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Assessing the effect of Climate Change on Water Resources and Hydrologic Cycles in Mkushi District (2000 – 2024): Trends, Risks and Adaptation Strategies

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ABSTRACT

The research was conducted in Chibefwe Ward of Mkushi District – Central Province. Its major objective was to assess the effects of climate change on water resources and hydrologic cycles and establish the trends, risks and adaptation strategies from 2000 and 2024. The study used a mixed methods approach and a sample of 60 ward residents was used to collect data from the field. Both quantitative and qualitative data from the respondents were collected using questionnaires. A statistical package of SPSS and Microsoft Office Excel was used in analyzing responses from the ward residents. The data analysis was done using statistical tools such as percentages, frequencies, and means. Furthermore, a Chi square test was conducted to determine whether there is an association between the described temperature and precipitation changes and climate related shocks (droughts or floods). Taking climate variations, Satellite Imagery and stakeholders' views into consideration, this study would help to explore the interrelationship between climate change and water resources in an all-around way. The findings indicate that the water availability, quality, distribution, and utilization are impacted by climate change, which has important implications for the local society and ecosystem. The key adaptation mechanisms include watershed development, water saving, and community level adaptation. This study has relevance for evidence-based interventions in policies and practices of sustainable groundwater management in Mkushi District. The results in this study could provide implications for the policy making and practice for climate risk-based water management which would reduce the climatic vulnerability of local communities and ecosystems. The findings of the study may have implications for water resource governance elsewhere where same conditions exist, and the necessity for an anticipatory adaptation and mitigation measures are being underscored.

1. Introduction

Climate change is one of the biggest adverse phenomena facing mankind today. Its effects have been cross-cutting in all sectors of the national economies. In low income countries, climate change has exacerbated the poverty levels of vulnerable communities due to the countries' weak adaptive capacities and inadequate climate change awareness for adaptation. The prolonged drought has resulted in low yields of crops especially to small scale farmers. Shortage of water has also impacted crop yields and livestock production due to moisture stress and shortage of pasture for animal grazing (IPCC, 2021)

Climate change is possibly the most significant environmental challenge of our time and poses serious threats to the sustainable development of the emerging economies in developing countries. Global climate change will impact on food and water security in a significant but highly uncertain manner in the coming years (IPCC, 2018). There is overwhelming evidence that Sub-Saharan Africa like other regions in Africa will bear the consequences of climate change. The 2016 Zambia National Climate Change Policy notes that countries like South Africa, Lesotho, Swaziland, Namibia, Mozambique and Angola experienced a 0.6°C to 1°C increase in temperature resulting into increased occurrence of droughts, floods and epidemics (Ministry of National Development Planning, 2016). The 2000 flood in Mozambique affected 2 million people, caused 500 deaths, displaced 329,000 people, while 1 million people were affected by food insecurity. Furthermore, the country recorded a reduced annual economic growth rate from 10 percent to 4 percent and crop destruction. The frequent occurrence of floods in Swaziland in 1984 caused widespread crop destruction, water contamination as well as property and infrastructure destruction. Similarly, the challenges for climate change in Zambia are substantial, due to its high dependence on climate sensitive natural resource sectors for food security, livelihoods and incomes (Ngoma et al, 2020).

It is inevitable that water scarcity will worsen, with demand outstripping supply in many countries with high population and economic growth, unless adaptation measures are implemented more widely that constrain and reduce rampant demand. Overarching the water crises is the looming threat of anthropogenic climate change which is believed to be the greatest threat facing Planet Earth. This threat extends naturally to water resources because of the climate driver, and the potential impacts on water scarcity. While there is no question that the planet is warming and that this will have impacts on the climate, clear evidence of impacts on drought and flood frequency and intensity in the presence of natural climatic variability remains elusive (Bouwman, 2023).

The dominant theme in water resources research is climate model-driven assessment of the impacts of climate change, with much less attention currently paid to water use efficiency which must be addressed if sustainable water resources management is to achieved. Against this background, a major issue is how to approach adaptation, given that water resource systems will become increasingly stressed in the future from a combination of socioeconomic pressures and climate variability/change. Firstly, there is the issue of whether to be proactive, and invest now in supply-side measures that can provide greater water security but which invite unsustainable depletion of our water resources, or to adopt a reactive or 'wait and see' approach. Making large and irreversible proactive investments in supply-side measures may not be either affordable or environmentally sustainable. On the other hand, demand-side measures are more incremental, and have much shorter time scales for implementation. They also provide a pathway to sustainability (CGE, 2021).

1.1 Statement of the problem

The Royal Society (2020) emphasize that any change in climate over time, whether due to natural variability or because of human activity is typically for decades or longer. On the other hand, water has become the main channel through which the effects of climate change are being felt. To put it simply, the UN (2019) estimates that the availability of water has become less and less predictable in most places, thereby increasing incidences of flooding, destruction of water points and sanitation facilities as well as contamination of water sources.

Zambia is already dealing with the early impacts of climate change. Every year since 2000, drought and floods have taken turns in destroying the livelihood options of the rural poor whose livelihood depends on a normally predictable rainfall pattern (Zambia Vulnerability Assessment Committee, 2004). Changes in climate patterns have a negative impact on the health and nutrition status of people and agricultural production. Society at large does not appear to be deeply concerned with global warming; as a result, it is not yet acting on the ever more urgent warming emanating from the science and advocacy communities. Despite encouraging signs, ignorance, disinterest, apathy, and opposition are still prevalent (Chisanga et al, 2018).

Climate – related warming of lakes and rivers has been observed over recent decades, with implications for freshwater ecosystems, such as changes in water salinity, water nutrient content, concentration of pesticides and other pollutants, salinization of groundwater, water chemistry and pH balance. With respect to fisheries and aquaculture, it has been projected that rising temperatures of around 1.5 to 2.0ºC will adversely affect fisheries. Subtle changes in key environmental variables such as temperature, salinity, wind speed and direction, ocean currents and strength of upwelling due to climate change could sharply alter the abundance, distribution and availability of fish populations. Climate change, particularly is reflected in reduced rainfall in many parts of Africa, would further compound the inability of the continent to meet people's demand for drinking water (IPCC, 2022).

1.2 Research objectives

1.2.1 General objective

The general objective of this research was to assess the effects of climate change on water resources and hydrologic cycles in Mkushi District including the trends, risks and adaptation strategies from the year 2000 – 2024.

1.2.2 Specific objectives

The following are the objectives that guided the study.

- Assess the main causes of climate change.
- Analyse the impact of climate change on water resources and highlight the effects of water resource and hydrologic cycle changes on local communities.
- Identify the necessary adaptation strategies.

1.3 Theoretical framework

The aim of the integrated impact assessment framework is to establish a consistent and comprehensive overview of the impact of climate change on a particular region or a particular system or sector, inclusive of the most important feedbacks between sectors. This is a major exercise. It can fail if a clear need or a firm commitment is lacking. It is best to start with an analysis of the system: Its components, its links and its issues. With such ambitious goals, it is essential to have clearly and firmly established a family of integrators. The purpose of integrators is to provide structure to the analysis. A clear structure is important because, to most of those involved, integrated analysis is something new. After the structure of the integrated analysis has been determined, a description is needed of the components, of the interactions between the components, particularly the inputs and outputs of each component, and of the type of analysis or model that would get one from the given inputs to the required outputs. Such analyses or models may be available. If so, these can be applied. Otherwise, these will have to be developed as part of the integration. Note that only at this stage does the full scope of the integrated analysis and the required resources become clear, so that only at this stage can the final work programme and budget be made. Physical, biological, and socio-economic studies, focusing on one sector or discipline, provide important information in their own right. In an Integrated Assessment, however, these activities also provide input to a new set of "clients" (integrators). The integrated analysis can be done in several ways, ranging between two extremes.

At the one extreme is soft-linking. At the other extreme is integrated modelling. Soft linking means that all component analyses are stand-alone, linked through input and output variables, joint scenarios, and combined results. Note that soft-linking does not imply lack of structure or coordination. Rather, each component analysis performs its task within strictly described boundary conditions. At the other extreme, integrated modelling combines all components into a single computer code, describing the entire system. Hard-linking of models lies between soft-linking and integration. Hard-linked models are part of a single computer code, but are recognizable as separate models and could in principle run in a stand-alone version. Integrated models, on the other hand, are no longer recognizable as separate entities and cannot run without the whole model. Soft-linking is the only way to include methods other than computer models. Soft-linking may be done by linking expert judgements in an expert panel (IPCC, 2018: IPCC, 2022).

1.4 Significance of the study

Full knowledge of the study would lead to major development, not only in Mkushi, but in Zambia at large. The study is so important that it shall lead to the development of adaptation strategies which will enable communities to adjust to climate change impacts on water resources and hydrologic cycle. In addition, local communities will be able to plan how best they can live through the changes in water availability.

2. Literature Review

2.1 Causes of climate change

Burning of fossil fuels, like oil, coal, and natural gas is adding CO2 to the atmosphere. The current level is the highest in the past 650,000 years. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (2015) concludes that most of the observed increase in the globally averaged temperature since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. According to Berbisi et al (2016), methane leakage from evolving petroleum systems: Masses, rates and inferences for climate feedback, the present-day warming trend has been attributed to an annual increase in the atmospheric methane concentration and CO2. On the other hand, only the sudden release of surface methane accumulations, formed over geological time scales, petroleum systems can influence climate (Environmental Protection Agency U.S., 2016).

Africa's contribution to climate change from fossil energy and transport sources in the global context is only worth a foot note. The main sources are power generation from coal in South Africa (approx. 350 million tons) and gas flaring in the Niger Delta (approx. 100 million tons). The annual per capita emissions of CO2 in sub Saharan Africa are put at approximately one ton. As a comparison, in Germany alone the number is approximately ten times as high (IPCC, 2014). The primary driver of climate change is the emission of greenhouse gases (GHGs). In Zambia, climate change is caused by deforestation which is the principal source of Zambia's GHG emissions, with Land-Use Change and Forestry accounting for 59% of total emissions in 2021 (WWF Zambia, 2025).

2.2 Impact of climate change on water resources and hydrologic cycles and effects of water resource and hydrologic cycle changes on local communities.

Water security for fulfilling social and ecological demands remains a key challenge in different parts of the world in the face of climate uncertainties. Goyburo et al (2023) assessed the potential water scarcity under socioeconomic and climate change scenarios and they suggested that a reduction in population growth and improving agricultural water use efficiency may reduce the demand and suppress the level of water scarcity. Risks in physical water availability and water-related hazards will continue to increase by the mid- to long-term in all assessed regions, with greater risk at higher global warming levels. Groundwater availability is threatened by climate change. At global warming of 4°C, approximately 10% of the global land area is projected to face increases in both extreme high and low river flows in the same location, with implications for planning for all water use sectors (Wang and Liu, 2023).

Studies suggest a general broadening of the wet and dry regions. In a substantial part of the wet regions (the high latitudes and the monsoonal regions), water availability is projected to increase. The increase in rainfall and evapotranspiration is projected to significantly enlarge the flood area in central North America, north of South America, Australia, and Asia, including the north of India, while the south of India, southern Africa, and southern parts of South America may undergo severe drought. A less severe precipitation increase in excess of evapotranspiration is closer to the edge of the flood in Western Europe, north eastern Asia, and northern regions of Africa, which demonstrates a tendency for regional climate change to persist. Additional water in excess of the local demand can help supply enough water for irrigated agriculture and mitigate problems of future water shortages. For almost all areas, especially developing countries, damage in some facet caused by increasing water resources is projected (Muthoni, 2025).

The societal implications are probably the hidden part of the iceberg, when we consider the hydrologic impacts of climate change. Fresh water is vital for human communities. It is essential for agriculture, domestic use, industry, construction, ecology (wildlife and aquatic life), and environment (Viola, Caracciolo & Deidda, 2021). Hence, the decline of fresh water is detrimental for human activities and the sustainability of communities and ecosystems. In order to accommodate for the increasing water demand, reservoirs and dams are frequently built. In regions with lesser potential of surface water harvesting, pumping groundwater has become an option. However, most of these compensating strategies seem to suffer from poor long-term planning. Consequently, groundwater depletion, streamflow alteration, and low reservoirs refill are becoming more frequent, inciting more competition for water resources (UNESCO, 2020: Yang, Yang and Xia, 2021). The hydrological systems of Africa exhibit extraordinary complexity and pronounced sensitivity to climate variability, presenting immediate water security challenges and longterm environmental changes. It has been further indicated by Global assessments that Africa's water resources are highly vulnerable to the combined pressures of climate change and rapid population growth (Adeyeri, 2025).

The southern parts of the country are projected to be more affected by climate change than are the northern parts and on average, rainfall is expected to be more variable, and rainy seasons are likely to shift (Ngoma et al, 2019; Ngoma et al. 2020). In addition, over reliance on rain-fed agriculture makes them particularly vulnerable to increased occurrence of climate-induced shocks such as floods, drought, prolonged dry spells and extreme temperatures. Diversity of household crop production is limited, with around 80% of households cultivating three or fewer crops. These largely, have made farmers (particularly female farmers who, in most cases are not able to quickly adapt to the changing environment) livelihoods more fragile, further compromising their adaptive capacity to climate-induced shocks and subsequently reducing their resilience to climate risks. (GRZ, 2016).

2.3 Necessary adaptation strategies.

Water managers are accustomed to adapting to changing circumstances, many of which can be regarded as analogues of future climate change, and a wide range of adaptive options have been developed. Water management is evolving continually, and this evolution will affect the impact of climate change in practice. Climate change is likely to challenge existing water management practices, especially in countries with less experience in incorporating uncertainty into water planning. The generic issue is incorporation of climate change into the types of uncertainty traditionally treated in water planning. Integrated water resources management (IWRM) (Kindler, 2000) increasingly is regarded as the most effective way to manage water resources in a changing environment with competing demands. Climate change must be considered as a factor in the development of improved management techniques. Adopting integrated water resources management will go a long way toward increasing the ability of water managers to adapt to climate change (Arnell et al, 2001). Africa should consider nature-based solutions, particularly Ecosystem-based Adaptation (EbA), offer promising pathways to climate resilience by leveraging ecological processes to mitigate water stress. EbA can provide multiple benefits, including mitigation, adaptation responses, and enhanced resilience, while simultaneously addressing climate change pressures and other environmental drivers. Beyond urban settings, restoring natural ecosystems such as mangroves, salt marshes, and coral reefs also offers cost-effective coastal protection and supports biodiversity. (Adeyeri, 2025). The climate change spending proposed in the water sector is in line with proposals made in the Zambia economic study and includes expansion of the hydro-meteorological monitoring network as well as investment to improve and expand water and sanitation infrastructure. The key question is whether the institutional capacity can be built to implement these plans, for example whether Integrated Water Resource Management can be operationalised as proposed (GRZ, 2023).

3. Materials and Methods

3.1 Research design

The researcher employs a mixed-methods approach, integrating both qualitative and quantitative research designs to gain a comprehensive understanding of how climate change impacts water resources and hydrologic cycles in Mkushi District.

3.2 Target population

The study targets Mkushi residents of Chibefwe ward. Chibefwe ward has a population of 47 124 people, hence, 47 124 was the target population. Secondly, it will be easier for the researcher to approach the residents since the researcher resides in the same district and ward. For the study to be effective, the data collected was sampled by stratified random sampling in order to have a comprehensive research study.

3.3 Sampling design

A stratified random sampling is used to select the respondents from Mkushi local communities. The characteristic that was used to create strata in this research was age.

3.4 Sample size and sampling techniques

To determine the sample size, I use the Cochran's formula. The notation is such that: n is the desired sample size, N is the population size per stratum, e (being ±10%) as Margin of error, the Confidence Level is 90%

The sample size was determined using a margin of error and confidence level appropriate for the study. It was calculated based on the estimated population size of each stratum. Therefore, the researcher collects data from a sample of 60 respondents.

3.5 Data collection methods

The research employed a mixed-methods approach, integrating both qualitative and quantitative research methods. Questionnaires were the major source of primary data used in the study. Secondary data were collected from Satellite imagery.

3.6 Data analysis

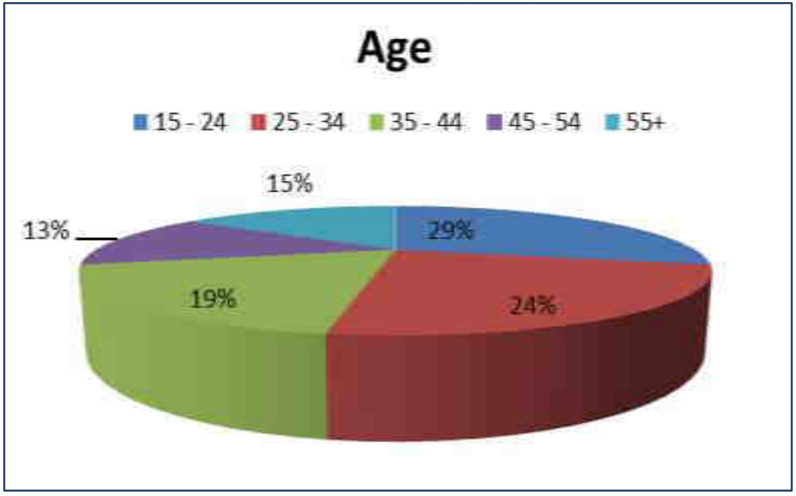
The results were subjected to statistical analysis using excel. Data were analyzed using Statistical Package of Social Sciences (SPSS). This formed the basis for interpreting the variables. However, a Chi – square test was used to determine whether there was a significant association between described temperature and precipitation changes and climate related shocks (floods or droughts) or not.

4. Results and Discussion

4.1 Demographic characteristics of respondents

This section presents Demographic characteristics of the respondents of the questionnaires. The Demographic characteristics of the respondents include age, sex, and number of years lived in Mkushi.

Chart 4.1.1: Summary of age



The results above indicate that 17 (29%) respondents were between the age of 15 and 24, 14 (24%) were between 25 and 34, 11 (19%) were between 35 and 44, 8 (13%) were between 45 and 54 while 9 (15%) were 55 years and above.

Table 4.1.2: Tabulation of Sex

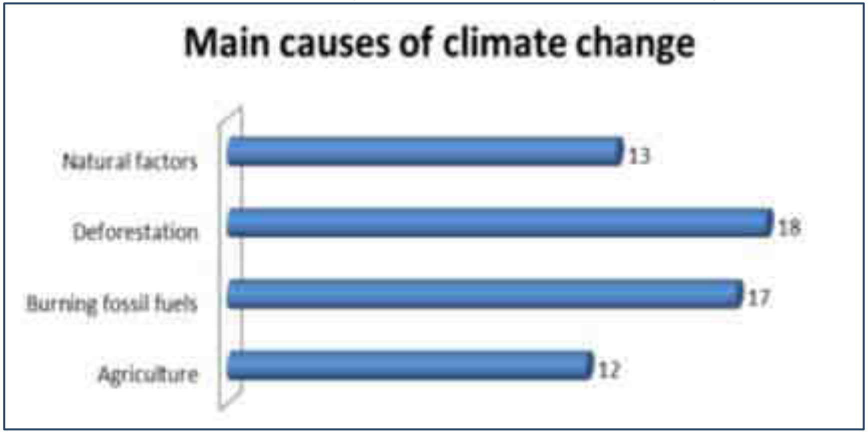
Sex				
Gender	Frequency	Percent	Valid Percent	Cumulative Percent
Female	31	51.7	51.7	51.7
Male	29	48.3	48.3	100.0
Total	60	100.0	100.0	

The results above indicate that 31 respondents were female and represent 51.7% while 48.3% represents males who were only 29 out of 60 respondents.

4.2 Causes of climate change

The results below show the main causes of climate change according to the respondents. 20% (12) of the respondents showed agriculture as the main cause of climate change, 28.33% (17) showed burning fossil fuels as the main cause, 30% (18) showed deforestation as the main cause and 21.67% (13) showed natural factors as the main causes of climate change.

Chart 4.2.1: Summary of main causes of climate change



Source: Field data (2025)

Effects of climate change on water resources and hydrologic cycles and effects of water resource and hydrologic cycle changes on local communities.

Table 4.3.1: Tabulation of increased or decreased temperature

Increase Or Decrease In Temperature	Frequency	Percent	Valid Percent	Cumulative Percent
Not sure	1	1.7	1.7	1.7
Decrease	2	3.3	3.3	5.0
Increase	57	95.0	95.0	100.0
Total	60	100.0	100.0	

Source: Field data (2025)

The results above show that 1.7% of the respondents were not sure whether there is an increase or decrease in temperature, 3.3% of the respondents indicated that there is a decrease while 95% indicated that there is an increase.

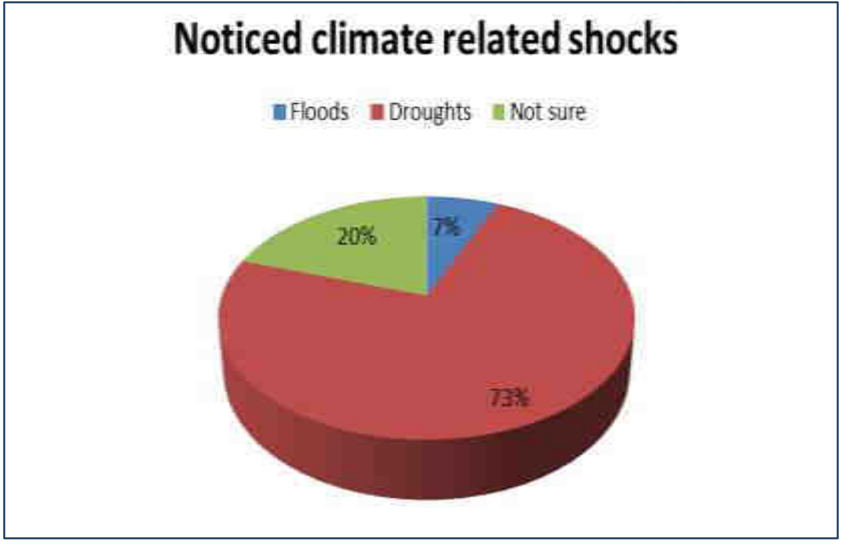
Table 4.3.2: Tabulation of noticed climate related shocks

Have you noticed any droughts or floods (climate related shocks) in the past 10 to 20 years?				
	Frequency	Percent	Valid Percent	Cumulative Percent
No	12	20.0	20.0	20.0
Yes	48	80.0	80.0	100.0
Total	60	100.0	100.0	

Source: Field data (2025)

Findings above indicate whether the respondents noticed droughts or floods in the past 10 to 20 years. 20% of the respondents did not notice floods or droughts in the past 10 to 20 years while 80% noticed droughts or floods in the past 10 to 20 years.

Chart 4.3.3: Summary of the exact climate related shocks that respondents noticed



Source: Field data (2025)

Findings specify the number of respondents who noticed droughts, floods and those who did not notice any of the climate related shocks. 20% of the respondents noticed neither floods nor droughts, 6.67% noticed floods while 73.33% noticed droughts.

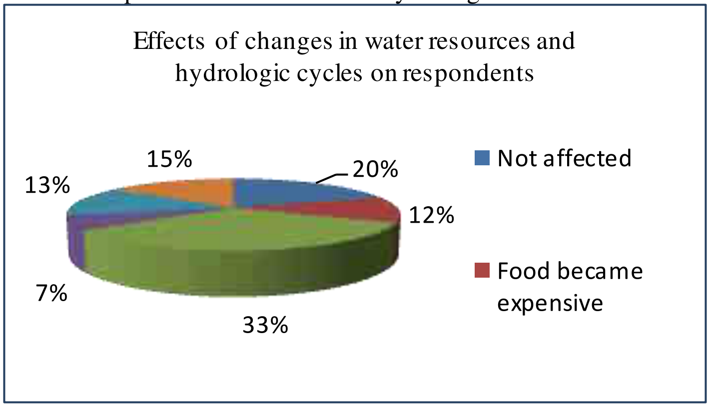
Table 4.3.4: Tabulation of noticed reduction in river flow, lake levels or groundwater levels

Have you noticed a reduction in river flow, lake levels or groundwater levels?				
	Frequency	Percent	Valid Percent	Cumulative Percent
No	7	11.7	11.7	11.7
Yes	53	88.3	88.3	100
Total	60	100	100	

Source: Field data (2025)

Results above indicate whether respondents noticed a reduction in river flow, lake levels or groundwater levels. 11.7% did not notice a reduction while 88.3% noticed a reduction in river flow, lake levels or groundwater levels.

Chart 4.3.5: Summary of how respondents were affected by changes in water resources and hydrologic cycles



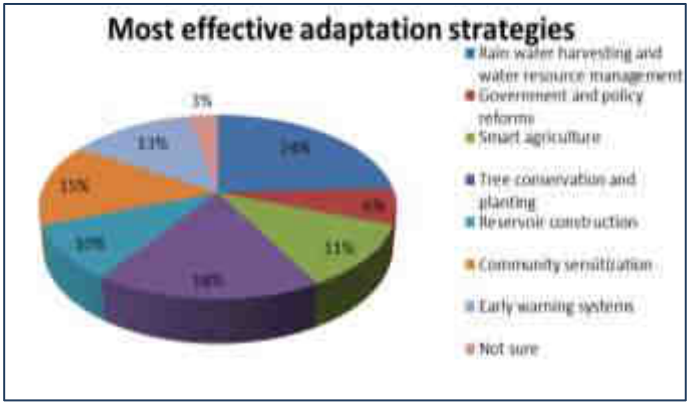
Source: Field data (2025)

Results show how the changes in water resources and hydrologic cycles affect respondents. 20% were not affected by the changes, 12% indicated that food became expensive, 33% indicated that they experienced water scarcity, 7% indicted that their animals died, 13% indicated that their crops did not grow well while 15% indicated that yields were reduced in their fields.

4.3 Necessary adaptation strategies

Results below show the necessary adaptation strategies suggested by the respondents.

Chart 4.4.3: Summary of the necessary adaptation strategies



Source: Field data (2025)

4.4 Chi Square Test of Association

Table 4.5.1: Tabulation of Chi Square Test of Association

Description of changes in temperature and precipitation	Observed and Expected Counts	Noticed droughts or floods (climate related shocks) in the past 10 to 20 years		Total	Statistic	Value	Df	p-value
		No	Yes					
Major	Count	0	11	11	Pearson Chi-Square	6.111	2	.047
	Expected Count	2.2	8.8	11.0				
Minor	Count	4	5	9				
	Expected Count	1.8	7.2	9.0				
Slightly major	Count	8	32	40				
	Expected Count	8.0	32.0	40.0				
Total	Count	12	48	60				
	Expected Count	12.0	48.0	60.0				

The statistics showed that the calculated Pearson Chi-Square result was at $p = 0.047$, measured with the assumed $\alpha = 0.5$ (at 95% level of significance). The corresponding specific objective was achieved and we reject the null hypothesis and accept the alternative hypothesis. Therefore, there was a significant association between the described temperature and precipitation changes and climate related shocks (droughts or floods).

5. Discussion of findings

The overall objective of the study was to assess the effects of climate change on water resources and hydrologic cycles in Mkushi District (2000 – 2024): Trends, risks and adaptation strategies. Out of 60 respondents that were sampled, 60 responded. This was a 100% response rate. However, this section discusses the findings of this study according to the objectives.

5.1 Causes of climate change

The objective sought to find out the main causes of climate change. It was apparent that the 60 respondents sampled, posted different opinions of which, 20% (12) of the respondents showed agriculture as the main cause of climate change, 28.33% (17) showed burning fossil fuels as the main cause, 30% (18) showed deforestation as the main cause and 21.67% (13) showed natural factors as the main causes of climate change. This means that most of the respondents highlighted human activities (deforestation, burning of fossil fuels and agriculture) as the main causes of climate change while only 21.67% highlighted natural factors as the main causes of climate change.

5.2 Effects of climate change on water resources and hydrologic cycles and effects of water resource and hydrologic cycle changes on local communities.

The findings revealed that 1.7% of the respondents were not sure whether there is an increase or decrease in temperature, 3.3% of the respondents indicated that there is a decrease while 95% indicated that there is an increase. In addition, the respondents were asked whether they noticed droughts or floods in the past 10 to 20 years or not. 20% of the respondents did not notice floods or droughts in the past 10 to 20 years while 80% noticed droughts or floods in the past 10 to 20 years. Furthermore, respondents specified whether they noticed floods, droughts or neither of the two. 20% of the respondents noticed neither floods nor droughts, 6.67% noticed floods while 73.33% noticed droughts. However, respondents indicated that whether they noticed a reduction in river flow, lake levels or groundwater levels. 11.7% did not notice a reduction while 88.3% noticed a reduction in river flow, lake levels or groundwater levels. This simply means that climate change has a number of effects on water resources and hydrologic cycles. Climate change reduced river flow, lake levels and groundwater levels. In addition, it caused droughts.

Finally, respondents showed how the changes in water resources and hydrologic cycles affect them. 20% were not affected by the changes, 11.67% indicated that food became expensive, 33.33% indicated that they experienced water scarcity, 6.67% indicted that their animals died, 13.33% indicated that their crops did not grow well while 15% indicated that yields were reduced in their fields. This means that water resources and hydrological cycle changes affect local communities. Water resources and hydrological cycle changes affect their livelihoods, especially for farmers who depend on rain fed agriculture, access to water and it promotes food insecurity.

5.3 Necessary adaptation strategies

Most respondents mentioned improving water storage strategies and rain harvesting technologies in order to ensure that water scarcity is reduced. Furthermore, respondents also mentioned the promotion of smart and conservative methods of agriculture, practicing afforestation and reforestation, avoiding deforestation and constructing more dams and boreholes.

6. Conclusion

The findings of the study it can therefore be concluded that changes in water resources and hydrologic cycles cause reduced water availability, reduced yields, food insecurity, loss of livestock and crops and loss of livelihoods for farmers. This makes local communities vulnerable to climate change. It is important to adapt to the climate crisis by imploring a number of strategies that lessen the burden and magnitude of climate change. This can make even the once most vulnerable communities and individuals resilient to climate change.

7. Acknowledgement

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