

INVESTIGATING THE IMPACTS OF CLIMATE VARIABILITY ON WATER LEVELS OF DOMASI RIVER

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MEC-204-19

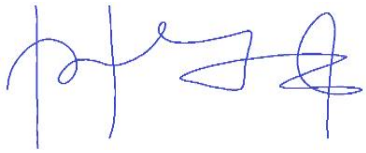
Thyolo,Malawi

DISSERTATION SUBMITTED TO NDATA SCHOOL OF CLIMATE AND EARTH SCIENCES OF THE MALAWI UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE

BACHELOR OF SCIENCE DEGREE IN METEOROLOGY AND CLIMATE SCIENCE.

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ABSTRACT

This research investigates the impact of climate variability, with a focus on temperature and rainfall, on water levels in the Domasi River basin. Despite the absence of significant individual trends in temperature and rainfall, their combined effects contribute to the dynamics of water resources within the region. While temperature trends remain relatively stable and the correlation between temperature and water levels is not statistically significant, there is evidence of the potential influence of temperature variations on hydrological processes and water availability. Moreover, although no significant trend in rainfall amounts was identified, a robust positive relationship between rainfall and water levels highlights the critical role of precipitation in driving hydrological processes. These findings underscore the substantial impact of climate variability on water availability and river discharge in the Domasi River basin. Recommendations include the establishment of a robust monitoring system, investment in advanced hydrological modeling tools, community involvement in water conservation efforts, implementation of nature-based solutions, and collaborative efforts between stakeholders to develop adaptive water management strategies. Continued monitoring and analysis of climate data are essential for informing adaptive strategies for sustainable water resource management in the face of climate variability and change, not only in the Domasi River basin but also in similar regions worldwide.

ACKNOWLEDGEMENTS

Firstly my whole hearted thanks to Almighty God for the gift of life and good health also for the guidance and protection throughout the entire period I have been doing my studies at this university (MUST).

I also express my gratitude to my supervisor Mr T. Kapichi for the guidance and support throughout this thesis also a big thank you to all lecturers for imparting me with knowledge and expertise on different spheres of my program of study, God bless you ladies and gentlemen.

I also intend to thank members from the Department of Climate Change and Meteorological Services (DCCMS),the Deputy Director Mr Clement Boyce and Mr Mtingwi for the provision of rainfall and temperature data for my study area Domasi river basin. In addition, my extended appreciation should go to Mr Mdala (Gauge Reader for Domasi river) and members of staff from the Ministry of Water and Sanitation for the provision of water levels data.

In particular,I want to thank my wife Mervis Mumba Ng'ambi for being supportive and understanding in all circumstances this academic life has exposed me to, I also take immense pleasure to thank my parents,my siblings and friends for their continued prayers, support and encouragement throughout my studies.

Special appreciation should go to all my classmates (MEC-4 2024) for the teamwork spirit during different academic assignment and schedules.

DECLARATION

I Alick Ng'ambi declare that this research project represents my own work and that it has never been submitted to this institution or any other institution for any academic purpose. All sources of information have been appropriately acknowledged.

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Chapter 1

1.0 introduction

Climate variability stands as one of the most critical global issues of our time and has already manifested observable impacts on the environment (Chellaney, 2007). It is characterized by variations in the mean state and other statistics of the climate across all spatial and temporal scales, extending beyond individual weather events, and can arise from natural processes within the climate system or anthropogenic external forcing (IPP, 2007).

To a significant extent, climate variability can be understood through fluctuations in a relatively small number of climate patterns, such as El Nino Southern Oscillation (ENSO), North Atlantic Oscillation, and Arctic Oscillation, among others. According to the UN Malawi (2010), climate variability significantly affects Malawi's development agenda by exerting notable effects on the functioning of natural ecosystems, with major implications for several weather-sensitive sectors such as agriculture, forestry, and water resources, as highlighted by Ozor et al. (2010).

Recent years have witnessed significant swings in river water levels across Africa due to altered rainfall patterns, rising temperatures, and an increase in extreme weather events. These variations have had significant impacts on the availability of water, agricultural output, human health, and ecosystem health. The African Climate Policy Center estimates that more than 50% of Africans live in areas classified as water-scarce, a figure expected to rise to 75% by 2025. Hence, addressing the influence of climatic variability on water resources is imperative.

For instance, decreased river water availability adversely affects irrigation and drinking water supplies, leading to poor crop performance and waterborne illnesses. Conversely, excessive rainfall can result in floods, causing property damage, forced eviction, and even fatalities.

However, it has been observed that the general public in Malawi discusses climate change and variability without giving it serious consideration, lacking adequate knowledge and awareness of the associated devastating impacts. According to the Government of Malawi (2008), nearly all socio-economic sectors of the country rely on water resources. However, Malawi is documented as a water-stressed country and may face water scarcity by 2025 if no action is taken to mitigate the impending crisis.

Climate variability emerges as the primary challenge affecting Malawi, rendering the country increasingly vulnerable to issues such as frequent dry spells or erratic rainfall, leading to problems such as low crop and hydro power production. Therefore, this study aims to assess the impacts of climate variability, in terms of temperature and rainfall variation, on the average annual water levels of Domasi River. Located in Zomba urban, in the southern region of Malawi, Domasi River serves as the focal point for this investigation. The study results may aid in addressing the impacts associated with climate variability on average annual water levels of various water sources and uncover several other research questions for further exploration.

1.1 Problem Statement

Domasi River, a crucial water source in Zomba district southern region of Malawi, is pivotal for sustaining irrigation farming and other economic activities. However, in recent years, there has been a concerning trend of the river drying up earlier than usual and experiencing heightened flooding during the rainy season. These fluctuations in the

river's behavior are likely linked to climate variability. Thus, it is imperative to investigate the impact of climate variability on Domasi River to understand its mechanisms and implement effective water resource management strategies. Doing so will mitigate the risks of both water scarcity and flooding, safeguarding the region's socio-economic stability.

1.2 Research Questions

1. What is the average annual water level for Domasi River?

2. What are the variations in temperature and rainfall for Domasi River?

3. How do changes in temperature and rainfall relate to water levels in rivers?

1.2.1 Research Hypothesis

The research hypothesis posits that there is an improvement in the average annual water levels of Domasi River due to the implementation of new and enhanced environmental and river conservation measures such as afforestation and re-afforestation along river banks. Alternatively, it is hypothesized that there is a reduction in average annual water levels of Domasi River due to both natural and anthropogenic factors, including cultivation and settlement along the riverbank, as well as climate variability-related factors such as temperature and rainfall variations.

1.3 Research Objectives

1.3.1 Main Objective

The main objective of this research is to evaluate the impacts of climate variability on the average annual water levels of Domasi River.

1.3.2 Specific Objectives

The specific objectives of this study are as follows:

1. To assess the trend of water level in Domasi River in Zomba from 2010 to 2018.

2. To analyze the trend of temperature and rainfall for Domasi River in Zomba from 2010 to 2018.

3. To establish the relationship between the trends of water levels in the river and the trends of rainfall and temperature during the same period.

1.4 Significance of study

Understanding the effects of climate variability on the average annual water levels of Domasi River is vital in assessing the broader impacts of climate change on water resources. As temperature and rainfall patterns fluctuate, they influence the flow of water in the river, leading to various consequences. One significant impact is the increased risk of flooding events. With rising temperatures and changing precipitation patterns, Domasi River can experience more frequent and severe floods, posing risks to nearby communities by damaging infrastructure, homes, and agricultural lands.

Conversely, climate variability can also lead to decreased water availability in Domasi River. Warmer temperatures enhance evaporation rates, reducing the amount of water reaching the river system. Additionally, alterations in rainfall patterns can diminish runoff into the river, further exacerbating water scarcity issues. This decline in water availability not only affects communities relying on the river for irrigation and drinking water but

also poses challenges for ecosystems dependent on consistent water flow for their survival.

Furthermore, climate variability can disrupt the biodiversity of Domasi River. Changes in water levels can impact the composition and abundance of plant and animal species within and around the river ecosystem. This alteration in biodiversity can have cascading effects on the entire river ecosystem, affecting ecological services such as recreational opportunities, food resources, and habitat provision. Overall, understanding the multifaceted impacts of climate variability on Domasi River is essential for implementing effective adaptation and management strategies to mitigate adverse consequences and safeguard the well-being of communities and ecosystems dependent on the river.

CHAPTER 2

2.0 LITERATURE REVIEW

The subject of linking climate variability (temperature and rainfall) to water levels in rivers is broad, involving two intricate fields: climate variability and river water levels. Climate variability encompasses various subsystems, while water levels in rivers encompass multiple subtopics.

2.1 Climate Variability (Rainfall and Temperature)

Climate variability denotes alterations in the mean and/or variability of climate variables, including temperature and rainfall, over a specified period. Malawi, situated in southern Africa, faces high vulnerability to climate variability, posing significant challenges to its agricultural sector and economy.

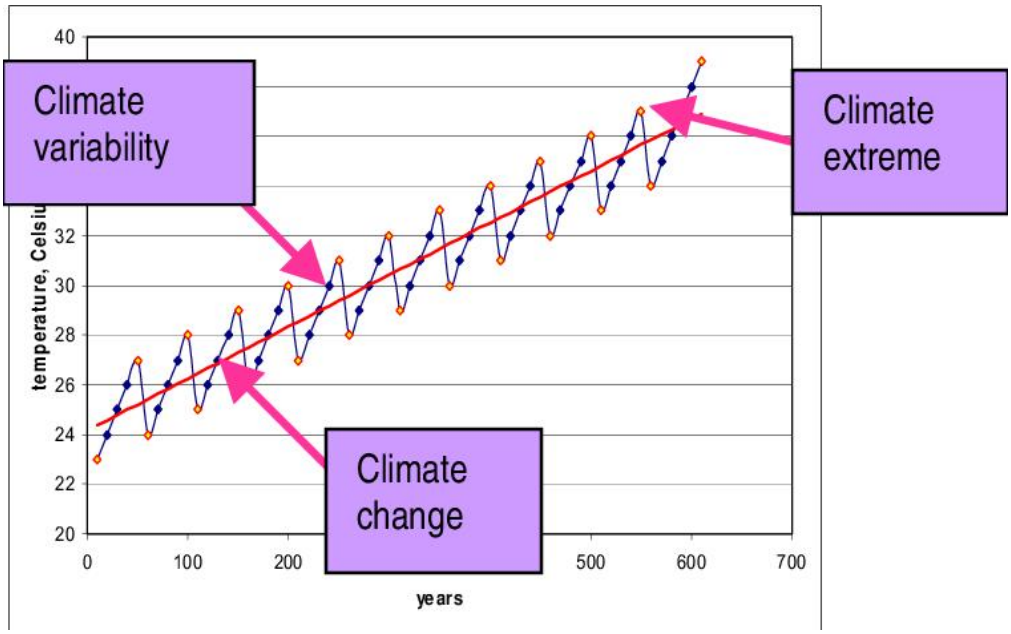


Figure 1 indicates the graphical representation of climate variability

Figure 1 above shows the alteration of the mean of temperature for a period of few years thus illustrating climate variability.

As per the Intergovernmental Panel on Climate Change (IPCC), Malawi has witnessed shifts in temperature and rainfall patterns over recent decades. Between 1960 and 2006, temperatures rose by 0.6°C, and rainfall became more erratic, characterized by longer dry spells and intensified rainfall events (IPCC, 2014). These changes have led to increased water stress, soil erosion, and reduced crop yields, particularly in the country's southern and central regions, which are more susceptible to droughts and floods (IPCC, 2014).

The impacts of climate variability in Malawi are compounded by poverty and limited access to resources, such as water, technology, and finance, hindering farmers' ability to adapt to changing climatic conditions (Schipper & Pelling, 2006). The Malawian government has formulated various policies and programs to tackle these challenges, including the National Adaptation Program of Action (NAPA), which aims to enhance resilience and reduce vulnerability to climate change (Ministry of Environment and Climate Change Management, 2012).

Climate variability in Malawi has significantly affected the country's economy and food security. Continued monitoring and assessment of these changes and the development of effective adaptation strategies are essential to mitigate the adverse effects of climate variability on the country's population and environment.

2.2 Water Levels in Rivers of Malawi

Malawi, a landlocked country in southern Africa, heavily relies on its rivers for various purposes, including irrigation, hydro power generation, and domestic water supply. However, water levels in Malawi's rivers have been fluctuating, primarily due to climate variability and human activities such as deforestation and unsustainable land use practices.

According to the Ministry of Irrigation and Water Development (MIWD) of Malawi, some major rivers in the country, such as the Shire and the Ruo, have experienced significant declines in water levels over the past few decades. For instance, the Shire River, Malawi's largest river and a key source of hydro power generation, witnessed a 35% reduction in water flow between 1990 and 2010 (MIWD, 2017). This decline has had severe repercussions for electricity generation, given Malawi's heavy reliance on hydro power for its energy needs.

Furthermore, diminishing water levels in Malawi's rivers have adversely affected irrigation and agriculture, critical to the country's food security. Reduced water levels have led to decreased crop yields, increased soil salinity, and limited access to water for domestic use (MIWD, 2017).

To address the challenges posed by declining water levels in Malawi's rivers, the Malawian government, through the MIWD, has implemented various programs and policies aimed at conserving and sustainably managing water resources. These initiatives include promoting the use of water-efficient irrigation technologies, regulating water abstraction, and advocating for sustainable land use practices (MIWD, 2017).

In conclusion, water levels in Malawi's rivers have been dwindling in recent decades, primarily due to climate variability and human activities. This has had significant implications for the country's energy generation, agriculture, and domestic water supply. Continued monitoring and sustainable management of water resources are crucial to ensure their availability and accessibility to current and future generations.

2.3 The Impact of Climate Variability (Temperature and Rainfall) On Water Levels

Several studies have investigated the impacts of climate variability on water levels in rivers. Here are some literature reviews on the topic:

- "Climate Variability and its Impact on River Water Levels in the United States" (Milly et al., 2008): This study examines how climate variability, specifically changes in rainfall and temperature, affects river water levels in the United States. The authors found that climate variability has altered the timing and magnitude of river flows, impacting water availability and quality. Although focusing on various locations in the United States, the research concept remains similar to the present study, with the study area being different.

- "Climate Variability and its Impact on Water Resources in Malawi" (Masangwi et al., 2016): This study explores the influence of climate variability on water resources in Malawi, concentrating on changes in rainfall and temperature. The findings indicate that climate variability has led to fluctuations in water availability, affecting agriculture and overall water security. The study underscores the necessity for enhanced water management practices and adaptation strategies to mitigate climate change impacts on water resources in Malawi. Unlike the current project, this study did not specifically focus on Domasi River in Zomba.

- "Assessing the Impact of Climate Change on Agricultural Production in Malawi" (Hachigonta et al., 2014): This study investigates the effects of climate change on agricultural productivity in Malawi, focusing on changes in rainfall patterns. The authors found that climate change has reduced agricultural output, impacting food security and livelihoods. The study emphasizes the importance of adaptive management strategies and policies to ensure sustainable agricultural production amidst climate change. Unlike the current project, this study primarily addresses the impact of climate variability on agricultural production rather than water levels in rivers.

- "Hydrological Modelling of Climate Change Impacts on Water Resources in Malawi" (Mukolwe et al., 2017): This study utilizes hydrological modeling to assess climate change impacts on water resources in Malawi. The authors found that changes in rainfall patterns have resulted in water availability fluctuations, affecting domestic and agricultural water usage. The study highlights the need for improved water management practices and adaptation strategies to mitigate climate change impacts on water resources in Malawi. Unlike the current project, this study did not focus on Domasi River as the primary study area.

- "Assessing the Impact of Climate Change on Fishery Resources in Lake Malawi" (Kanyerere et al., 2019): This study examines the influence of climate change on fishery resources in Lake Malawi, a vital food and livelihood source for the region. The findings suggest that temperature and nutrient availability changes have affected fish populations, impacting the fishing industry and food security. The study underscores the importance of enhanced water management practices and adaptive strategies to ensure sustainable fishery resource utilization amidst climate change. Since the topic is broad, the study primarily focuses on climate variability's impact on fishery resources.

CHAPTER 3

3.0 METHODOLOGY

Introduction to Methodology

Understanding the impact of climate variability on water levels is critical for effective water resource management, particularly in regions vulnerable to climatic changes. In the case of the Domasi River in Zomba district, Malawi, where water is a vital resource supporting agricultural, domestic, and industrial activities, assessing the influence of climate variability on its water levels is of paramount importance. This section outlines the methodology employed to investigate the relationship between climate variability and water levels in the Domasi River, aiming to provide valuable insights into the dynamics of this vital water system.

The methodology encompasses a quantitative technique to comprehensively analyze the complex interactions between climate factors and river water levels. Through the systematic application of various data collection methods, statistical analyses, and modeling techniques, this study seeks to elucidate the drivers of water level fluctuations in the Domasi River and their relationship with climate variability.

Key components of the methodology include the collection of historical climate data, hydrological measurements, and relevant socio-economic information to establish baseline conditions and trends. Additionally, advanced statistical methods such as regression analysis and time series modeling will be employed to identify patterns,

correlations, and potential causal relationships between climatic variables and water level fluctuations.

Overall, the methodology adopted in this research endeavor is designed to provide a robust framework for assessing the impact of climate variability on the water levels of the Domasi River. By integrating diverse data sources and analytical techniques, this study aims to generate actionable insights that can inform evidence-based decision-making and contribute to the sustainable management of water resources in Zomba district, Malawi.

3.1 Research Design Description

The research design for assessing the impact of climate variability on water levels in the Domasi River of Zomba district, Malawi, will employ a quantitative approach utilizing secondary data analysis. This design allows for the systematic examination of historical climate data and hydrological measurements to investigate the relationship between independent variables representing climate variability and the dependent variable of water levels in the Domasi River.

3.2 Threats to Internal and External Validity:

1. Internal Validity:
    - Selection bias: Possible bias in the selection of data sources or time periods may affect the internal validity of the study.
    - Measurement error: Inaccuracies in the recorded climate and hydrological data could compromise the internal validity of the findings.
    - Confounding variables: Unaccounted variables influencing both climate variability and water levels may confound the observed relationships.
2. External Validity:

- Generalization: Findings may not be generalize beyond the specific context of the Domasi River in Zomba district.
- Transfer ability: The applicability of findings to other regions with different hydrological characteristics may be limited.

3.3 Independent and Dependent Variables:

- Independent Variables (Operational Definitions):
    1. Precipitation: Total rainfall measured in millimeters over specified time periods (e.g., monthly or annually).
    2. Temperature: Mean temperature recorded in degrees Celsius, typically on a monthly or annual basis.
- Dependent Variable (Operational Definition):
    1. Water Levels: Height of water in the Domasi River, measured in meters at designated monitoring points along the river course.

3.4 Conceptual Framework:

The conceptual framework for this study is based on the understanding that climate variability, including fluctuations in precipitation and temperature, and changes in land use/land cover, influence water levels in the Domasi River. The approach will involve analyzing historical climate data and hydrological measurements to identify patterns and correlations between these independent variables and water levels in the river.

This framework aligns with the research questions by providing a systematic way to assess how variations in climate factors contribute to fluctuations in river water levels over time. By analyzing secondary quantitative data, this approach enables the investigation of long-term trends and relationships, offering valuable insights into the dynamics of water resource management in the study area (Babbie, 2016; Creswell, 2014).

3.5 Study Area

The study area for this research is the Domasi River, located within Zomba district, Malawi. Zomba district is situated in the southern region of Malawi, bordered by Mozambique to the east. The Domasi River is a key watercourse in the district, serving as a vital source of water for various socio-economic activities, including agriculture, domestic use, and industrial purposes (Ngongondo et al., 2017).

Zomba district experiences a subtropical climate characterized by distinct wet and dry seasons. The rainy season typically occurs from November to April, with peak rainfall usually observed between December and March. The dry season extends from May to October, during which precipitation levels decrease significantly (Nath et al., 2019).

The Domasi River originates from the highlands of Zomba Plateau and flows in a southerly direction through the district, eventually joining lake Chilwa, one of Malawi's water bodies. The river's catchment area encompasses diverse land uses, including agricultural fields, forested areas, and settlements (Ngongondo et al., 2017).

The topography of the study area varies from highland areas in the north, characterized by steep slopes and dense vegetation, to lowland plains in the south. These geographical features influence the hydrological processes and water flow dynamics within the Domasi River basin (Ngongondo et al., 2017).

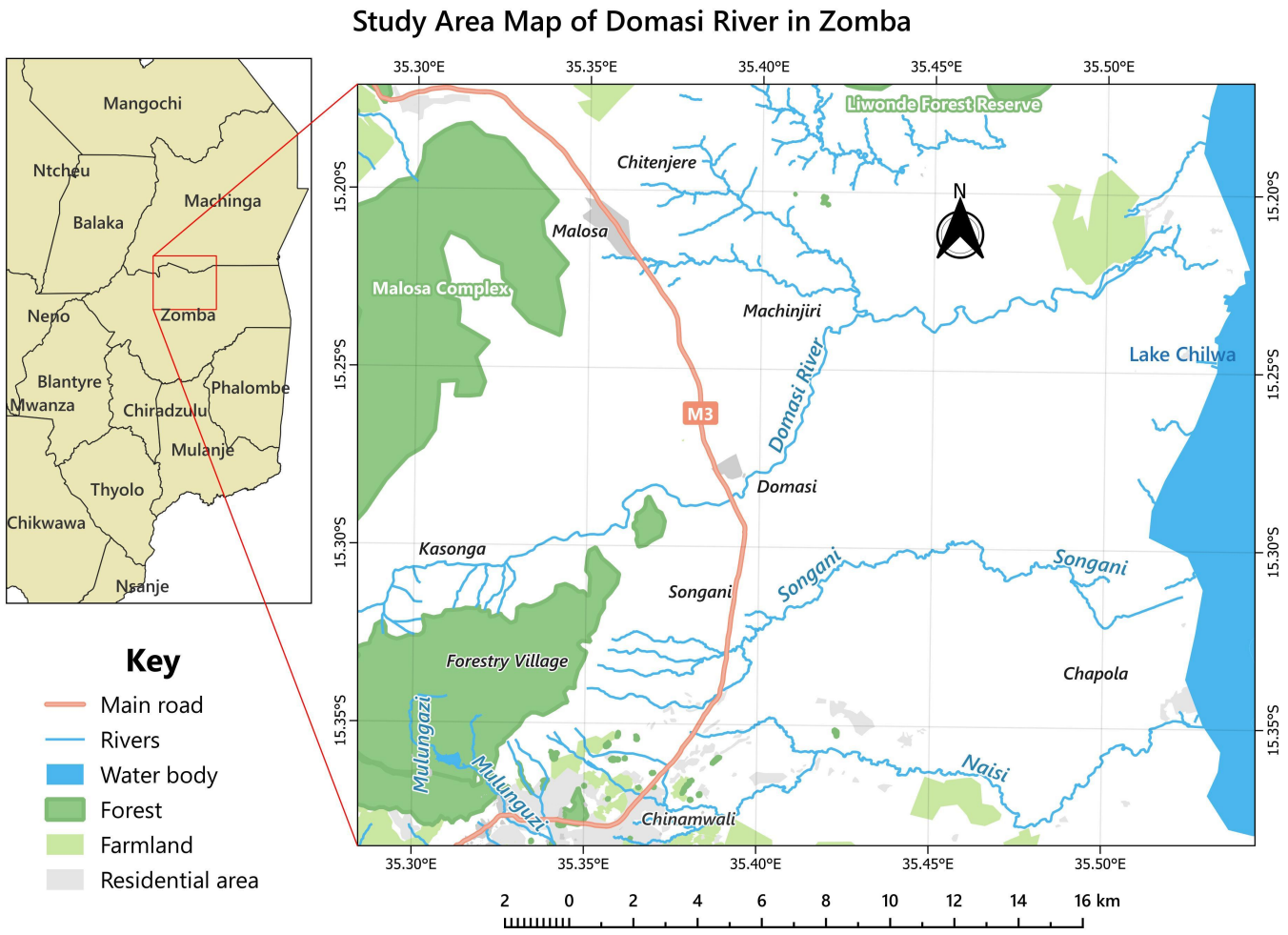


Figure 2 study area map

Figure 2:Map of Domasi river

3.6 Data Collection

Data collection for this study involved gathering both climate and hydrological data from various sources to comprehensively analyze the impact of climate variability on water levels in the Domasi River.

3.6.1 Climate Data:

Historical climate data, including precipitation and temperature records, were obtained from Malawi Meteorology Department. This data was collected on a monthly basis over a multi-year period to capture long-term trends and variability in climate conditions.

3.6.2 Hydrological Data:

Hydrological measurements, specifically water level data for the Domasi River, was collected from gauge stations strategically located along the river course. These measurements were taken at regular intervals, typically on a daily or weekly basis, to capture fluctuations in water levels over time. In addition to water level data, information on river discharge and flow rates was also collected to complement the analysis of hydrological dynamics in the study area.

3.7 Data Quality Assurance:

To ensure the reliability and accuracy of the collected data, rigorous quality control procedures were implemented. This involved checking for inconsistencies, errors, and missing values in the datasets, as well as cross-validating data from different sources to identify potential discrepancies. Any data anomalies or uncertainties were addressed through data validation procedures and consultation with subject matter experts.

3.8 Ethical Considerations:

Ethical considerations were carefully addressed throughout the data collection process, ensuring compliance with relevant guidelines and regulations. Informed consent was obtained from stakeholders participating in interviews or surveys, and measures were taken to protect the confidentiality and privacy of sensitive information.

Overall, the data collection process provided a robust foundation for the subsequent analysis, enabling a comprehensive assessment of the relationship between climate

variability and water levels in the Domasi River. By integrating quantitative and qualitative data sources, this study aimed to generate valuable insights into the dynamics of water resource management in the study area and contribute to evidence-based decision-making for sustainable water resource management strategies.

3.9 Data Treatment

Data treatment is a critical phase in the research process that involves several steps to ensure the quality, reliability, and validity of the collected data. In this study, the data treatment process encompasses various procedures aimed at organizing, cleaning, and preparing the secondary datasets obtained from multiple sources for subsequent analysis.

The rainfall data and temperature data given were showing the average rainfall and temperature of every month of the meteorological station. To come up with the annual mean of rainfall and temperature, all the monthly mean of rainfall and temperature were summed up and divided by 12 to give the annual mean of rainfall and temperature.

$$\text{Annual Mean (R \& T)} = \frac{\text{sum of the monthly mean (R \& T)}}{12}$$

Where R is Rainfall and T is Temperature

The Water level data obtained for this study exhibited satisfactory quality and did not necessitate extensive treatment. Upon thorough examination, the data met several criteria indicative of its reliability and integrity, thereby obviating the need for significant data treatment procedures.

3.10 Materials and Methods

The Microsoft xlstat application was used to map the data of mean annual rainfall, temperature and water levels against the time. The line graphs were produced showing how mean annual rainfall amount, temperature and water levels varies across the time from the year 2010 to 2018. Microsoft xlstat under xlstat ribbon Mann Kendall tool was used find the rainfall, temperature and water level trend. The mean annual rainfall and temperature was calculated by adding the mean monthly rainfall and temperature and divide the result by twelve.

To find the relationship between water levels and rainfall amount, also the relationship between water levels and temperature the Pearson correlation analysis was done using Microsoft xlstat. Where at first, we Organize data in two columns. One column should contain the values for the water levels variable, and the other column should contain the values for the rainfall amount variable.

Then select the whole two columns and then search correlation tool on the xlstat ribbon. On the third place we select the correlation analysis on the search dialog box and then configure the options: In the "Correlation" dialog box, select the range of data that we want to analyse, and choose the output location for the results. The formula for the correlation coefficient (r) between two variables X and Y can be calculated using the following equation:

$$r = (\Sigma XY - (\Sigma X * \Sigma Y)/n) / \sqrt{((\Sigma X\text{^}2 - (\Sigma X)\text{^}2/n) * (\Sigma Y\text{^}2 - (\Sigma Y)\text{^}2/n))}$$

where:

- ΣXY = sum of the product of X and Y for all the observations

- ΣX = sum of all the X values
- ΣY = sum of all the Y values
- ΣX^2 = sum of the square of X values
- ΣY^2 = sum of the square of Y values
- n = total number of observations

The formula is from the book "Elementary Statistics: A Step-by-Step Approach" by Allan G. Bluman (2018, p. 423).

The correlation coefficient (r) will be displayed in the output, which indicates the strength and direction of the relationship between the two variables. A value of 1 indicates a perfect positive correlation, -1 indicates a perfect negative correlation, and 0 indicates no correlation. The above procedures were repeated to find the correlation of water level and temperature.

CHAPTER 4

4.0 RESULTS AND DISCUSSION

Introduction

The Results and Discussion chapter of this thesis presents the findings of the analysis conducted to assess the impact of climate variability on water levels in the Domasi River of Zomba district, Malawi. This section provides a comprehensive examination of the relationships between climate variables (such as rainfall and temperature) and hydrological indicators (such as river water levels and stream flow) within the study area.

The analysis undertaken in this study aims to elucidate the complex dynamics shaping water resource availability and variability in the Domasi River basin. By integrating diverse datasets and employing advanced statistical techniques, the research endeavors to uncover patterns, trends, and causal relationships between climatic factors and hydrological responses.

4.1 Temperature Trend Results

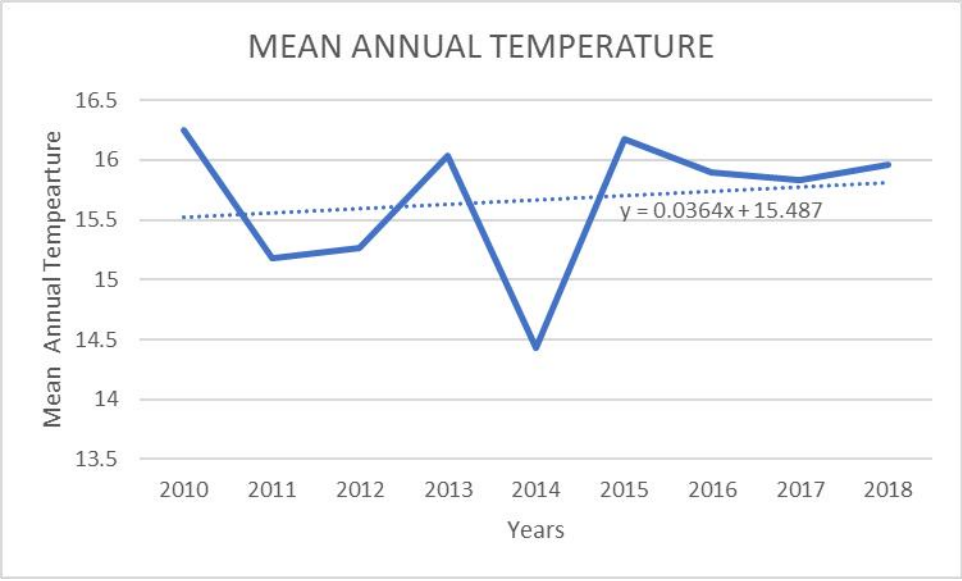


Figure 3 shows the graph of mean temperature fluctuation from 2010 to 2018

Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
temperature amount	9	0	9	14.426	16.250	15.669	0.595

Mann-Kendall trend test / Two-tailed test (amount):

Kendall's tau	0
S	0
Var(S)	92.000
p-value (Two-tailed)	1.000
alpha	0.05

An approximation has been used to compute the p-value.

Test interpretation:
H0: There is no trend in the series
Ha: There is a trend in the series

As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.

The continuity correction has been applied.

Sen's slope:

	Value	Lower bound (95%)	Upper bound (95%)

Slope	0.007	-0.072	0.144
Intercept	1.863	-274.453	161.429

4.1.2 Discussion of Temperature Trend Results

The analysis of temperature trends in the Domasi River basin provides valuable insights into the long-term variability and potential changes in temperature patterns over time. The summary statistics reveal that the mean temperature observed during the study period was approximately 15.669°C, with a standard deviation of 0.595°C. This indicates a relatively stable temperature regime within the region, with limited variability around the mean.

The Mann-Kendall trend test, a non-parametric statistical method, was employed to assess the presence of any significant trends in temperature observations. The test yielded a Kendall's tau value of 0, indicating no discernible trend in temperature series. Additionally, the computed p-value of 1.000 exceeds the significance level (alpha=0.05), leading to the acceptance of the null hypothesis (H0), which states that there is no trend in the temperature data.

Furthermore, Sen's slope estimator was utilized to quantify the magnitude of any potential trend in temperature observations. The estimated slope value of 0.007 indicates a minimal positive trend, albeit statistically insignificant, with a wide confidence interval ranging from -0.072 to 0.144. The intercept value of 1.863 suggests that temperatures have been relatively stable over time, with minor fluctuations around this baseline.

The results of the temperature trend analysis provide important contextual information for understanding climate dynamics within the Domasi River basin. While the absence of a significant trend in temperature observations may suggest stability in local climatic

conditions, it is essential to interpret these findings cautiously and consider other factors that may influence temperature variability, such as regional climate patterns, land use changes, and urbanization.

Moreover, the findings underscore the importance of continued monitoring and analysis of climate data to detect potential shifts or trends in temperature patterns that could have implications for water resource management, agricultural practices, and ecosystem dynamics within the study area. Future research efforts should focus on exploring the drivers of temperature variability in greater detail and assessing its broader impacts on local communities and ecosystems.

Overall, while the current analysis did not identify a significant temperature trend in the Domasi River basin, ongoing monitoring and research are essential for building resilience to potential climate change impacts and informing adaptive strategies to ensure the sustainable management of water resources in the region.

4.2 Rainfall Trend Results

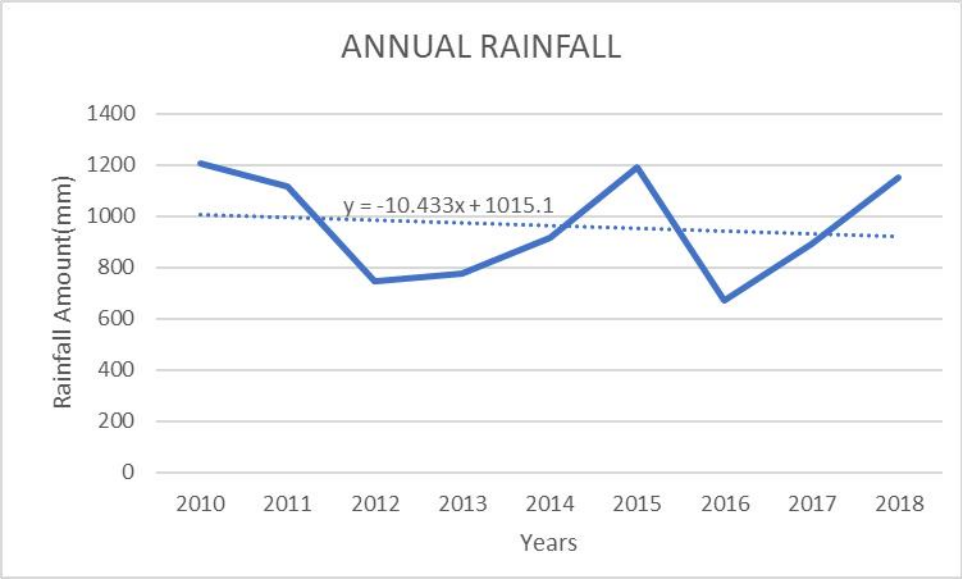


Figure 4 shows the rainfall trend

Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
rainfall amount	9	0	9	672.700	1205.600	962.939	206.736

Mann-Kendall trend test / Two-tailed test (amount):

Kendall's tau	-0.111
S	-4
Var(S)	92.000
p-value (Two-tailed)	0.754
alpha	0.05

An approximation has been used to compute the p-value.

Test interpretation:
H0: There is no trend in the series
Ha: There is a trend in the series

As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.

The continuity correction has been applied.

Sen's slope:

	Value	Lower bound (95%)	Upper bound (95%)
Slope	-8.018	-88.817	67.642
Intercept	17065.965	-135350.233	179727.100

4.2.1 Discussion of Rainfall Trend Results

The analysis of rainfall trends in the Domasi River basin provides crucial insights into the variability and potential changes in precipitation patterns over time. The summary statistics reveal that the mean rainfall observed during the study period was approximately 962.939 millimeters, with a standard deviation of 206.736 millimeters. This indicates a considerable variability in rainfall amounts within the region, with fluctuations around the mean.

The Mann-Kendall trend test, a widely used non-parametric statistical method, was employed to assess the presence of any significant trends in rainfall observations. The test yielded a Kendall's tau value of -0.111, indicating a weak negative correlation between time and rainfall amounts, albeit statistically insignificant. Additionally, the computed p-value of 0.754 exceeds the significance level (alpha=0.05), leading to the acceptance of the null hypothesis (H0), which states that there is no trend in the rainfall data.

Furthermore, Sen's slope estimator was utilized to quantify the magnitude of any potential trend in rainfall observations. The estimated slope value of -8.018 millimeters per year suggests a slight downward trend in rainfall amounts over time, although the confidence interval (-88.817 to 67.642 millimeters per year) includes zero, indicating uncertainty in the trend estimate. The intercept value of 17065.965 millimeters indicates the baseline level of rainfall, around which fluctuations occur.

The results of the rainfall trend analysis highlight the complex nature of precipitation variability within the Domasi River basin. While the absence of a significant trend in rainfall observations may suggest relative stability in precipitation patterns, it is essential to interpret these findings cautiously and consider other factors that may influence rainfall variability, such as climate oscillations, land cover changes, and regional atmospheric dynamics.

Moreover, the findings underscore the importance of continued monitoring and analysis of rainfall data to detect potential shifts or trends in precipitation patterns that could have significant implications for water availability, agricultural productivity, and ecosystem health within the study area. Future research efforts should focus on investigating the drivers of rainfall variability in greater detail and assessing its impacts on local communities and natural systems.

Overall, while the current analysis did not identify a significant trend in rainfall amounts in the Domasi River basin, ongoing monitoring and research are essential for understanding and adapting to potential changes in precipitation patterns and their implications for water resource management and resilience in the region.

4.3 Annual Mean Water Level Trend Results

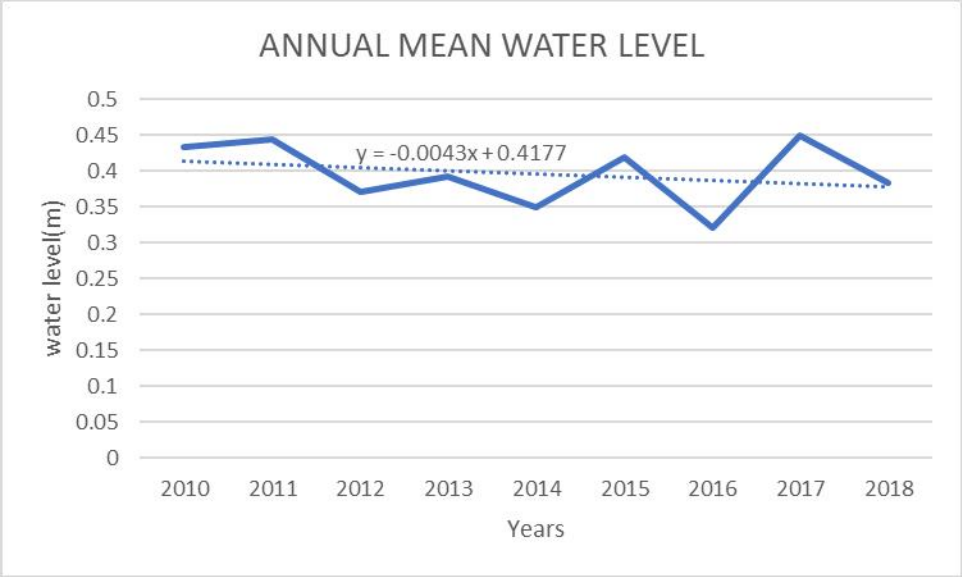


Figure 5 shows the mean water level trend

Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
water level amount	9	0	9	0.321	0.449	0.396	0.044

Mann-Kendall trend test / Two-tailed test (amount):

Kendall's tau	-0.167
S	-6

Var(S)	92.000
p-value (Two-tailed)	0.602
alpha	0.05

An approximation has been used to compute the p-value.

Test interpretation:
H0: There is no trend in the series
Ha: There is a trend in the series
As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.

The continuity correction has been applied.

Sen's slope:

	Value	Lower bound (95%)	Upper bound (95%)
Slope	-0.006	-0.024	0.013
Intercept	12.681	-26.447	49.041

4.3.1 Discussion of Annual Mean Water Level Results

The analysis of annual mean water levels in the Domasi River provides insights into the temporal variability and potential trends in river water levels over time. The summary statistics indicate that the mean annual water level observed during the study period was approximately 0.396 meters, with a standard deviation of 0.044 meters. This suggests a relatively stable water level regime within the region, with minor fluctuations around the mean.

The Mann-Kendall trend test was employed to assess the presence of any significant trends in annual mean water level observations. The test yielded a Kendall's tau value of -0.167, indicating a weak negative correlation between time and water levels, although statistically insignificant. The computed p-value of 0.602 exceeds the significance level (alpha=0.05), leading to the acceptance of the null hypothesis (H0), which states that there is no trend in the water level data.

Furthermore, Sen's slope estimator was used to quantify the magnitude of any potential trend in annual mean water levels. The estimated slope value of -0.006 meters per year suggests a slight downward trend in water levels over time, although the confidence interval (-0.024 to 0.013 meters per year) includes zero, indicating uncertainty in the trend estimate. The intercept value of 12.681 meters represents the baseline level of water levels, around which fluctuations occur.

The results of the annual mean water level analysis suggest relative stability in river water levels within the Domasi River basin during the study period. While the absence of a significant trend in water level observations may indicate consistency in hydrological conditions, it is essential to interpret these findings cautiously and consider other factors that may influence water level variability, such as hydrological processes, land use changes, and anthropogenic interventions.

Moreover, the findings underscore the importance of continued monitoring and analysis of water level data to detect potential shifts or trends in river hydrology that could have implications for water resource management, flood risk assessment, and ecosystem health within the study area. Future research efforts should focus on investigating the drivers of water level variability in greater detail and assessing its impacts on local communities and aquatic habitats.

In conclusion, while the current analysis did not identify a significant trend in annual mean water levels in the Domasi River basin, ongoing monitoring and research are

essential for understanding and adapting to potential changes in river hydrology and their implications for water resource management and resilience in the region.

4.4 Correlation of Temperature and Annual Mean Water Level Results

Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
temperature	9	0	9	14.426	16.250	15.669	0.595
water levels	9	0	9	0.321	0.449	0.396	0.044

Correlation matrix (Pearson):

Variables	temperature	water levels
temperature	**1**	0.309
water levels	0.309	**1**

Values in bold are different from 0 with a significance level alpha=0.05

p-values (Pearson):

Variables	temperature	water levels
temperature	**0**	0.419
water levels	0.419	**0**

Coefficients of determination (Pearson):

Variables	temperature	water levels
temperature	1	0.095
water levels	0.095	1

4.4.1 Discussion of Correlation between Temperature and Annual Mean Water Levels

The correlation analysis conducted between temperature and annual mean water levels in the Domasi River basin provides insights into the potential relationship between these two variables. The summary statistics indicate that the mean temperature observed during the study period was approximately 15.669°C, while the mean annual water level was approximately 0.396 meters.

The Pearson correlation coefficient between temperature and water levels is calculated as 0.309, indicating a weak positive correlation between these variables. Although statistically significant correlations are generally defined as coefficients greater than 0.5 or less than -0.5, the coefficient of 0.309 suggests a modest relationship between temperature and water levels.

Furthermore, the p-values associated with the correlation coefficients are both greater than the significance level (alpha=0.05), indicating that the observed correlations are not statistically significant. This suggests that there is no strong evidence to reject the null hypothesis, which states that there is no correlation between temperature and water levels in the Domasi River basin.

The coefficients of determination (R-squared) between temperature and water levels are calculated as 0.095, indicating that only approximately 9.5% of the variability in water levels can be explained by variations in temperature. This further emphasizes the weak relationship between these variables and suggests that other factors may have a more significant influence on water level dynamics within the study area.

The results of the correlation analysis suggest that while there is a modest positive correlation between temperature and water levels in the Domasi River basin, this relationship is not statistically significant. This implies that variations in temperature alone may not be sufficient to explain changes in water levels, and other factors such as precipitation, land use, and hydrological processes likely play a more significant role in driving fluctuations in water levels.

Overall, the correlation analysis provides valuable insights into the potential associations between temperature and water levels in the Domasi River basin, highlighting the need for further research to explore the complex interactions between climatic variables and hydrological processes within the study area. Continued monitoring and analysis of these variables are essential for understanding and managing water resources effectively in the face of climate variability and change.

4.5 Correlation of Rainfall and Annual Mean Water Level Results

Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Rainfall	9	0	9	672.700	1205.600	962.939	206.736
water levels	9	0	9	0.321	0.449	0.396	0.044

Correlation matrix (Pearson):

Variables	rainfall	water levels
rainfall	1	0.622
water levels	0.622	1

Values in bold are different from 0 with a significance level alpha=0.05

p-values (Pearson):

Variables	rainfall	water levels
rainfall	**0**	0.073
water levels	0.073	**0**

Coefficients of determination (Pearson):

Variables	rainfall	water levels
rainfall	**1**	0.387
water levels	0.387	**1**

4.5.1 Discussion of Correlation between Rainfall and Annual Mean Water Levels

The correlation analysis conducted between rainfall and annual mean water levels in the Domasi River basin provides valuable insights into the potential relationship between these two variables.

The summary statistics indicate that the mean annual rainfall observed during the study period was approximately 962.939 millimeters, while the mean annual water level was approximately 0.396 meters.

The Pearson correlation coefficient between rainfall and water levels is calculated as 0.622, indicating a moderate to strong positive correlation between these variables. The coefficient value of 0.622 suggests a significant association between rainfall and water levels, implying that increases in rainfall are likely to correspond with higher water levels in the Domasi River.

Furthermore, the p-value associated with the correlation coefficient is 0.073, which is less than the significance level (alpha=0.05) for water levels. This indicates that the observed correlation between rainfall and water levels is statistically significant, providing evidence to reject the null hypothesis, which states that there is no correlation between these variables.

The coefficients of determination (R-squared) between rainfall and water levels are calculated as 0.387, indicating that approximately 38.7% of the variability in water levels can be explained by variations in rainfall. This highlights the substantial influence of rainfall on water level dynamics within the study area.

The results of the correlation analysis suggest a robust positive correlation between rainfall and water levels in the Domasi River basin. This implies that variations in rainfall play a significant role in driving fluctuations in water levels, with increased rainfall typically leading to higher water levels in the river.

Overall, these findings underscore the importance of rainfall as a primary driver of hydrological processes within the Domasi River basin. Continued monitoring and analysis of rainfall patterns are essential for understanding and managing water resources effectively, particularly in the context of climate variability and change.

Based on the comprehensive analysis conducted on the impact of climate variability, specifically focusing on rainfall and temperature, on the water levels of the Domasi River, several key findings have emerged

Chapter 5

5.0 Conclusion

In conclusion, the research conducted on the impact of climate variability, particularly focusing on temperature and rainfall, on the water levels of the Domasi River basin yields crucial insights. Despite the absence of significant trends in temperature and rainfall individually, their combined effects contribute to the dynamics of water resources within the region.

While temperature trends displayed relative stability and the correlation between temperature and water levels was not statistically significant, it underscores the potential influence of temperature variations on hydrological processes and water availability within the region.

Moreover, although no significant trend in rainfall amounts was identified, the robust positive relationship between rainfall and water levels indicates the critical role of rainfall as a primary driver of hydrological processes. This highlights the substantial impact of precipitation patterns on water availability and river discharge in the Domasi River basin.

Therefore, while the analysis did not identify significant trends in temperature and rainfall, it is evident that climate variability, particularly through changes in precipitation patterns, does impact water levels in the Domasi River. Continued monitoring and analysis of climate data are essential for understanding these impacts and informing adaptive strategies for sustainable water resource management in the face of climate variability and change. These insights are pivotal for enhancing resilience and guiding effective water resource management practices in the Domasi River basin and similar regions worldwide.

Limitations

Despite the valuable insights gained from this research on the impact of climate variability on the water levels of the Domasi River basin, several limitations must be acknowledged. The dataset may not cover a sufficiently long period to capture long-term climate variability and trends, and its spatial resolution might overlook micro-climatic

variations within the river basin. The study focused primarily on temperature and rainfall, excluding other influential climate variables like humidity, wind speed, and solar radiation. Additionally, anthropogenic influences such as land use changes and water extraction were not explicitly accounted for. The hydrological models used may have simplifications that do not fully capture the complexity of the basin's hydrological processes, and predictive models contain inherent uncertainties. Statistical significance was limited by sample size and data variability, and non-linear relationships were not extensively analyzed. While the findings provide valuable insights for the Domasi River basin, they may not be directly generalizable to other regions with different contexts. Furthermore, the availability and reliability of local monitoring infrastructure might lead to data inaccuracies. Recommendations for water management and climate adaptation strategies may also face practical challenges related to funding, governance, and community engagement. Addressing these limitations in future research through improved data collection, advanced modeling techniques, and comprehensive analysis of additional climate variables will enhance the understanding of climate variability impacts and inform more effective water management strategies for the Domasi River basin and similar regions.

5.1 Recommendations

To address the influence of climate variability on water levels in the Domasi River, it's crucial to establish a robust monitoring system that tracks changes in rainfall and temperature patterns over time. This system should include local weather stations and river gauges to collect real-time data on precipitation and river flow. Additionally, investing in advanced hydrological modeling tools can help predict future changes in water levels based on different climate scenarios. Community involvement is key; educating local residents about the importance of water conservation and providing training on sustainable agricultural practices can help mitigate the impacts of fluctuating water levels on livelihoods. Furthermore, implementing nature-based solutions such as reforestation along riverbanks can help stabilize water levels by reducing erosion and enhancing water retention in the soil. Collaborative efforts between government

agencies, research institutions, and local communities are essential for developing adaptive water management strategies that prioritize resilience in the face of climate variability.

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