility issues [9].

This strategy might offer a precise time period with a well-defined interval demonstrating the sensitivity of tiny or even dramatic fluctuations in rainfall and the consequences on water dams. The study may be more beneficial in detecting unusual drought situations, especially when limited data, such as rainfall, is employed [10].

At each month, low rainfall periods will be detected, and the percentage departure from the mean monthly rainfall for Machaph dam will be calculated. If the percentage deviation has a substantial negative value (50%) or a negative deviation for two months in a row with a cumulative value of 50%, this indicates exceptionally low rainfall. Using the previously identified drought period, the water level patterns for dams will be analysed.. This is to assess how much the drought affected the dams, water levels, and how robust the dams were as water supply sources in terms of sustaining a continuous flow of water during the drought episode. Following that, the dams' risk of water insecurity will be assessed by calculating the number of days a certain dam spent in a water-insecure condition, when the water level fell below significant levels [11].

2.4 Method

2.4.1 Normal Ratio Method

To find the missing data, the normal ratio approach was used. Because the yearly precipitation at the neighbouring gauge is larger than 10%, this approach was used. The data was derived using the formula stated below, where x represents the missing gauge and P represents precipitation, with N being normal yearly precipitation [12].

$$P_x = \frac{N_x}{3}\left(\frac{P_A}{N_A} + \frac{P_B}{N_B} + \frac{P_C}{N_C}\right) \qquad \textbf{Eq. 1}$$

2.4.2 Percentage Deviations

The drought-affected months were determined using the percentage deviation. The variance was calculated by subtracting the mean yearly rainfall from the monthly rainfall data. To calculate the percentage deviations, the acquired number was divided by the mean annual rainfall and multiplied by 100.

3. Result And Discussion

3.1 Annual Rainfall Pattern

According to **Figure 2**, the highest rainfall occur was recorded in 2018 with a precipitation value of 2333.5 mm/year, while the lowest precipitation was recorded in 2019 with a precipitation value of 1699 mm/year. The ten-year average precipitation is 2050.37 mm.

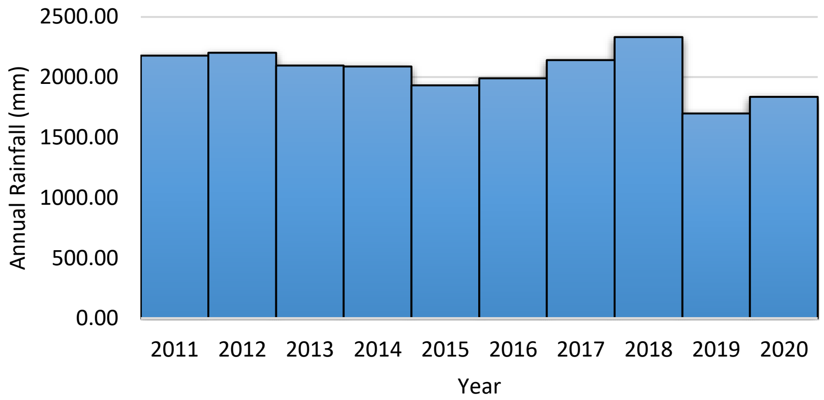

Figure 2: The annual rainfall over years from 2011 to 2020.

3.2 Number of Months Experienced Drought

Based on the **Figure 3**, the year that has highest number months that experience drought is 2014 with 8 months. Meanwhile the year with lowest number of months that experience drought in 2013 is 3 months.

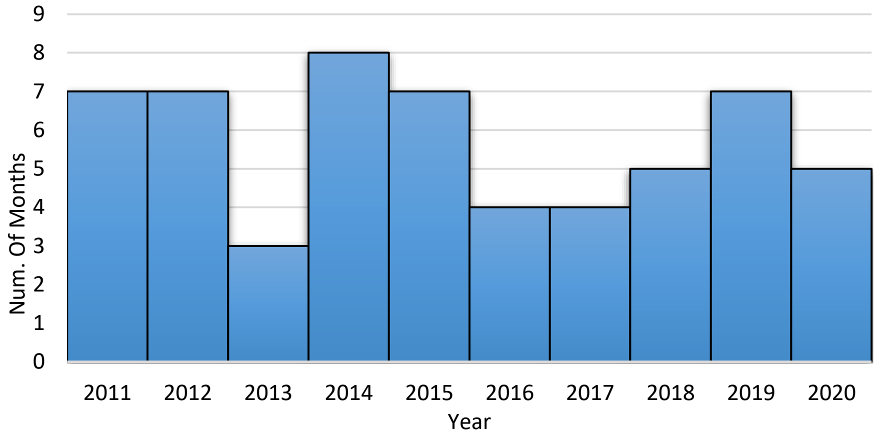

Figure 3: The number of months experienced drought.

Table 1: The number of months experienced drought from 2011 to 2020.

Year	The Month That Experience Drought
2011	February, March, April, May, June, July, August
2012	January, February, March, April, May, Jun, July
2013	Jun, July, August
2014	January, February, March, Jun, July, August, September, October
2015	January, February, Jun, July, August, September, October.
2016	May, June, July, August
2017	February, March, May, June
2018	February, March, July, August, September

2019	January, February, March, April, July, August, September.
2020	February, Mac, April, November, December

Table 1 shows the months that experienced drought from year 2011 to 2020. According to **Table 1**, the months with the highest frequency of drought (eight times in ten years) are February and July. Meanwhile, November and December have the lowest incidence of drought, occurring just once every ten years. Based on the months that have been listed, it is recommended that the repeated months as mentioned earlier should be given attention in the coming years and early preparations should be made to face them.

3.3 Comparison Between CDI/CCDI With Method Use In This Project

The CDI approach employs 10 factors to discover the underlying causes of drought episodes, while also taking supply and demand for water, soil moisture, and vegetation conditions into account. During the index's development, it is feasible to determine which components contribute the most to the index.

CCDI's methodology is therefore comparable to CDI's, with the difference being the amount of variables used. CDI requires 10 variables, but CCDI just requires five variables. In each of these strategies, each of these elements was assigned a distinct priority in terms of contributing to CDI and CCDI.Following that, data from the water resources and hydrology management (SPRHiN) system were used to analyse the extreme drought climate in the Machap water dam. Water Resources and Hydrology Management data are necessary to examine the incidence of such severe drought situations (SPRHiN). Data for 10 years beginning in 2011 and ending in 2020 were used to calculate the drought year. Then, throughout the past 10 years, create hydrograph and histogram graphs to determine the month when the drought occurred.

The difference between the CDI and CCDI processes and the method used is in the focusing. Whereas the CDI/ CCDI methodology focuses on discovering which variables contribute to the occurrence of the drought, the method used in this project focuses on determining the month when the drought occurs based on objective 2 given in this project.

4. Conclusion

As a last thought, Precipitation was computed after constructing all of the graphs for each year. The highest precipitation occurs in 2018, with a precipitation value of 2333.5 mm, and the lowest precipitation occurs in 2019, with a precipitation value of 1699 mm, with a ten-year average precipitation of 2050.37 mm. The extreme drought climate that occurred in 2019 occurred because the drought occurred for two seasons, the first from January to March with a total percentage deviation of -158.38 percent for three months and the second from May to September with a total percentage deviation of -200.53 percent for five months, according to the data. The first and second objectives may be determined to be successful, with the first focused on establishing annual rainfall intensities from 2011 to 2020 and the second focusing on detecting year or month droughts that occurred between 2011 and 2020. The initial purpose is to generate a graph of yearly rainfall intensity for each year focused utilising rainfall data given by SPRHiN. Finally, it can be concluded that the first and second objectives can be successfully achieved, with the first objective being further achieved through the production of a deviation percentage graph and precipitation data, with the results obtained revealing that 2019 is the year that received extreme drought climate with the highest percentage, thus being the year to receive the least precipitation. As a result of the discussion, the project report for this period can be successful since it fulfills all of the report's objectives.

It is suggested that several different types of data be utilised in this study, including dam water level data, dam water catchment area data, and stream flow data. It is simpler to acquire pleasing results with several types of data; with more data, it is feasible to deliver more accurate results. Furthermore, several methods for measuring the level of extreme drought climate, such as the Normal Ratio Method and deviation percentage, are required to improve the accuracy of the analysis, with the addition of calculation methods can produce more results needed in determining the level of past drought climate.

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