# THE IMPACT OF CLIMATE CHANGE AND LAND USE/LAND COVER CHANGE ON WATER AVAILABILITY IN THE NASIA CATCHMENT, NORTHERN GHANA

**By**

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## DECLARATION

hereby declare that this thesis is my own work towards the Master of Philosophy Degree in Geography and Rural Development under the supervision of my academic advisor. To the best of my knowledge, except for the references cited which have been duly acknowledged, no section of the work is a reproduction or submitted wholly or in part, for the award of any degree in any university elsewhere.

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## DEDICATION

I dedicate this work to my mother Mrs. Josephine Doe Tettey. I say thank you very much for your encouragement, prayers and financial assistance. God bless you abundantly.

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## ABSTRACT

Water remains the basic necessity for human survival on earth. The study examined the impact of climate change and land use/land cover change on water availability in the Nasia catchment. It employed a concurrent embedded mixed method design of quantitative and qualitative methods, using both primary and secondary sources of data. One-hundred and forty-seven (147) household heads and three (3) key informants were sampled from the study communities in the West Mamprusi, Karaga and Savelugu Municipalities\Districts (Nasia river catchment) using simple random and purposive sampling techniques respectively. Questionnaires, interview guide and focus group discussion guide were used to obtain the primary quantitative and qualitative data from the sampled household heads, key informants and community heads. Quantitative data was analysed based on descriptive statistics including percentages with the help of IBM Statistical Package for the Social Sciences (SPSS) (Version 23) while qualitative data was analysed using thematic analytical framework. The secondary data (temperature, rainfall and discharge time series data) were analysed using MAKESENS Solver from Python software, while Landsat satellite images were processed and analysed using QGIS. Again, time-series data points from secondary sources were used to perform multiple linear regression analyses. Frequency distribution tables, bar charts, graphs as well as verbatim quotations were used to present the analyses. The study found that annual temperatures indicate increasing trends over the past four decades, with minimum temperature increasing relatively faster than the rest. Mean and minimum temperatures in the last two decades have increased by about 1.5$^0$C while maximum temperature has increased by about 1.0$^0$C. River discharge is declining in the catchment leading to water deficit in some areas over the years. The decline in river discharge in the Nasia catchment corresponds to increasing trends in temperature and variability in rainfall of which all were statistically significant. The Nasia catchment is experiencing changing LULC. Between 1980 and 2020, there was remarkable increase in the extent of built-up/bare land, while farmland, vegetation and water bodies drastically reduced in same period. The study found that rainfall variability makes the river unavailable for domestic applications. The respondents indicated that the water smells, has odor and contains particles. Unfortunately, the study communities have no option but to depend on the river in that state due to the low water table (poor aquifer) in the area. Households at the inlet and outlet of the catchment employ distinct coping strategies to address water-related challenges. In West Mamprusi and Savelugu (outlet), respondents use rain harvesting, alum addition, and water filtering whereas in addition to these strategies, respondents in Karaga (inlet), had to reduce and reuse water. The study recommends that the Department of Water and Sanitation especially in Karaga District should provide the study communities with adequate storage facilities such as poly tanks to store excess rainwater during rainy seasons. This will be somewhat sufficient to supplement the short fall especially in the dry months.

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| | |
|---|---|
| **CC** | Climate Change |
| **CRS** | Catholic Relief Services |
| **CSC** | Clean Storage Containers |
| **CV** | Climate Variability |
| **FGD** | Focus Group Discussion |
| **GMA** | Ghana Meteorological Agency |
| **GSS** | Ghana Statistical Service |
| **HSD** | Hydrological Services Department |
| **IDI** | In-depth Interviews |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **LULC** | Land Use Land Cover |
| **NGOs** | Non-Governmental Organisations |
| **PEA** | Political Ecological Approach |
| **QGIS** | Quantum Geographic Information System |
| **SDG** | Sustainable Development Goal |
| **SPI** | Standardised Precipitation Index |
| **SPSS** | Statistical Package for the Social Sciences |

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| **TM** | Thematic Mapper |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **UNEP** | United Nations Environment Programme |
| **USGS** | United States Geological Survey |
| **WAN** | Water Access Now |
| **WRC** | Water Resources Commission |

# CHAPTER ONE

# GENERAL INTRODUCTION

## 1.1 Introduction

Global climate change in the 21st century has gained wide attention by countries because of its effects on both people and ecosystems (Swinburn et al., 2019). The effect of this change has resulted in the changes and shifts in the patterns of the climate elements, especially precipitation, temperature and humidity across the globe (Asamoah and Ansah-Mensah, 2020). The Inter-governmental Panel on Climate Change (IPCC) Sixth Assessment Report revealed that global temperature has increased by 0.8 °C over the past century (IPCC, 2021b) and is projected to keep rising in the coming decades (Tollefson, 2021). The timing, distribution, and quantity of water resources are anticipated to be impacted by climate change, which would increase the water stress situations in most African countries in the next decade (AdjeiMensah and Kusimi, 2020).

The pressure on the hydrological cycle brought about by the climatic change may have a considerable impact on the distribution and availability of water resources, in terms of both quantity and quality (Merga et al., 2022). The hydrological cycle is essential for controlling the dynamics of both human and ecosystems (Yang et al., 2021). The amount of precipitation received in an area determines the availability of water to meet various demands such as hydropower generation, agriculture, transportation, industrial, and domestic water supply (IPCC, 2013; Nyatuame et al., 2014). Global climate change may affect long-term rainfall patterns affecting the availability of water as well as increasing the danger of drought and flood occurrences (Pal and Mishra, 2017).

Africa is expected to experience adverse climate change impacts due to an increase in the already high temperatures and a decline in the largely erratic rainfall (World Bank, 2010). West Africa is much more prone to the shocks of climate change/variability and global warming by virtue of their geographical locations (Joiner et al., 2012; Niang, et al., 2017). According to Serdeczny et al. (2017), demand for water in sub-Saharan Africa is posing serious threats to water security, which is exacerbated by climatic changes affecting river runoff, resulting in higher irrigation water demand. Accordingly, access to clean water has become a great challenge in sub-Saharan Africa, which hinders their social and economic development (Shackleton et al., 2015).

The United Nations Framework Convention on Climate Change (UNFCCC, 1992) defines climate change as "change in climate which is attributed directly or indirectly to human activities that alter the composition of the global atmosphere in addition to natural climate variability observed over comparable time periods". Climate variables especially temperature and rainfall are gradually changing and are stimulated by both anthropogenic and natural factors (Nwankwoala, 2015). However, in recent years, anthropogenic causes are more rampant (Lelieveld et al., 2019). That is to say, anthropogenic factors have contributed massively in recent years to climate change, aggravating the natural causes of climate change (Sivelle et al., 2021). Anthropogenic factors result from gases and aerosols produced from combusting of fossil fuel and other greenhouse gas emission sources (Lelieveld et al., 2019). The continuous increase of Greenhouse Gas (GHG) emissions into the atmosphere will consequently lead to water dearth (Lelieveld et al., 2019). This is because change in climate will increase temperature and will subsequently lead to evapotranspiration and consequently cause a reduction in rainfall (Hagemann et al., 2013).

Changes in land use and land cover, particularly the conversion of vegetation cover into agricultural lands by humans, are likely to alter Earth's surface, which will likely worsen the climate change situation because responses from land surface processes and vegetation interactions affect regional and local climate patterns (Aduah et al., 2017). This modifies the hydrological cycle in a way that makes floods and droughts more frequent and severe – a situation which tends to have an impact on water availability, agriculture, and environmental sustainability (Aduah et al., 2017).

Report by IPCC (2014) indicates that about 93% of the associated impacts of climate change will be felt on surface and groundwater resources. Based on the climatic projections and the current trends of climate variability and change in Ghana, it is predicted that freshwater availability will be adversely affected in the coming years (Ministry of Foreign Affairs, Government of Ghana, 2018). Adjei-Mensah and Kusimi (2020), also reported that as a result of climate change, water resources are declining. The study reported a reduction in the water resource base for domestic water provision in the Sekyere-Kumawu District of Ghana. The reduction was perceived to be as a result of rising temperature, declining rainfall amount and stormy weather. They concluded that climate change has worsened water demand in the District. In the same vein, a study led by Yeleliere et al. (2018) revealed that for the past years, Ghana's per capita availability of freshwater resources is declining. This is indicative of how water related issues are very critical for development. The flow of most rivers has changed in recent years as a result of climate change (Dinpashoh et al., 2019). According to Kankam-Yeboah et al. (2013), the White Volta Basin's mean annual streamflow values for the 2020s and 2050s would decline by 22% and 50%, respectively. The hydrologic cycle of the river basins has significantly changed as a result of the combined effects of climate variability and change and changes in land use and cover (Bao et al., 2019).

Ghana is therefore undertaking numerous initiatives to safeguard its water resources. These efforts include putting the Sustainable Development Goals (SDGs) into effect, particularly Goal 6, which has the sole purpose of expanding access to a clean, sufficient supply of water and efficient management of freshwater resources (Nkiaka, 2021).

The Northern regions of Ghana are more vulnerable to the changing climate compared to the southern regions, which are marked by rising temperatures, long period of dry season, unimodal and variable rainfall (Stanturf et al., 2011). Abagale et al. (2009) noted that the change in climate, particularly rainfall patterns, might have a significant impact on the hydrological system of the Nasia river catchment. This implies that, the Nasia river catchment which is the left bank tributary of the White Volta Basin in

Northern Ghana is of no exception to climate change impacts (Addai et al., 2016). The White Volta Basin and Nasia river catchment provide the majority of the surface water for the North East and Northern Regions (Addai et al., 2016). The impact of climate variability/change in the northern region of Ghana has a substantial effect on rural populations because of their strong reliance on surface water resources for their domestic use as well as agriculture activities. Moreover, flooding as a result of high intensity rainfall and droughts as a result of long periods of dry season and a shorter wet season affect the water availability in Northern Ghana. The northern part of Ghana is therefore thought to be the most susceptible to the changing climate, with detrimental consequences on water supplies, agriculture (the nation's main economic sector), poverty, and many social dynamics, including the likelihood of conflict and land tenure. Understanding climate variability and change and also land use and land cover changes in the Nasia river basin are crucial for both of these regions. The main element affecting both regions' well-being and standard of living is the availability of water.

## 1.2 Problem Statement

Water is the most essential element for human survival on earth's surface as it supports socio-economic development (Connor, 2015). Its availability and distribution is largely determined by the climatic elements particularly temperature and rainfall. Accordingly, the increase in temperature coupled with rainfall variability has adversely affected the distribution and availability of fresh water resources including river basins in Ghana (Obahoundje and Diedhiou, 2022; Oyebande and Odunuga, 2010). According to IPCC (2021b), the variations in meteorological conditions such as storms, floods and droughts ensuing from climate variability, have resulted in the variations of river discharge, among others (hydrological systems) in the sub-Sahara African (SSA) countries, Ghana inclusive.

Nasia river catchment, the sub-catchment of the White Volta River system in Northern Ghana has not been spared of the consequences of climate change. According to Amisigo (2018), the depth of the White Volta channel has reduced drastically due to the change in rainfall patterns. This implies that the projected 10% decrease in rainfall by 2050 in sub-Saharan Africa (Misra, 2014) will worsen the situation, reducing water availability from the basin sub-catchments including the Nasia river. Aside climate change, land use/land cover changes as a result of human activities within the Nasia catchment including deforestation and agricultural expansion might have myriad consequences on the catchment in particular by increasing evapotranspiration and increasing surface runoff (Arias et al., 2018; Dias et al., 2015). This has serious implications on the availability of water for human consumption as well as other water applications and consequently affect the efforts made toward the achievement of the sustainable development goal (6), which aims to ensure clean water and sanitation for all. Specifically, it affects the targets 6.1 and 6.4, which focus on providing universal and equitable access to safe and affordable drinking water, improving water-use efficiency across all sectors, and ensuring sustainable withdrawal and supply of fresh water in response to water scarcity challenges in Ghana.

However, more focus has been placed on the impacts of climate change on major river basins with limited attention given to their sub-catchments like the Nasia catchment despite the fact that these sub-catchments contribute significantly to the socioeconomic development of the inhabitants of such catchments (Yeleliere et al., 2018). For instance, Kankam-Yeboah et al. (2013); McCartney et al. (2012) and KankamYeboah et al. (2010) focused their studies on the impacts of climate change on major basins including Volta and the Pra basins of Ghana at the neglect of sub-catchments. McCartney et al. (2012) investigated the water resource implications of changing climate in the Volta river basin using a dynamic regional climate model (CCLM), a hydrological model (SWAT) and a

water resource model (WEAP). Using the climatesensitive hydrological model SWAT and projected temperatures and precipitation from the ECHAM4 and CSIRO global climate models, Kankam-Yeboah et al. (2013)
explicitly investigated the effects of climate change on stream flow in the White Volta and Pra river basins in Ghana. The few studies conducted on the Nasia river catchment have also focused on the effects of land degradation on the flow pattern (Abagale et al., 2009) and hydrological parameters of the catchment for its socio-economic development (Abdul-Ganiyu et al., 2011) without quantifying the effects of climate variability/change on the availability of water in the Nasia river for domestic applications within the catchment. Besides, a holistic investigation into how land use/land cover has changed and its implication on the Nasia river in the catchment, water availability and coping strategies in the basin is yet to be undertaken.

The desire to fill the aforementioned lacuna coupled with the importance of water to socio-economic development of the nation is what motivated the researcher to examine the impact of climate change and land use/land cover change on the availability of water in the Nasia catchment, Northern Ghana.

### 1.3 Research Questions

1. What are the climatic (temperature and rainfall) trends in the Nasia river catchment over a 40- year (1981-2020) period?
2. What impact has changes in temperature and rainfall patterns have on Nasia river discharge?

3. To what extent are the land use/land cover (LULC) in the Nasia basin changing and it implication on the river from 1980 to 2020?
4. How is climate change affecting water availability for domestic use in the study area?
5. What coping strategies are being used by households in the study setting amidst the changing climate?

**1.4 Objectives of the study**

Generally, the study examined the impact of climate change and land use/land cover change on water availability in the Nasia river catchment, Northern Ghana. The study specifically sought to achieve the following objectives;

1. To analyse temperature and rainfall data from 1981-2020 for local climatic trends in the Nasia river catchment.
2. To examine the impact of climate change (temperature and rainfall) on Nasia river discharge from 1988-2010.
3. To determine the extent of LULC change in the Nasia catchment and it implication on the river from 1980 to 2020.
4. To assess the effect of climate change on water availability for domestic use in the study setting.
5. To examine coping strategies that are being used by households in the study setting amidst the changing climate.

## 1.5 Hypotheses

The following hypotheses were tested:

1. $H_0$: There is no statistically significant relationship between rainfall and river discharge in the study area.

   $H_1$: There is a statistically significant relationship between rainfall and river discharge in the study area.

2. $H_0$: There is no statistically significant relationship between temperature and river discharge in the study area.

   $H_1$: There is a statistically significant relationship between temperature and river discharge in the study area.

## 1.6 Propositions

1. Water for domestic use has been affected by land use/land cover change at the Nasia catchment.
2. Water for domestic use has been affected by climate change at the Nasia catchment.
3. Rainfall harvesting is the only coping strategy at the Nasia catchment.

## 1.7 Scope of the study

The study examined the impact of climate change and land use/ land cover change on water availability for domestic use in the Nasia river catchment. Geographically, the research was carried out in the Nasia catchment, which is located in the Northern and North East Regions of Ghana. The Nasia catchment traverses four Districts: West

Mamprusi and East Mamprusi Municipalities (North East Region), Savelugu-Nanton and Karaga Districts (Northern Region). The study was conducted specifically in the West Mamprusi Municipality, Savelugu-Nanton District and Karaga District. However, in East Mamprusi Municipality, the Nasia river flows beneath the Gambaga escarpment hence there is no community in close proximity using the river for domestic purposes.

### 1.8 Limitations of the Study

Few limitations were encountered. The first had to do with the coverage of the basin (3 Districts). This was resolved by employing two research assistants to assist the researcher in collecting the data. The second was language barrier. The researcher overcame this challenge by employing the services of field assistants who were natives of the area and understood the language to assist in the data collection.

The study was unable to obtain equivalent river discharge data to commemorate with the climate data hence interpretation, conclusion and generalisation to this aspect of the study should be carefully done.

### 1.9 Contributions of the Study

In terms of methodology, the study makes tremendous contributions. The adoption of mixed method in this study brought dynamism in the inquiry methods of the discourse. That is, it diversified the predominantly modelling and quantitative ways of studying the impact of climate change on water resources to incorporate the qualitative aspect.

Hence, this varied technique made this study useful.

This research expands knowledge by empirically examining how climate change and land use \ land cover changes are affecting water availability at the Nasia catchment. This research provides insights to policymakers on the need to develop an integrated approach in assessing and managing climate change impact on water availability at local, regional and national levels.

Conceptually, the study developed a framework on the basis of PEA and literature in the field to incorporate climate change, land use/cover, water availability, and coping mechanisms. This will definitely give other students, researchers, and readers a plethora of information to analyse water availability issues and to create their own.

Also, the study contributes to knowledge on the impacts of climate change on the Nasia river catchment specifically water availability for domestic use as well as provide information to support future water resources planning and management in Ghana and beyond. Knowledge of the potential impacts of climate change on the catchment will help guide practical initiatives, such as policies, programs, and actions as well as sustainable water coping strategies and management in the catchment as climate continues to change.

The research ended by identifying areas for further research. Thus, the current work provides the basis for future research in the areas of water availability using hydrological models. These models take into consideration all the physical characteristics of the catchment. Besides, this adds to the valuable literature on water availability and coping strategies.

# CHAPTER TWO

# EMPIRICAL AND CONCEPTUAL PERSPECTIVES OF CLIMATE CHANGE, LAND USE\LANDCOVER CHANGE AND WATER AVAILABILITY

## 2.1 Introduction

The preceding chapter presented the study background and the problem statement which highlighted the knowledge gaps that the present study aims to fill. It addressed the general and specific objectives of the study, the hypotheses and propositions on which the study is hinged and justified the need for this study.

This chapter situates the study within a scholarly context. It systematically reviews existing literature on climate change, changes in land use/land cover, water availability and sustainable coping strategies globally and some specifics in Ghana. The review is based on the objectives set forth in the previous chapter. It also explains the conceptual framework of the study and its theoretical underpinning.

## 2.2 Definition of Terms and Concepts

### *2.2.1 Climate*

Climate is the long-term average weather for a particular location. Often that average is over a 30-year period as defined by the World Meteorological Organization (Arguez and Vose, 2011). Similarly, IPCC (2014) defined climate as the statistical description in terms of the mean and variability of significant quantities over a time period ranging from months to thousands or millions of years. The working definition of climate in this study is therefore, the "average" weather (current atmospheric condition) for a particular

location or a specific geographical region based on long-term averages. The elements of climate are temperature, humidity, atmospheric pressure, wind, and precipitation. That being said, only the elements of temperature and rainfall would be considered in this study. This is because such elements are germane and its variability due to the emission of anthropogenic greenhouse gasses always have dire impacts on every aspect of human endeavors including water bodies (Asante and Amuakwa-
Mensah, 2014).

### *2.2.2 Climate Variability (CV)*

Climate variability refers to variations in the average condition of the climate as well as other statistics (such as standard deviations, the frequency of extremes, etc.) on all spatial and temporal scales outside of those of specific weather events (IPCC, 2014). Climate variability usually occur over a few years period and this could be due to minor changes in solar radiation, an El Niño event as well as a major volcanic eruption. Hence, when there is climate change, it is the long-term average that actually changes, not just the change over a few years. Climate has variability on all time and space scales and will always be changing.

### *2.2.3 Climate Change (CC)*

Climate change can be a change in either the average climate or climate variability that persists over an extended period. In other words, climate change can be any systematic change in the long-term statistics of climate elements sustained over several decades or longer. According to IPCC (2014), climate change is the state of the climate that can be detected (e.g. via statistical tests) by changes in the mean and/or the variability of its attributes, and that continues for a protracted period, generally decades or longer. As a result, climate change can be characterised as any long-term and substantial change in the expected patterns of a region's average weather over a sufficiently long period. The change may be due to natural internal processes or external forces including changes of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use (Bergesen et al., 2018).

However, the definition of climate change by IPCC (2014) differ slightly from the definition given by the Bergesen et al. (2018). Bergesen et al. (2018), defines climate change as the change of climate that is attributed directly or indirectly to human activities that alter the composition of the global atmosphere in addition to natural climate variability observed over comparable periods. The former refers to climate change as any change in climate over time, whether due to natural variability or as a result of human activity whereas the latter later makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes (IPCC, 2014). For the purposes of this study, climate change is described as a measurable statistical change in major climate elements over time, such as average temperature, and rainfall patterns, induced either by natural or anthropogenic factors or both.

### *2.2.4 River Basin*

A river basin is a region that is primarily determined by the run-off areas of surface water that converge toward a single watercourse as specified by nature (Dourojeanni, 2001). The concept of the river basin basically pertains to the field of physical geography (Molle, 2017). A river basin is primarily a volumetric and hydrological concept since it is a natural area of collection and concentration of surface and ground water (Dourojeanni, 2001). In other terms, a river basin is a geographical area that designates the region where most of the basin's water consumers interact and live (Bandaragoda, 2001). The boundary of the basin is formed by watershed that separate it from adjacent areas draining into other rivers. The size and shape of a basin is usually determined by the underlying geology and its ability to allow vertical erosion (McNabb, 2017).

Hydrologically, economically, and environmentally, river basins are significant. In order to provide hydropower, agricultural irrigation, and recreational activities, they absorb and channel the majority of the flow from snowfall and rain that can ultimately produce fresh drinking water. The functions of basins include flood control, water storage, and water filtration (McNabb, 2017). River basins are also often called catchments in British English, while watershed, which in American English designates smaller basins of a few thousand square kilometers, refers to the line dividing two river basins. Basins have been recognised as a practical hydrological unit for water resources management (McNabb, 2017). Therefore, river basin in this study represents an area of the earth surface drained by different streams or rivers into a single river system, as well as an administrative area where various users of the basin's water work and interact.

### *2.2.5 Land Use and Land Cover Change (LULCC)*

Land use and land cover (LULC) change have attracted considerable attention and it is a widely studied phenomenon in climate change, ecology, landscape ecology and earth science (Ayele et al., 2018). The terms land use and land cover are not synonymous, and literature highlights their peculiarities so that they can be understood in their proper perspective (Briassoulis, 2019). Meyer and Turner (1994) state that land use relates to land cover in several ways and impact it with diverse implications.

"Land cover by Meyer and Turner (1994) means the physical, chemical, or biological categorization of the terrestrial surface, e.g. grassland, forest, or concrete". Similarly, the biological and physical condition of the earth's crust and the immediate subsoil is referred to as land cover (Kummer and Turner, 1994). In other words, land cover refers to the physical or natural features of the planet's surface, such as water, mountains, forests, crops, and earth materials, as well as their quantity and kind of surface vegetation (Belete et al., 2020). Land use patterns determine how changes in land cover affect the climate. Through variations in surface albedo and transpiration, changes in land cover have an impact on the circulation of gases, water, and energy within the atmosphere. Land use, as defined by the Food and Agriculture Organization (FAO, 1997) refers to the use that human populations make of their land and is classified as "human activities." Similarly, it also explains how humans utilise the land and its resources (Belete et al., 2020). According to Meyer and Turner (1994) land use is used to describe the human activities that are connected to a particular area of land, such as farming, recreation, or urban habitation. Land use is an important and inevitable driver of environmental alteration with many effects specially to climate and water resource, such as vegetation cover depletion.

### *2.2.6 Coping Capacity*

The ability of a system to naturally or humanly respond to and recover from the impacts of stress or disruptions that have the potential to modify the structure or function of the system is referred to as coping capacity (Burkett, 2013). IPCC (2014) defines coping capacity as the ability to draw on available skills, values, beliefs and resources to address, manage and overcome adverse conditions, in the short to medium term. Sawalha (2020), defines coping capacity as the way people, organisations and systems employ existing resources and skills to manage unexpected, abnormal and adverse conditions of a disaster phenomenon or process (Sawalha, 2020). Generally, coping strategies involve counteractive actions to aid in the reduction of disasters and are mostly undertaken by people whose survival and livelihood are threatened by disasters. The ability to cope, both in times of instability and during disasters or bad situations, demands continual awareness, resources, and competent management.

### *2.2.7 Greenhouse Gases*

Greenhouse gases (GHGs) such as water vapor, carbon dioxide, methane, nitrous oxide, and ozone exist naturally in the environment (Latake et al., 2015). GHGs help keep the Earth at a habitable temperature, unless there is too much of them (Kweku et al., 2018). GHGs are thought to cause the atmosphere to behave like glass (Kweku et al., 2018). They absorb infrared radiation with short wavelengths from the sun and reemit it as long wave radiation, raising the temperature of the atmosphere. Other substances produced and emitted by human activity include sulfur hexafluoride (SF6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs) (Iwata and Okada, 2014). They also absorb and trap heat in the atmosphere, thereby enhancing the natural greenhouse effect defined as global warming. Greenhouse gases are produced by natural processes and human activities (Kweku et al., 2018). However, human activities are contributing significantly to the level of naturally occurring greenhouse gases, which leads to more warming and consequently, changes in climate (Kumar and Pooja, 2020). These changes are affecting many human activities.

### *2.2.8 Global Warming*

Climate change is one of the noted changes felt around the world currently and this is as a result of Global warming associated with greenhouse gas emissions into the atmosphere with the consequential effect of raising the global mean temperatures

(Akinwumi et al., 2021; Andah et al., 2014). The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2014) notes unequivocally that the climate system has warmed, the atmosphere and oceans have warmed, snow and ice have melted, sea levels have risen, and greenhouse gas concentrations have risen (Stocker et al., 2013). According to the US Geological Survey, global warming refers to the rise in global temperatures due to the increasing concentrations of greenhouse gases in the atmosphere. This implies that the emissions of GHGs results in global warming (Akinwumi et al., 2021). They also postulate that global warming is not climate change but just one aspect of climate change. The Earth's climate has always changed because of natural processes (IPCC, 2014).

These changes in the past were natural and caused by phenomena such as volcanic activity, changes in solar and a slow shift in the earth orbit. However, scientific evidence suggests that the Earth's atmosphere is now shifting because of human activity, a phenomenon known as "anthropogenic climate change (Hamilton, 2016). About 80% of climate change since the industrial revolution has been caused by human activity, primarily the burning of fossil fuels for transportation and industry, as well as deforestation for agriculture, urbanisation, and infrastructural growth (Huisingh, 2015). The amount of heat-trapping greenhouse gases (GHG) in the soil, atmosphere and oceans has increased, which has led to global warming.

Major climatic changes brought about by warming include more frequent and severe weather occurrences like precipitation events like floods, and heat waves, droughts as well as increased health risks, rising sea levels, and other detrimental effects (IPCC, 2014; Yawson et al., 2016). The primary greenhouse gases in the earth's atmosphere include nitrous oxide, carbon dioxide, methane, and halocarbons. Anthropogenic emissions fueled by population and economic growth have caused a rapid increase in the emissions of these gases in recent years (Pachauri, 2014). The Earth's surface temperature rises as the greenhouse effect intensifies over time.

According to Solomon et al. (2010), human-caused warming connected to carbon dioxide is nearly irreversible for more than 1,000 years, even if carbon dioxide emissions were to be entirely removed. Belay (2021) revealed that recent warming has coincided with drying trends observed across Africa, including the Ethiopian region, over the 1950–2008 period. Apart from the possibility of human-caused dryness, present drying trends could be linked to the ENSO (El Niño Southern Oscillation) or El Niño increasingly frequent and intense warm periods. The trend of global warming could significantly alter the precipitation pattern, water availability and water management in different parts of the world (Gan et al., 2016).

### *2.2.9 Water Availability*

Water circulates throughout the earth's system, condensing from the atmosphere and becoming available as surface and groundwater (Winter, 1999). The quality, quantity, use and timing of water resources reflect water availability (Flörke et al., 2018). Water availability encompasses the need for a specific amount of water to meet the intended purpose, the adequate quality of the water for the intended purpose, the timing characteristics with which water is delivered, and the need for water to meet human and ecological uses. Brauman (2015) also argues that water availability is a comprehensive concept that includes the biophysical supply of water, water demand, and water access. The physical presence of water does not guarantee its availability for use (Brauman, 2015). People experience water scarcity, when their demand for water is unmet.

The source of that water in the semi-arid regions of Ghana is mostly surface water from streams and rivers, lakes, or reservoirs, or groundwater as boreholes and standpipes. There is high consumption of water for different applications including domestic, agriculture, industrial and transport. The use of water domestically includes indoor and outdoor uses in households, and comprises application such as drinking, cooking, cleaning, washing clothes and dishes, bathing, flushing toilets among others (Turner, 2019). Water, unlike food, is essential to human survival. Water is a basic requirement, yet it is quickly becoming scarce. As a result, its supply is dwindling.

### *2.2.10 River Discharge*

The discharge of a river is the volume of water that flows past a point in the river's channel per second and measured in cubic metres per second (cumecs)or $m^3s^{-1}$ (Brinkerhoff et al., 2020). According to Malede et al. (2022) river discharge is a combined effect of hydrological processes in a river system in conveying runoff from rainfall. Precipitation, storage variables, and evapotranspiration all play a significant role in determining a river basin's discharge. When it rains heavily, rivers discharge more water than when it rains lightly (Mccarthy et al., 2022).

### *2.2.11 Impact*

The term impact is often referred to as the consequence or outcome of a phenomena (IPCC, 2014). Thus, simply, impact is most often used to describe the effects of extreme weather and climate disasters, as well as climate change, on natural and human systems (IPCC, 2014). Impact in this study refers to the effects and consequences of climate change on water resources and applications dependent on it.

## 2.3 Scientific Dimension on Rainfall and Temperature Trends

According to the IPCC (2014), global annual precipitation variations are not constant across the world. While some areas for instance, Akure in Nigeria have experienced higher precipitation levels (Olujumoke et al., 2016), other area especially subtropical areas have experienced a steady decline in average precipitation amounts. Extreme precipitation events are likely to become more intense and widespread over much of the mid-latitude and tropical regions (IPCC, 2014). India for instance, has witnessed changes in the rainfall patterns (Hijioka et al., 2014). The study accordingly found an increase in the frequency of heavy and severe rainfall events as well as monsoon break days in the said country. Unseasonal and heavy rainfall and hailstorms in February and March 2015 are two examples of extreme weather events in India (Bhushan et al., 2015). The extreme events may be a foreshadowing of what is to be expected in the future because of continued global warming (Bhushan et al., 2015). Similarly, the findings of Mukherjee et al. (2019) show that between 1901 and 2017, the average temperature and precipitation in India increased by 0.034°C and 3.71 mm, respectively. A study by Gobiet et al. (2014)

also concluded that temperatures would rise faster after the 2050s, globally and today's severe weather events will be considered natural.

In the African continent, there are uncertainties about the future change of rainfall pattern due to inadequate scientific data especially in West Africa (IPCC, 2014; Sultan and Gaetani, 2016). The average precipitation on the continent is expected to increase, according to Faramarzi et al. (2013); however, Hagemann et al. (2013) disagree. The study predicted that in most parts of sub-Saharan Africa (SSA), rainfall levels would decrease in the coming decades. In Ghana for instance, the trends of rainfall are expected to decrease from south to north (Asante and Amuakwa-Mensah, 2014). AduBoahen et al. (2019) also revealed that there were yearly irregularities in the amount and intensity of rainfall with increasing number of dry seasons in the Northern region, implying the area is currently contending more with climate variability. However, in Nigeria, a research concluded that the current climate indicates alternating wet and dry periods in rainfall, and that the start of rainfall is becoming later implying a likely short rainy season in the area (Olujumoke et al., 2016).

Temperature is anticipated to rise in the future, unlike the pattern of rainfall in Africa. This is based on the observation that surface temperatures have risen by 0.5 °C throughout most of Africa over the past few years, with minimum temperatures rising at a higher rate than maximum temperatures (Collins, 2011; Niang et al., 2017). A study by Olujumoke et al. (2016) showed an increasing trend of temperature in Nigeria throughout the year.

Ghana's climate is affected by the interaction of the Inter-Tropical Convergence Zone

(ITCZ) and the West African Monsoon (Adu-Prah et al., 2019). The Inter-Tropical Convergence Zone (ITCZ), also known as the Equatorial Convergence Zone or the Inter-Tropical Front, is a stable zone that separates the northeasterly and southeasterly trade winds. The ITCZ moves from the northern to the southern hemisphere every year, reaching its northernmost extent in the summer and its southernmost extent in the winter (Byrne et al., 2018). Due to the ITCZ and West African Monsoon's motions, Ghana's climate is characterised by alternating rainy and dry seasons. There are two different wet seasons in southern Ghana, but there is only one in the north (Adu-Prah et al., 2019). Temperature data indicates that Ghana's climate is warming, with the dry northern region warming more quickly than the southern region (Dyoulgerov et al., 2011). Ghana's yearly temperature has increased by 1.0°C on average since 1960 (Dyoulgerov et al., 2011). In general, the temperatures in the north rose at a faster pace than the south. The number of warm days and nights in Ghana increased between 1961 and 2003 (Stanturf et al., 2011). In today's climate, a warm day or night is described as one in which the temperature exceeds 10 percent of the time. In Ghana, annual rainfall varies greatly, making long-term trends difficult to distinguish (Stanturf et al., 2011).

Temperature in Ghana has been rising in recent years. For instance, Stanturf et al. (2011) showed an increase of around $1^{0}$C from northern to southern parts and an average yearly increase of 0.9 $^{0}$C along the coastal savannah (Oduro et al., 2022). Yiridomoh et al. (2021) discovered that Ghana's temperatures are rising across all ecological regions, despite experiencing erratic rainfall patterns. Projections indicate that Ghana's climate elements are on an increasing trend, with temperature expected to rise between 1.3°C and 2.0°C in most regions, and higher increases of 2.1°C to 2.4°C in the northern regions (Guinea and Sudan Savannah) (World Bank, 2010). These findings imply varying implications for water resources, agriculture among others. Similarly, Mabe et al. (2014) found out that the climate in the area has gotten warmer during the previous 40 years in Ghana's Northern region. The predicted warming with temperature increases will however have adverse effects on water availability, human well-being and food security (Gitz et al., 2016).

## 2.4 Climate Change and Water Availability for Domestic Use

Several studies conducted globally on climate change impacts on water resources have concluded that climate change have had an enormous influence on water resources due to the sensitive nature of water resources to climatic variations (IPCC, 2013). These influences as found by the scholars include; change in the surface runoff (Lu et al., 2019; Lui et al., 2017), increased stream flows from glacier melting (Miller et al., 2012), increased extreme precipitation (Zhang and Villarini, 2017), decreased surface runoff in summer (Bavay et al., 2013), decreased ground water reservoir (Okkonen and Klove, 2010), and increased carbon and nutrients in water bodies (Statham, 2012).

According to the Report of the fifth Assessment of Intergovernmental Panel on Climate Change (IPCC, 2014), climate change is anticipated to worsen its impact on water resources in the near future. The report indicated that about 93% of the associated impacts of climate change would be felt on surface and groundwater resources. Occurrences of floods and droughts due to change in the total amount of precipitation, its frequency and intensity would negatively affect the availability and quality of water resources including rivers, lakes, streams and other water bodies especially in the less developed nations (Faramarzi et al., 2013). However, the severity of these effects would depend on the baseline state of the water supply system and the capacity of water resource managers to respond to climate change in addition to pressures due to an increase in demand as a result of population growth, technology, and economic, social, and legal conditions (Pulwarty, 2006).

African countries particularly Sub-Saharan African countries, would be more vulnerable to climate change impacts on water resources due to their background characteristics such as very hot and dry, relying on surface and ground water for freshwater coupled with their low level of technology to adopt (Niang, et al., 2017). Many of the rivers in Africa are ephemeral, flowing during and shortly after the rainy season. Aygün et al. (2020), specified that the situation would be more pronounced in the arid and semi-arid countries because rainfall and river water supply are only spread over a short period in the course of a year in such regions. In the Middle East and North Africa, water resources are already diminishing due to less precipitation and increasing temperatures, coupled with rising water demand ensuing from population growth and economic development (Tekken and Kropp, 2012). This is resulting in rapidly decreasing water availability that could be 30 to 70% less per person in 2025 (Sowers et al., 2011). In the cold regions, changes in precipitation, warmer temperatures, and associated changes in snow and soil metrics are altering the magnitude and seasonality of streamflow (Aygün et al., 2020). According to the report, the warming climate will become more pronounced in the coming decades, with higher temperatures and reduced precipitation, as well as decreased surface water,

water quality, and rising water demand (IPCC, 2014), with the Northern-Saharan populations projected to be significantly impacted.

In lieu of climate change, Adjei-Mensah and Kusimi (2020) reported that water resources are declining and this has worsened water demand in certain regions. The study reported a reduction in the water resource base for domestic water provision in the Sekyere-Kumawu District of Ghana and this reduction is perceived to be as a result of rising temperature, declining rainfall amounts and stormy weather. Misra (2014), in the same vein stated that majority of the fresh water resources has already been depleted especially in Sub-Saharan Africa. The problem of water shortage is mostly exacerbated in arid and semiarid areas due to their sole dependence on rainfall and rivers for domestic purposes, agriculture, hydropower generation, increasing population among others (Freitas, 2015; Ngoran et al., 2015). Similarly, Yeleliere et al. (2018), noted that the quality and quantity of freshwater resources are steadily dwindling. Approximately 1% of this freshwater is available for domestic use in lakes, river channels, and underground. Konapala et al. (2020), reported that water supplies in many regions are expected to reduce due to increased evaporation and this is as a result of increased temperatures coupled with erratic rainfall. This implies that as temperature rises, not only will water supplies reduce but also more water will be needed by people and other economic activities in order to thrive (Konapala et al., 2020).

Domestic water is defined by the World Health Organisation (WHO) in its Guidelines for Drinking-Water Quality as water used for all common domestic uses, including eating, bathing, and food preparation (WHO, 2017). This implies that the adequacy of water is not solely in relation to consumption of water but across all the aforementioned uses. Hence, water demands for domestic purposes include drinking, food preparation, washing, bathing, toilet flushing, watering of lawns and gardens among others (Wang et al., 2018). The increased demand of water for domestic use globally coupled with climate change will aggravate the water crisis in many regions of the world that are already facing water shortages owing to population and economic growth.

According to Niang et al. (2014), there will be less water available in Africa in the future due to a number of factors, including climate change, particularly in Northern and Southern Africa. Similarly, Andah et al. (2014), found that lower rainfall amounts over the years as a result of lengthier dry seasons have led to main rivers and their tributaries drying up quickly, leading to reduced amounts of surface and ground water available to meet the demands of the increasing population.

Similarly, Oti (2019), indicated that the Densu River Basin will experience a temperature increase and reduction in rainfall that will reduce water resources in the area. Further, the climate change impact analysis conducted indicated a reduction in the streamflow due to decrease in rainfall and as a result water demand for domestic and irrigation purpose will not be met in the said basin. The study concluded that sustainability of water resources will continue to face threats of climate change. In the same vein, Opare (2018), reported that Nsaakye river, which served as the main source of water for the population, had low water levels, which was a sign of the water deficit. Obuobie et al. (2012), further opined that even without climate change, the White Volta and Pra Basins will attain water stress and water scarcity by 2020 and 2050, respectively. Therefore, coupled with climate change, water conditions in both basins will worsen.

Over 60% of peri-urban and rural residents in the Nasia catchment rely on unprotected sources of water supply like the Nasia river, boreholes, wells, streams and sometimes are faced with intermittent water supply or limited access to safe drinking water. Some peri-urban areas have access to standpipes and mechanised boreholes, but struggle to access water from these sources regularly due to lack of maintenance among others (Tetteh et al., 2023). The Nasia catchment in Northern Ghana is a significant source of surface water resources for domestic applications among others (Tetteh et al., 2023). However, previous studies have indicated that the volume and quality of the Nasia river have declined over the past decade, resulting in increased pressure on the already scarce water resources (Tetteh et al., 2023; Nyadzi et al. 2021). As a result, in order to obtain water for household purposes, women and children, in particular, are required to wake up early and endure long journeys. Additionally, research conducted by Addai et al. (2015) revealed that groundwater availability is diminishing, and projections suggest that rising temperatures in the upcoming decade may lead to higher evaporation rates. The study further points out that signs of water scarcity and potential droughts are emerging in the catchment area.

### 2.5 Land Use/Cover Changes and its Implications on Rivers

LULC are rapidly changing in many countries. Previous research has established that rapid changes in land use and land cover (LULC) is as a result of rapid global population growth, which necessitates an increase in anthropogenic activities, resulting in forest degradation and the conversion of fertile land to urban construction (Mariye et al., 2022; Ampim et al., 2021). Through variations in surface albedo and transpiration, land cover changes have an impact on the circulation of gases, water and energy in the atmosphere (Nwankwoala, 2015). Hence, these conversions subsequently lead to increased run-off, increased carbon dioxide concentration, erosion, flooding, and other environmental repercussions (Houghton, 2012; Al-sharif and Pradhan 2014; Sharma et al., 2018). Haddeland et al. (2014), also reported that current anthropogenic factors particularly LULC change have a greater effect on mean annual runoff.

Likewise, according to Wu et al. (2015), LULC is also understood to influence hydrological process. Aduah et al. (2017) reported that land cover changes, predominantly vegetation, are expected to exacerbate the decline in water quantity in water bodies by exposing water bodies to already high air and surface temperatures. This will have an impact on water supply, agriculture and environmental sustainability (Tahiru et al., 2020).

### 2.6 Household Coping Strategies for Domestic Water Shortage

Many studies have identified rainwater harvesting as a coping strategy for people living with high rainfall variability, both for domestic and agriculture supply (Aladenola and Adeboye, 2010; Owusu and Teye, 2015; Yannopoulos et al., 2019). In areas where the current water supply source is insufficient to meet demand, rainwater collection is a potential approach for supplementing surface and subterranean scarce water resources (Aladenola and Adeboye, 2010). Rainwater harvesting is therefore the process of collecting, storing, and utilising rainwater for home, industrial, and irrigational applications (Yannopoulos et al., 2019). This technology is flexible and adaptable at the local context. At the same time, it can be used to recharge aquifers (Owusu et al., 2017). Rainfall is the sole source of recharge for rainwater harvesting. Rainwater is commonly collected directly from rooftops and stored for home use in constructed cement reservoirs or other storage tanks (Andoh et al., 2018). According to Yannopoulos et al. (2019), given the limited availability to a public water supply, rainwater is a particularly good choice for rural populations to obtain potable water for domestic usage.

Rainwater is free, and gathering it requires only a few simple tools or supplies, hence it is strongly suggested for individuals to help minimise water supply issues (Owusu and Teye, 2015). With the exception of November, December, January, and February, Aladenola and Adeboye (2010) stated that captured rainfall in Abeokuta can meet household's monthly water demand for WC flushing and laundry. If there is enough storage, the excess rainwater from September and October can make up for the shortfall during the dry months. Thus, rainwater can be used to minimise water loss and at the same time augment water supplies in any watershed systems (Owusu and Teye, 2015).

Opare (2018), also identified some coping strategies adopted in Dupong. This included reduced use of water, reuse of waste water, male roles in household water provision which was hitherto considered disrespectful in the rural setting, identifying alternative water source and improving existing water supply sources (Opare, 2018). Similarly, other studies also reported reliance on alternative sources of water, rainwater harvesting, storage of water, increased roles of males in household water collection among others as household adaptation strategies. Furthermore, he came to the conclusion that although affordable, indigenous adaptation strategies may be modified to increase their effectiveness as coping mechanisms for a diminishing water supply brought about by climate change. In the same vein, Adjei-Mensah and Kusimi (2020) also concluded that coping mechanisms for managing water resources, such as water storage and short-term rainfall harvesting, should be used.

## 2.7 Theoretical Framework

The study is grounded in the Political Ecological Approach (PEA), which provides the theoretical foundation for the research. PEA is chosen as it explicitly recognizes the crucial role of power dynamics and inequalities in relation to access to natural resources. According to Nygren and Rikoon (2008), PEA offers robust analytical tools that enable a comprehensive understanding of the complex interactions between humans and the environment, along with the resulting challenges. Similarly, Forsyth (2008) highlights that this approach sheds light on the intricate connections between environmental processes and societal interactions, with a particular emphasis on the social implications of human-environment interactions. The central focus of PEA lies in examining how global and local power structures, as well as the unequal relationships within them, shape diverse outcomes for various actors in the face of environmental change, effectively politicizing environmental issues.

From this theoretical framework, power relations are conceptualised as the pathways through which various actors including governments, chiefs and local communities exert influence and control over access to and utilisation of natural resources such as land and water (Bennett, 2017).

The implications of climate change and changes in land use/land cover (LULC) for water availability are embedded in the prevailing power dynamics. Water is not solely a physical resource but also a politically contested resource (Götz and Middleton, 2020). The impacts of climate change disproportionately affect different regions and communities, creating uneven vulnerabilities (Savelli et al., 2022). Vulnerable and marginalized groups typically possess limited power and resources to adapt to changing water availability (Savelli et al., 2022). They often lack access to necessary technologies, infrastructure, and financial resources to cope with challenges related to water scarcity, flooding, and other climate-induced water issues. This heightens their vulnerability and exacerbates existing social inequalities.

The power dynamics within societies play a pivotal role in shaping the control and ownership of water resources. From this view, where ownership of water resources is invested in communities, individuals outside these areas may be conceived as free riders and denied access to such resources (Van Koppen, 2022). Such individuals who face acute water shortages may then resort to other less hygienic sources to meet domestic needs. The power dynamics underlying these processes contribute to social and environmental conflicts, particularly affecting marginalized communities.

From a different perspective, where local communities are excluded from major land use and land cover change projects, decisions about land transformations may least reflect the concerns of such people. Powerful actors who own and control landed assets therefore engage in activities that have adverse impacts on community water resources. Given climate change and changes in land use, power dynamics play a role in determining vulnerability and ability to adapt. Marginalized and socioeconomically disadvantaged groups often face greater susceptibility to the impacts of these changes due to limited resources for adaptation and less influence in decision-making.

Overall, within the political ecological approach, power relations shape how ownership of water resources is contested. Power imbalances can lead to unequal distribution of water resources, differential impacts of climate change on vulnerable communities, exclusion of marginalized groups from decision-making processes, and prioritization of economic interests over sustainable water management. Addressing power dynamics is crucial for promoting equitable and sustainable water governance, ensuring access to water resources for all, and building resilience to the impacts of climate change and land use changes, particularly in the Nasia catchment of northern Ghana.

## 2.8 Conceptual Framework

Climate change impact on water resources has become a global concern, with notable changes in river discharge patterns and shifts in climate variables such as temperature and rainfall (Asante and Amuakwa-Mensah, 2014). Furthermore, alterations in Land Use/Land Cover (LULC) have demonstrated significant influence on climate change at global, regional, and local scales (Halder et al., 2021). Deforestation, for instance, is a major contributor to global warming due to the release of greenhouse gases into the atmosphere (Houghton, 2012), and LULC changes have been observed to affect temperature, especially minimum temperature (Yaung et al., 2021).

These changes in temperature and precipitation patterns can lead to accelerated evaporation rates, resulting in increased water loss from rivers, reservoirs, and other water bodies. Consequently, some regions experience more frequent and intense droughts, ultimately reducing overall water availability. The competition for scarce water resources as a result of acute water shortage in such regions can escalate social tensions and conflicts among different user groups, including communities, farmers, and industries, industries as expounded by the PEA (Deng and Zhao, 2015; Payus et al., 2020). The issue of water ownership and access also exacerbates the water conflicts, where individuals residing outside specific communities may be perceived as free riders and denied access to essential water resources (Van Koppen, 2022). In turn, these individuals may be compelled to resort to less hygienic water sources to meet their domestic needs.

To minimize water scarcity and its associated conflicts and vulnerabilities, effective coping and sustainable water management strategies at the individual, societal and institutional levels must be undertaken. The conceptual framework explains the relationship between climate change, land use/land cover changes and the resulting effect on water availability for domestic use, as well as some effective coping strategies that could be utilized to minimize the effect of climate change on water availability for domestic use.

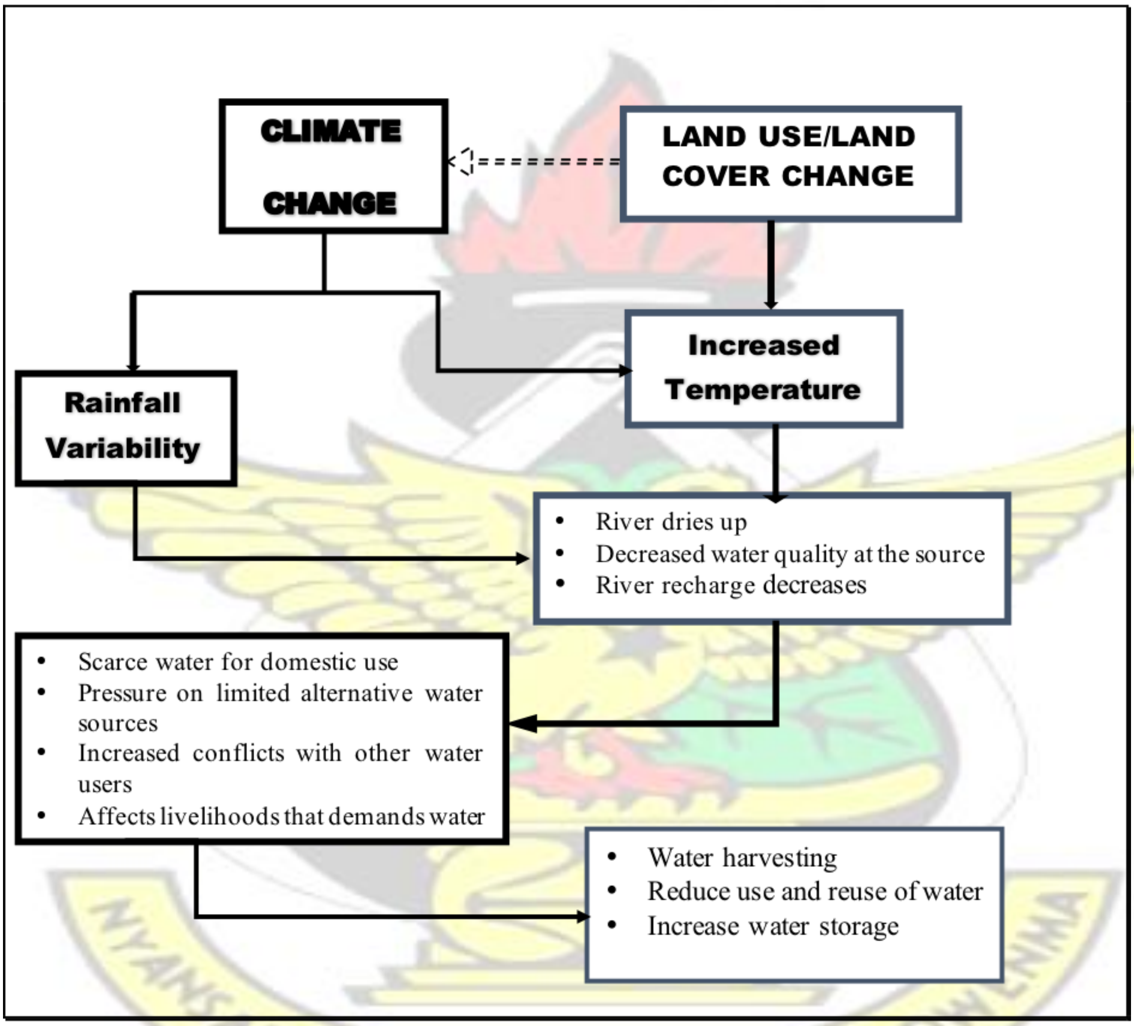


**Figure 2.1: Climate Change and LULC Change Effects on Water Availability and Coping Strategies.**

**Source: Author's construct (2021)**

# CHAPTER THREE

# BACKGROUND OF THE STUDY AREA AND METHODOLOGY

## 3.1 Introduction

This chapter is devoted to the description of the background characteristics of the study environs and also the methodology. The background characteristics of the study environs covered the physical area of the study (location and size, climate, topography, vegetation, drainage, soil, and geology) and also the demographic and socioeconomic characteristics. The methodology section of the chapter covers the research philosophy, study design, methods and procedures for gathering and analysing data. The chapter ends with ethical considerations.

## 3.2 Physical Features

### *3.2.1 Location and Size*

The Nasia river catchment, which is bounded by 9°55' and 10°40' latitude and 1°05'W and 0°15'E longitude in the north-eastern part of Ghana, is one of the White Volta river system's sub-catchments (Abdul-Ganiyu et al., 2011). The basin is situated in Ghana's North East and Northern Regions(Yidana et al., 2016); however, prior to the formation of the new regions, it was entirely within the Northern Region of Ghana. The East Mamprusi and West Mamprusi Municipalities in the North East region respectively are located at the western and eastern parts of the basin, while Savelugu – Nanton, Karaga, and Gushiegu Districts in the Northern region cover the southern half. The Nasia river basin has a total area of approximately 5326 $km^2$ (Yidana et al., 2016). Figure 3.1 shows the outlined map of Ghana showing the Nasia river basin and sampling points.

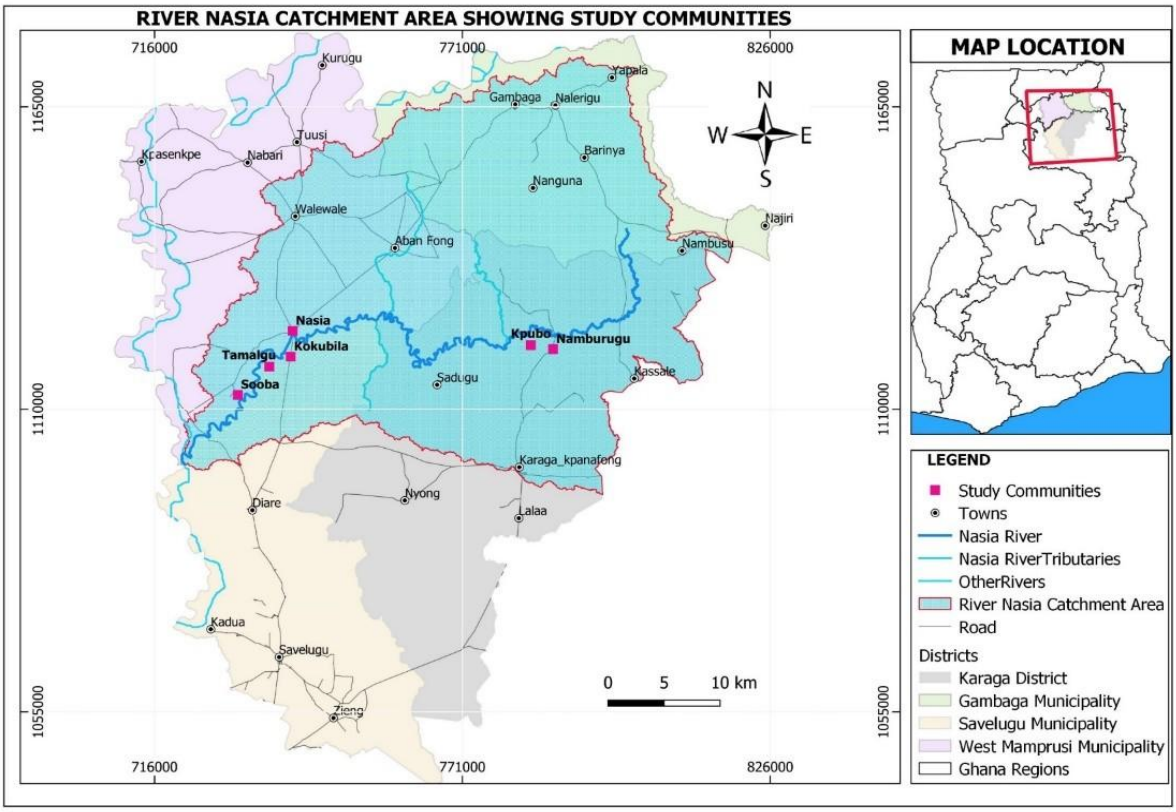


**Figure 3.1: Nasia River Basin and Study communities**

Source: Authors construct using GIS (2022)

### *3.2.2 Climate*

The region is characterised by one rainy season (unimodal), average temperatures of 29°C, and 1000–1300 mm of annual rainfall. A reference evapotranspiration (ETo) of more than 1600 mm/yr occurs during the rainy season, which lasts between 140 and 190 days (Abdul-Ganiyu et al., 2011). The rainy season typically lasts from May to October, and the wettest months are late August and early September (GSS, 2014). Rainfall patterns however, have become more unpredictable in recent years, with the first rains usually occurring in late June and July (Yidana et al., 2016). Rainfall is characterised by thunderstorms or intense showers. The erratic distribution and short duration of rainfall greatly impede flow, crop and vegetative development (GSS, 2014). Torrential rains during the peak season trigger severe drainage issues because penetration rates are poor due to the largely impervious nature of the various lithologies, resulting in high volumes of runoff, which causes erosion and places major constraints on water resources (Addai et al., 2016).

### *3.2.3 Topography and Vegetation*

The study area has a flat topography with a few scattered hills, such as the Gambaga escarpments (GSS, 2014). Thus, the region is distinguished by low relief in the south and a few high-elevation areas in the north, which are connected with the Gambaga escarpment. Since the Nasia Basin is in the Interior Savannah Ecological Region, its vegetation is dominated by grasses. The current vegetation is a fire sub-climate that has evolved over time as a result of human activities, especially farming and burning (Abdul-Ganiyu et al., 2011). These activities tend to pose a threat to the climate of the area. Also, the loss of vegetation can have implications for streamflow as it increases evaporation (Afzal and Ragab, 2019). This might negatively affect water availability use for domestic purpose and other water applications in the basin.

### *3.2.4 Soil and Geology*

The basin is built on Voltaian sediments, according to Adu (1995). The region's soils are formed over Upper Voltaian sandstones, Lower Voltaian shales, and alluvial floodplains and sloughs. Alluvial and savanna ochrosol soil types are prevalent in the basin (Adu,1995). Alluvial soils, which are usually found along the basin, are potentially fertile. Hence, many farmers farm along the basin's banks. However, farming close to the bank of the basin is likely to impact on the flow routine of the Nasia river (Abagale et al., 2009).

### *3.2.5 Drainage*

The Nasia river is one of the sub basins of the White Volta River System. The White Volta and Nasia River Basins contain much of Northern Ghana's surface water resources (Abdul-Ganiyu et al., 2011). In the context of the White Volta, seasonal climate oscillations have an impact on the regimes across a large watershed that stretches from north of Ghana to the center of Niger. Rivers in the White Volta Basin, especially the Nasia river, often flow for just three to four months each year, causing seasonal shortages throughout the region (Abdul-Ganiyu et al., 2011).

## 3.3 Socio-Economic Activities

The basin's principal economic activity is agriculture, which includes food crop production, livestock rearing, and fish farming (GSS, 2014). Some of the plants cultivated are rice, maize, sorghum, millet, peanuts, cowpea, soybeans, yam, and vegetables. Fishing and livestock are used to augment crop production. This explains why the majority of the settlements are clustered around the White Volta. Rice milling, Shea butter manufacturing, and groundnut oil extraction are among the basin's large and small-scale agro-based businesses (GSS, 2014). Conventional rain-fed agriculture faces significant challenges in the Nasia river catchment due to erratic rainfall patterns and frequent droughts, especially as global food demand rises. This makes agriculture a risky means to make a living. Also, the income from these economic activities is often little, hence they are more vulnerable to environmental changes (GSS, 2014).

## 3.4 Methodology

### *3.4.1 Philosophical underpinning of the research*

The philosophy underpinning this study is the pragmatic philosophy. Pragmatic philosophy incorporates both positivist and interpretivist ideologies thus, the use of both quantitative and qualitative methods in research. According to the positivist paradigm, real events can be observed empirically and interpreted using logical reasoning. In the social sciences, the interpretivist theory emerged as a criticism of positivism (Pathak and Thapaliya, 2022). The theoretical conviction that reality is socially constructed and fluid underpins interpretivist positions (Denzin, 2017). As a result, what we know is often negotiated within societies, social contexts, and interpersonal relationships. Individuals are complex, and different individuals have different experiences and understandings of the same "objective truth". Thus, positivists believe that society shapes the individual and prefer quantitative methods that allow the researcher to remain distant from the respondent, while interpretivists believe that individuals shape society and prefer qualitative methods that allow for close interaction with the respondent (Pathak and Thapaliya, 2022).

The thesis involved an integrated approach, combining positivist and interpretivist perspectives, to investigate the impact of climate change and land use and land cover change on water availability for domestic use. The positivist methodology involved analysing meteorological data from the Nasia catchment to identify climate change trends. Additionally, the positivist approach was used to analyse river discharge data in conjunction with meteorological data to understand the effect of climate change on river discharge. In contrast, the interpretivist perspective was used to assess the perceived effect of climate change on water availability for domestic use and to gain deeper insights into indigenous water coping strategies in the study area, particularly during times of severe water scarcity. Therefore, the pragmatist philosophy was employed in this study to holistically address the research objectives which could not be addressed by either the positivist or interpretivist approach alone.

Therefore, based on the pragmatist philosophical perspective, this study employed both quantitative and qualitative strategies to seek complementary and corroborative assessment, description and understanding of climate change and anthropogenic impact on the Nasia catchment (Creswell et al., 2003; Creswell and Clark, 2017). Pragmatism allows mixed methods researchers to be more versatile in their research methods (Morgan, 2013). Employing a mixed methods approach allows for a more profound comprehension of the investigated issues from multiple perspectives, surpassing the insights that could be derived from relying solely on one method. This integrated approach yields comprehensive results, enabling the compensations for any limitations in one method through the strengths of the other (Creswell and Creswell, 2018).

### *3.4.2 Justification for the Selection of the Study Area*

Six communities were selected for the study (as shown in Table 3.1) based on their great dependence on the Nasia River as well as proximity. They include Nasia, Sooba, Kokubila, Tamalgu, Namburugu and Kpubo. Aside Nasia and Kokubila communities with few standpipes and boreholes which are inadequate, the rest solely rely on the Nasia river for domestic and other applications. In addition, the Nasia river catchment holds the majority of the surface water resources in the study communities.

### *3.4.3 Research Design*

The study employed a cross-sectional study design following a mixed method approach to assess the impact of climate change and land use/land cover change on water availability in the Nasia river catchment in Northern Ghana. Cross-sectional studies offer a snapshot of data at a specific moment, enabling researcher to simultaneously gather information about climate change impacts on water availability in diverse locations and population groups (Setia, 2016). It provides a quick and broad understanding of the current situation. Compared to longitudinal studies that span extended periods, cross-sectional studies are cost and time-efficient, making them more practical in resourceconstrained situations. Researcher can examine multiple variables related to climate change and water availability simultaneously, exploring potential interconnections (Setia, 2016). Additionally, the cross-sectional design allows for comparisons between different groups or regions, facilitating the identification of disparities, patterns, and variations in climate change impacts on water availability across diverse settings.

In this research a concurrent embedded mixed method approach was used, that is employing both quantitative and qualitative methods of data collection and analysis at different stages of the research process in a single study. This allows to comprehend a research problem more wholly (Creswell et al., 2003). The use of mixed method may fully capture the actual effect of climate change and land use/land cover change on the availability of water in the Nasia river as well as incorporate its effects on domestic water use as against the use of quantitative research method alone (Grewal and Ritchie, 2006). This method further provides deeper understanding of the problem under investigation and also allows for generalisation of results (Hanson et al., 2005).

#### *3.4.4 Unit of Analysis*

The unit of analysis for this study were households, community heads and institutions. According to GSS (2014), a household is described as "a person or a group of people who live together in the same house or compound, share the same housekeeping arrangements, and are catered for as one unit." A typical household consists of a man, his wife, children, and possibly other relatives or a housekeeper. It must be noted that members of a household are not always related (by blood or marriage), as non-relatives (such as housekeepers) can be included (GSS, 2014). The household head is also defined "as a male or female member of the household recognised as such by the other household members". In most cases, the head of household is the one who is responsible for the household's economic and social well-being. Hence, all relationships are defined with reference to the head (GSS, 2014). Research participants were made up of male and female heads of households.

Community heads are members of a community who hold certain positions or play specific social or political roles. They include chiefs, assembly members, opinion leaders among others. They are regarded as local authorities responsible for managing affairs with regard to the general wellbeing of the community.

The term "institution" has several different meanings. Institutions are stable patterns of behavior that define, govern, and constrain action. An institution can also be defined as a formal social framework that rules a sphere of action (Parto, 2005). The operational definition of institution for this study is that, it is a large-scale organisation that is stable and predictable, developed and maintained to serve the requirements of society, such as the Hydrological Service Department and the Water Resource Commission among others. Heads of these institutions were also sampled and participated in the study.

### *3.4.5 Sampling*

#### *3.4.5.1 Sampling Techniques*

Simple random and purposive sampling techniques were used in the study. Study communities were purposively selected. Nasia and Sooba in the West Mamprusi Municipality, Kokubila and Tamalgu in Savelugu-Nanton District, Namburugu and

Kpubo in the Karaga District were selected based on their proximity and use of the Nasia river for domestic purposes in the respective districts. In each community, a simple random sampling was used to select individual houses using the fishbowl draw method. This involved writing each of the house numbers on a small slip of paper which was then folded and put into a bowl. Shuffling was done thoroughly and then picked one-by-one until the required sample size was obtained (Kumar, 2020). In each house visited, the head of a household was selected for questionnaire administration. Data obtained through random sampling is more likely to be reflective of the entire population of interest. Random sampling further ensures that all units in the target group have an equal probability of being chosen, preventing bias. For selecting household heads, random sampling was favoured over other methods since it ensures that the likelihood of selection is the same regardless of the population. The household head in each house was preferred for administering questionnaire.

Community heads were purposively sampled for the study. The inclusion of local authorities namely; chiefs, assembly members and opinion leaders, is because as stakeholders, they have significant responsibilities in ensuring the general wellbeing of the people in their various communities. Further, key informants, one (1) each from Hydrological Services Department (HSD), Water and Sanitation Department (WSD) and the Nasia Basin board were sampled purposively. In the absence of the head, assistants present and persons who are knowledgeable about the situation were interviewed. To ensure that the people with the right information are interviewed, this method was strictly adhered to.

#### *3.4.5.2 Sample Size*

The Nasia catchment comprises of 55,672 households (GSS, 2021). Among these households, 4% (equivalent to 2,400 households) rely on the Nasia river for their domestic needs, forming the basis of the sampling frame used to select a total of 147 respondents. The sample size was calculated using the formula, ! = % ______ &$$()* (Yamane,

1967), in which n is the sample size, N is the overall number of household in the six (6) selected communities, and e is the margin of error. With an 8% error margin (92% level of confidence), from a total household of 2400 the sample size was 147 (refer to Table 3.1).

The study used 8% margin of error against the social science standard of 5% because of the quantitative nature of the study (Puisa et al., 2023). By using 8% margin of error, the 147 sample size derived was representative enough of the population to draw conclusions considering the homogenous nature of the population under study hence does not require a large number of respondents. The sample size of 147 was meant for questionnaire administration for quantitative data analysis. Six focus groups comprising six individuals who were community heads were convened in the 6 study communities to provide qualitative information. Three institutions were also interviewed for information for qualitative data analysis as well. Table 3.1 gives a summary of the sample size from the various communities using a simple proportion method.

**Table 3.1: Sample size determination of selected communities in the Nasia catchment**

| S/No | Communities | No. of Household | Sample size (n) |
|---|---|---|---|
| 1 | Nasia | 1088 | %+„ ___ x 147 =67 -.++ |
| 2 | Sooba | 84 | „. ___ x 147 = 5 -.++ |
| 3 | Kokubila | 630 | /0+ ___ x 147 = 39 -.++ |
| 4 | Tamalgu | 138 | %0, ___ x 147 = 8 -.++ |
| 5 | Namburugu | 240 | $\frac{240}{2400}$ x 147 = 15 |
| 6 | Kpubo | 220 | $\frac{220}{2400}$ x 147 = 13 |
| | **Total** | **2400** | **147** |

Source: 2021 Population and Housing Census

### *3.4.6 Data Collection Methods*

Data collection in Nasia catchment took place in November 2021. Surveys are important and widely used in social research because it provides researchers the opportunity to estimate study characteristics for further detail analysis (Creswell, 2017) and allows researchers to efficiency and quickly collect data to ensure accurate measurements of study characteristics for generalisation (Creswell, 2017). This study employed surveys to gather data about climate change impacts on water availability, and how inhabitants cope with the issues of water scarcity.

Questionnaires were administered to respondents specifically household heads in the selected communities. Data from the household included the background information as well as those related to their climate change experience. It covered sociodemographic and economic characteristics of the respondents such as sex, age, educational background, household number, occupation and average monthly income.

In addition, other information obtained from the household heads included availability of water for domestic use as well as the various coping strategies employed in the catchment.

To support understanding, FGD guide was used to solicit information from community heads through FGDs on issues of climate change effects on domestic use of water and coping strategies. A total of six (6) focus groups were convened, one in each of the six (6) study communities, with six (6) discussants in each session, at convenient locations for both the participants and the researcher. Each discussion lasted for about 55 minutes. Community heads were interested and actively contributed since the issue under discussion was of utmost importance to them. The optimum size for a focus group is six to eight participants (excluding researchers) (Mishra, 2016). The reason being that small groups risk limited discussion occurring, while large groups can be chaotic, difficult to manage for the moderator and frustrating for participants who feel they get insufficient opportunities to speak (Mishra, 2016).

Through in-depth interviews with key informants, qualitative data was gathered using an interview guide. Each discussion lasted approximately 40 minutes to ensure that all themes were covered in the discussion. Discussions covered specific themes and included respondents' views on extensive variety of issues regarding the effects of climate change on domestic water use as well as coping strategies they adopt. All FGDs and interviews were tape-recorded as well as recorded in the field notebook which served as a backup to the recorded interviews. All the research instruments were developed after a thorough and extensive literature search on all issues relevant to the research taking into consideration the specific objectives of the research and the relationships to be established.

Field testing (or pre-testing) of research instrument was carried out. The purpose for pre-testing was to identify problems associated with the instrument in order to revise the instrument before the actual survey was carried out. FGDs were carried out to identify potential issues with the instrument and to ensure consistency in the design of the instrument. This provided qualitative insights that guided meaningful revisions. Some areas of concern included time required to administer the instrument, respondents' understanding and willingness to answer specific questions, correctness of sequence of questions among others. All issues/errors identified during the pre-testing of the research instruments were accordingly corrected before actual data collection. Pre-testing was conducted in the Buipe community of the Central Gonja District in the Savannah Region. The assumption underlying the choice of this community was that the Buipe community's environmental circumstances and population closely reflect those of the population under investigation (GSS, 2014).

Pre-testing and subsequent field data collection were carried out with the help of two field research assistants. They were selected from among colleagues and Research Assistants within the Department of Geography and Rural Development, Kwame Nkrumah University of Science and Technology, Kumasi. Experience in social science field research served as one of the primary criteria for selection during the recruitment procedure. All of the field research assistants received training to help them understand the requirements and the objectives of the research. The field researchers from the department were natives of the area and understood the language, hence obtaining permission from local authorities and communicating with the local people was not a barrier to the study.

### *3.4.7 Data Sources and Types*

#### *3.4.7.1 Data Sources*

Both primary and secondary sources of data were employed in the study. Secondary data in the form of daily rainfall and temperature data was provided by the Tamale Meteorological Agency, covering a period of 40 years (1981-2020). Daily discharge of the Nasia river from 1988 to 2010 were obtained from the Hydrological Service Department, Tamale. Landsat satellite photos were obtained from the United State Geological Survey (USGS) via their earth explorer website, for five different years (1980, 1990, 2000, 2010 and 2020) and were classified and analyzed to determine the extent of land use and land cover (LULC) changes and its implication on the river in the Nasia Basin. Primary data was obtained from household heads, community heads and key informants in the various selected communities within the Nasia river catchment.

#### *3.4.7.2 Data types*

Quantitative data was obtained from appropriate institutions such as the Tamale

Meteorological Agency, Hydrological Service Department and the United State Geological Survey (USGS) website in the form of secondary data. Quantitative data was also gathered through the administration of questionnaires to a cross section of household heads. The questionnaire was developed based on some of the study objectives. Data from the household included the background information as well as those related to their climate change experience. It covered socio-demographic and economic characteristics of the respondents such as sex, age, educational background, household number, occupation and average monthly income. In addition, other information obtained from the household heads included availability of water for domestic use as well as the various coping strategies employed in the basin.

Qualitative data was again collected from community heads through FGDs and key informants via in-depth interview to complement the quantitative responses from the household heads in the various communities. Data covered issues of climate change effects on domestic water use and coping strategies. This allowed for detailed information since information from questionnaire is limited and cannot be probed further. A FGD involves assembling people from similar experiences or backgrounds together to discuss a particular topic of interest. The purpose of the FGDs is to obtain data from a deliberately selected group of individuals rather than from a statistically representative sample of a broader population (Nyumba et al., 2018). Hence, FGDs help in gaining insights into people’s shared understanding of everyday life (Mishra, 2016).

### *3.4.8 Concepts/Variables, Definition and Measurement*

The term impact is often referred to as the consequence or outcome of a phenomena (IPCC, 2014). In this study, the dependent or outcome variable is the availability of water. Water availability has several different definitions (See Chapter 2). Quantity, quality, and timing are the three key determinants of water availability. Water availability in this work is defined to include not only the quantity, quality, and timing of the water, but also its usability. In this study, quantity is determined by discharge, hence discharge is the dependent variable. The independent variables that can influence water availability specifically discharge is temperature and rainfall.

### *3.4.9 Data Processing and Analysis*

#### *3.4.9.1 Analysis of rainfall and temperature data*

Trend analysis was conducted on the rainfall and temperature acquired, using both Mann-Kendell trend test and Excel 2016 with aid of the Python and Microsoft software respectively. Mann- Kendall test is one of the non-parametric tests that has gained dominance in climate trend studies (Li et al., 2018). These data were analysed using various descriptive statistics to reveal the trends and patterns of these variables. The alpha level was set at 0.05. In order to ascertain whether the climatological data exhibit a monotonic trend, the trend line, trend equation, and time series plots were utilised as proxies in the Nasia river catchment. The use of Mann-Kendall helps to explore relationships and patterns of temperature and rainfall (Chepkoech et al., 2018). Since

Mann-Kendall is insensitive to outliers and provides a precise computation of slope, it is substantially more accurate than simple linear regression for rainfall and temperature data that may be skewed and heteroscedastic (Campion and Venzke, 2013). The test is used for finding statistically significant trend in variables like rainfall, temperature and discharge (Da Silva et al., 2015). The test assumes that data set is randomly ordered and independent. It is a statistical method, which is frequently used to check the null hypothesis of no trend against the alternative hypothesis of the existence of monotonic increasing or decreasing trend of hydro-climatic time series data.

The Mann-Kendell test is statistically calculated with the formula

$$S=\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} \operatorname{sgn}\left(X_j - X_i\right) \qquad 1$$

The nonparametric Sen's approach can be used to estimate the true slope of the linear trend, Q. (Gilbert, 1987). To determine the slope of a linear trend, the Sen's method uses a linear model. A time series of identically spaced data was used to calculate the Sen's slope estimate, as indicated in equation (2):

$$Q=\frac{X_j - X_i}{j-i} \qquad 2$$

Where: Q = slope between data points $X_j$ and $X_i$

$X_j$ = data measurement at time j

$X_i$ = data measurement at time i, j

= time after time i,

A Sen's estimator with a positive value indicates an upward (increasing) trend in a time series data whiles a negative value indicates a downward (decreasing) trend in the time series data.

The Standardised Precipitation Index (SPI) is a widely used index to characterise meteorological drought (severe rainfall deficits) on any geographic location and range of timescales. The SPI indicator was developed by McKee et al. (1993). For any given region, severe rainfall deficits are indicated as SPI decreases below –1.0, while increasingly severe excess rainfall are indicated as SPI increases above 1.0. SPI values are in units of standard deviation from the long-term mean hence the indicator can be used to compare precipitation. The SPI was computed by taking the average of the annual totals. Wetness is shown by a positive (+) SPI value, whereas dryness is indicated by a negative (-) SPI value; however, the intensity is contingent on the SPI value. A positive anomaly for temperature indicates that the observed temperature exceeded the reference value, whereas a negative anomaly indicates that the observed temperature fell below the reference value.

#### *3.4.9.2 Analysis of the Impact of Climate Change On River Discharge*

The impact of changes in rainfall and temperature patterns on discharge were analysed using the Multiple Linear Regression Model in SPSS. The general multiple regression model is mathematically specified as:

$Y= \beta_0 +\beta_1 x_1 +\beta_2 x_2+\beta_3 x_3 \ldots\ldots\ldots.+\mu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$

Where;

Y is the dependent variable which is also referred to as the explained variable. It represents the variable we are trying to explain.

X1.....X3 are the independent variables. This quantity's variation will be utilized to account for variations in the dependent variables.

$\beta_0$ is the Y -intercept which corresponds to the expected value of Y when X = 0 (may or may not be meaningful). Typically, we are more interested in $\beta_1$ than $\beta_0$, but $\beta_0$ forms a vital part of any regression estimation.

$\beta_1$.......$\beta_3$ are the independent variables of the coefficients and $\mu_i$ is the error term. The coefficients determine the degree of the contributions of the independent variables on the dependent variable.

#### *3.4.9.3 Diagnostic Tests*

The diagnostic tests play a crucial role in assessing the effectiveness and robustness of the linear regression model. These tests include the examination of normality, multicollinearity and heteroscedasticity to evaluate the accuracy of the model's estimations. By conducting these diagnostic tests, we can confirm whether the model meets all the underlying assumptions. Moreover, the diagnostic tests determine whether the model is suitable for analyzing the data and assessing the impact of rainfall and temperature on river discharge. The reliability and validity of the regression results are established based on the outcomes of the diagnostic tests. Specifically, the absence of multicollinearity and heteroscedasticity, along with a normal distribution of residuals, confirms the model's robustness and validates the outcomes. This ensures the strength of the model and validates the results, making it suitable for drawing conclusions about the relationships between rainfall, temperature, and river discharge.

#### *3.4.9.3.1 Normality test*

Normality test is used to test regression model to determine whether the dependent variable and independent variable have normal distribution or not. Normality data is tested using the methods of Shapiro Wilks (SW) and Kolmogorov-Smirnov (SF). If the significant value is more than 0.05, it means the data is normally distributed. Normality test result is shown in table 3.2.

**Table 3.2: Normality test**

| | **Tests of Normality** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Kolmogorov-Smirnov (KS)** | | | **Shapiro-Wilk (SW)** | | | |
| **Variables** | **Statistic** | **df** | **Sig.** | **Statistic** | **df** | **Sig.** | **Explanation** |
| River discharge | .217 | 23 | .006 | .903 | 23 | .029 | Non-normal |
| Rainfall | .125 | 23 | .200 | .944 | 23 | .216 | Normal |
| Mean Temp | .151 | 23 | .186 | .954 | 23 | .348 | Normal |

Source: SPSS Data Processed, 2021

The significant value based on the normality test results (SW) for mean temperature and rainfall is 0.348 and 0.216 respectively. It means that the data is normally distributed. On the other hand, the normality test results (SW) for discharge is 0.029 meaning the data is non-normally distributed.

### *3.4.9.3.2 Square root transformation*

The primary objective of data transformation is to make the data more amenable to statistical assumptions, such as normality and constant variance, which are often required for certain statistical methods like linear regression. Transformations often reduce the complexity of the model by reducing the need for non-linear modeling. Square root transformation was used to transform the discharge data to normal data due to the data characteristics (for instance the skewness, the distribution among others). The square root transformation involves taking the square root of each data point. The formula for the square root transformation is: sqrt(x), where x is the original data point. The square root transformation is applicable to zero and positive values, making it suitable for datasets that may include zero values and useful for reducing the skewness of positively skewed data. By taking the square root of the data values, the transformation compresses the higher values more than the lower values, effectively "stretching" the lower end of the distribution. As a result, the data distribution becomes closer to a normal distribution, which is often a desirable property for many statistical analyses. The square root transformation is easier to interpret when compared to other transformations such as logarithmic or Box-Cox transformations. This is because it retains the original units of measurement. It is easier to understand the magnitude of the effect on the original scale using the square root transformation. After subjecting the river discharge data to a square root transformation, the statistical significance value obtained from the normality test (SW) is 0.133, indicating that the transformed data follows a normal distribution.

#### *3.4.9.3.3 Multicollinearity Test*

Multicollinearity test is used to test whether the independent variables are correlated or not. A regression model is good if there is no correlation between independent variables. Multicollinearity test can be done by calculating Variance Inflation Factor (VIF) and Tolerance Value in every independent variable. The criteria are if VIF ≥ 10 or Tolerance value ≤ 0.10.

**Table 3.3: Multicollinearity Test**

| **Multicollinearity Test** | | | |
|---|---|---|---|
| Independent variables | Collinearity Statistics | | Conclusions |
| | Tolerance | VIF | |
| Rainfall | .840 | 1.190 | No Multicollinearity |
| Mean Temp | .840 | 1.190 | No Multicollinearity |

Source: SPSS Data Processed, 2021

Based on the multicollinearity test result (table 3.3) the independent variables are not correlated.

*3.4.9.3.4 Heteroscedasticity test*

The Heteroscedasticity test examines the variation in residual variance among different observations in an inequality equation model. When the residual variance differs between observations, it is considered as heteroscedasticity, whereas the model is considered good if it exhibits homoscedasticity. To determine whether the variable shows heteroscedasticity or not, a plot graph can be utilized, plotting the predicted values of the dependent variable (ZPRED) against the residuals (SRESID). If the pattern on the graph spreads randomly, it indicates homoscedasticity.

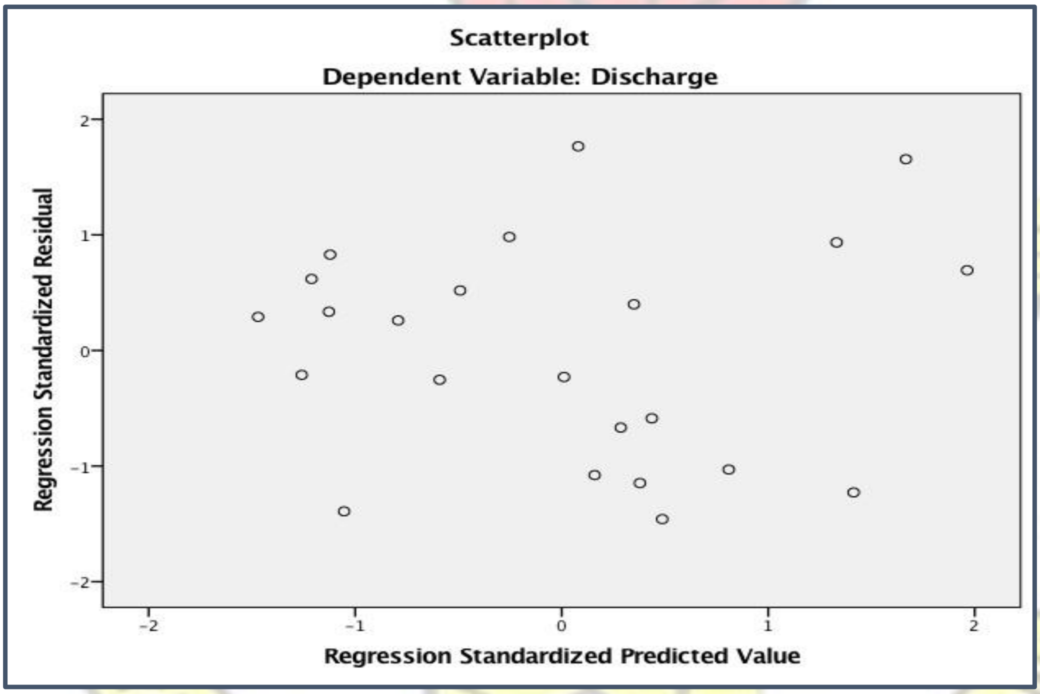


**Figure 3.2: Heteroscedasticity test**

Source: SPSS Data Processed, 2021

Based on figure 3.2 the residual data is spread randomly and didn't form a specific pattern meaning the variables have no heteroscedasticity in the regression model.

*3.4.9.4 Satellite Image Processing and Analysis*

To ascertain the extent of land use and land cover (LULC) changes in the Nasia river catchment, satellite photos specifically Landsat were obtained from USGS (table 3.4), and were classified and analysed for five different years (1980, 1990, 2000, 2010 and 2020) using QGIS software. The results of the 1980, 1990, 2000, 2010 and 2020 satellite images were broadly put into four classes: built up/ bare lands, vegetation, farmland and water (table 3.4.1). The results were analysed quantitatively in hectares on comparative basis to assess the pattern of change.

**Table 3.4: Satellite Images Characteristics**

| YEARS | SATELLITE IMAGE | DATE ACQUIRED | NO OF BANDS | SPATIAL RESOLUTION |
|---|---|---|---|---|
| 1980 | Landsat 5 TM | 22nd November | 7 | 30m x 30m |
| 1990 | Landsat 5 TM | 20th November | 7 | 30m x 30m |
| 2000 | Landsat 7 ETM+ | 26th November | 7 | 30m x 30m |
| 2010 | Landsat 7 ETM+ | 22nd November | 7 | 30m x 30m |
| 2020 | Landsat 8 OLS | 20th November | 7 | 30m x 30m |

(Authors' computations, 2020).

**Table 3.4.1: Land Use and Land Cover Classes**

| LULC Class | Description |
|---|---|
| Built-up/Bare lands | Sandy Lands, Bare Exposed Ground, Transitional Lands, Barren Land, Residential and Industrial, Housing, Mixed Urban or Built-up Land. |

| | |
|---|---|
| Farmland | Include all arable land |
| Vegetation | Areas covered by green forest, vegetative trees, Cropland and pasture, bush and shrub, and grassland. |
| Water bodies | Portion of the area covered by rivers, lakes and streams. |

(Authors' computations, 2020).

#### *3.4.9.5 Household Data Analysis*

Data collected through the field survey was critically examined and edited in order to ensure the consistency of responses. The data was cleaned, coded and entered into an electronic database and analysed using IBM Statistical Package for the Social Sciences (SPSS, version 23) and Microsoft Excel 2016. Descriptive statistics was used with the application of statistical tools such as bar charts, frequency, cross-tabulation embedded in (SPSS), to analyse the effects of climate change on domestic water use as well as the coping strategies employed in the area. Tables, graphs, and charts created in Microsoft Excel 2016 were used to display the study' findings. The use of graphs to view data provided a more appealing visual impression. Where necessary pictorial evidence was used as well.

Qualitative data obtained from FGDs and interviews on the effects of climate change on the availability of water for domestic use and coping strategies adopted in the study area, were analysed using the thematic analytical framework. A thematic analytical framework is a method for identifying, describing, categorizing, assessing, and recording themes discovered in a data set (Nowell et al., 2017). This analytical process included a number of phases. First, an English transcription of the audio recordings was done. All the FGDs were done using Mampuli (the main local dialect) and were later transcribed into English for analytical purposes. After that, the transcripts were carefully read. The transcript was arranged according to the themes of the study. To help readers understand what the themes are exactly about, they were given names and definitions. In order to avoid distorting or misrepresenting the perspectives of the research participants, the final thematic categories and sub-categories have been presented as narratives. Verbatim quotes from interview transcripts were used when applicable to highlight key points.

### 3.5 Ethical Issues

For studies involving human participants, ethical considerations are important due to the need to protect study subjects, the research method, and the validity of research results (Flick, 2009). This research ensured that the ethical concerns in the process of data collection were taken into consideration and as such, confidentiality and anonymity of the responses were ensured. Permission was sought from appropriate authorities and institutions before data collection commenced in order to gain entry into the study area. Thus, traditional rulers and appropriate institutions were briefed on the main purpose of the study. Likewise, before the appropriate action of carrying out interviews and administering questionnaires, permission was sought from all research participants. All interview participants were required to sign a participant consent form. This was after they were given information sheets that adequately clarified the research's intent and nature. That is, informed written and oral consents were obtained from all research participants. Again, all research participants were assured of the confidentiality of information. The participants were assured that all information received through data collection would be held with utmost confidentiality. Also, individual's right to decline to participate were respected in this study. Further, only pseudonyms were used in the analysis and presentation of data to protect the identities and anonymity of all research participants.

# CHAPTER FOUR

# THE IMPACT OF RAINFALL AND TEMPERATURE ON RIVER DISCHARGE AND CHANGES IN LAND USE/ LAND COVER IN THE NASIA CATCHMENT

## 4.1 Introduction

This chapter, first and foremost, analyses the trend in rainfall and temperature in the Nasia catchment over the last four decades and determines whether the trend is significant using MAKESENS trend test. Also, the chapter looks at the relationship between rainfall, temperature and discharge using multiple linear regression analyses in SPSS. Discharge was regressed against all the explanatory variables (rainfall and temperature). The changes in land use and land cover and its implication on the Nasia river was also analysed. It draws information from secondary data sources to explain the spatio-temporal incidence of water availability in the Nasia basin.

## 4.2 Analysis of the Rainfall Trend and Variability from The Period of 1981-2020

The trend of rainfall spanning over 40 years (1981-2020) in the Nasia catchment was analysed using Mann-Kendall trend test and the Sens slope (MAKESENS). Results are captured in Figure 4.1 and Table 4.1. The results show that there is monotonic upward trend of rainfall over the preceding forty years in the study setting, with a gradient of 2.4812 (Figure 4.1). However, the trend is not statistically significant as the probability value of 0.2301 is greater than 0.05 (Table 4.1). The result also revealed several variabilities in annual rainfall totals in the Nasia basin throughout the 40-year period. It is difficult to spot long-term trends in rainfall patterns since rainfall varies so much across years and decades. This finding justifies the conceptual framework, particularly the aspect of climate change with emphasis on rainfall variability. This finding is also in agreement with a discovery made by Adu-Boahen et al. (2019) in the Bawku West District, that there was annual variability in the amount and intensity of rainfall in the Northern region, implying the area is currently contending more with climate variability.

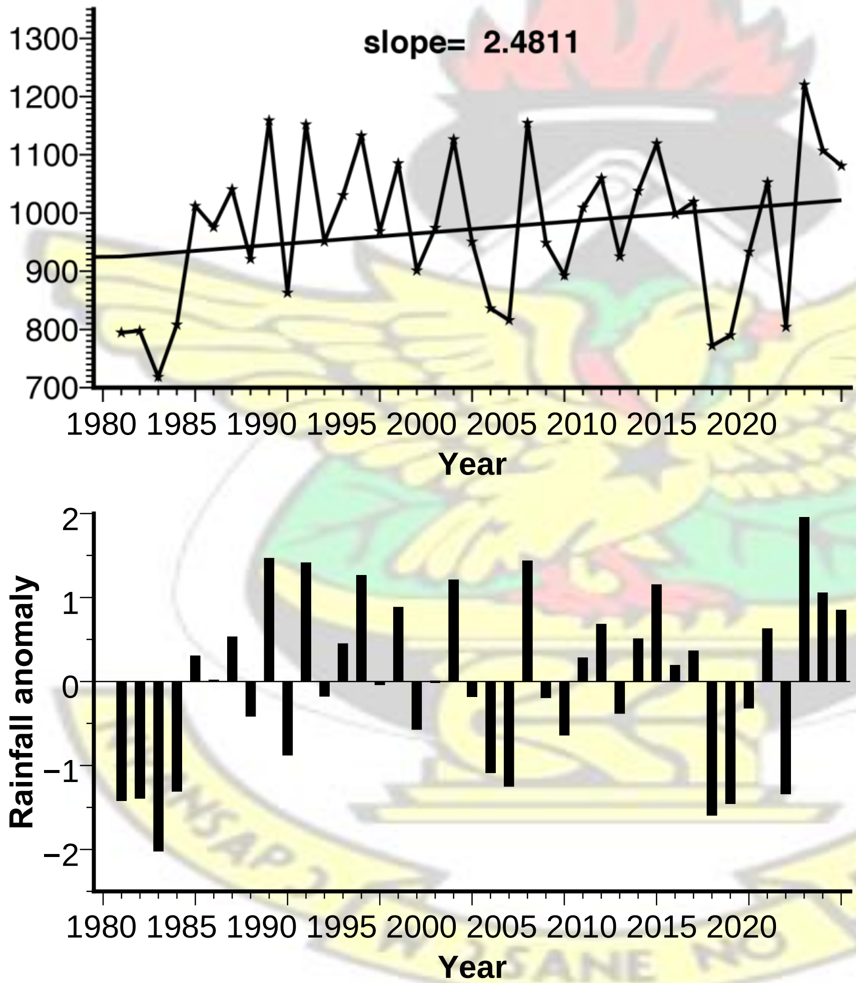


**Figure 4.1: Annual Rainfall Trend and Anomaly from Period of 1981 to 2020**

Source: Ghana Meteorological Agency

**Table 4.1: Mann-Kendall Trend Statistics for Rainfall in the Nasia Catchment**

| Description | Rainfall Statistics |
|---|---|
| p-value (one-tailed) | 0.2301 |
| alpha | 0.05 |
| Sen's slope | 2.4812 |

Source: Ghana Meteorological Agency

For the 40-year period, inter annual rainfall totals depict a usually high variability trend. While some years recoded rainfall values, which were above the mean rainfall of the study setting, others recorded less than the mean. Specifically, as shown in figure 4.1, while, 1981, 1982, 1983, 1984, 1988, 1990, 1992, 1995, 1997, 2000, 2001 2002, 2004, 2005, 2008, 2013, 2014, 2015 and 2017 had annual rainfall amounts below the baseline of 973.50mm, 1985, 1987, 1986, 1989, 1991, 1993, 1994, 1996, 1998, 1999, 2003, 2006, 2007, 2009, 2010, 2011, 2012, 2016, 2018, 2019 and 2020 had annual rainfall totals above the baseline (973.50mm). However, the values for the years 1986 (975.83mm) and 1998 (974.39mm) were closer to the baseline of 973.50mm indicating a fairly normal annual rainfall amounts (figure 4.1). The year 1998 had relatively low rainfall amount of 974.39mm among the annual totals above the basin's baseline. Within the 40-year period, (as indicated in Figure 4.1) the year with the highest and lowest annual rainfall amount was 2018 and 1983 with an associated total rainfall of 1220.21mm and 718.41mm respectively.

The forgoing analysis of the distribution of rainfall among the years implies that there is high inter-rainfall variability in the study setting. This might however have negative repercussions on the availability of water in the Nasia catchment used for domestic and other water applications. This finding corroborates the previous studies conducted by Oti et al. (2020) in the Densu River Basin and Mahe et al. (2013) in major river basins in North, West and Central Africa. Accordingly, both of these studies found that rainfall variability has reduce the streamflow of the Major river basin, affecting the availability of water used for domestic and other water applications.

The study further computed and analysed the anomalies of the total rainfall over the period of investigation based on the Standardised Precipitation Index ((SPI) (see Figure 4.1). This was required due to the importance of rainfall in ensuring water availability for domestic and other purposes for the basin's residents. The use of SPI was to identify years in the study area that were wetter or drier than others.

In Figure 4.1, the SPI value for 1983 is ≥- 2.0 implying an extremely dry year among the years studied. The years of 2018 and 2013 had SPI value between 1.5 to 1.99 and −1.5 to −1.99 respectively indicating very wet and dry years. The years 1989, 1991, 1994, 1999, 2003, 2010 and 2019, had SPI values between 1.0 to 1.49 indicating moderately wet years while 1981, 1982, 1984, 2001, 2002, 2014 and 2017 have SPI values between −1.0 to −1.49 implying moderately dry years (see figure 4.2). Also, 1985, 1986, 1987, 1993, 1996, 1998, 2006, 2007, 2009, 2011, 2012, 2016 and 2020 had

SPI values of 0.0 to 0.99 which suggest mild wetness. 1988, 1990, 1992, 1995, 1997, 2000, 2004, 2005, 2008 and 2015 recorded SPI values of 0.0 to −0.99, implying mild dryness. The overall observation shows great variability, hence it is difficult to pinpoint longest dry and wet periods marked by negative and positive anomalies. However, it is worth noting that the longest dry period was observed from 1981- 1984 while the longest wet period was from 2009 – 2012 for the 40-year period under investigation.

### 4.3 Analysis of the Temperature Trend and Variability from the Period of 1981-2020

The trend in annual maximum, minimum, and mean temperature values over the past forty years were also analysed. This was to help better understand the trend of temperature distribution across different years in the Nasia river catchment. As shown in Figure 4.2, annual maximum, minimum, and mean temperatures indicate increasing trends over the past four decades, with minimum temperature increasing relatively faster than the rest. The gradient of these trends are 0.0098, 0.0180 and 0.0125 respectively. The results also show that these trends are statistically significant at 0.05 (Table 4.2).

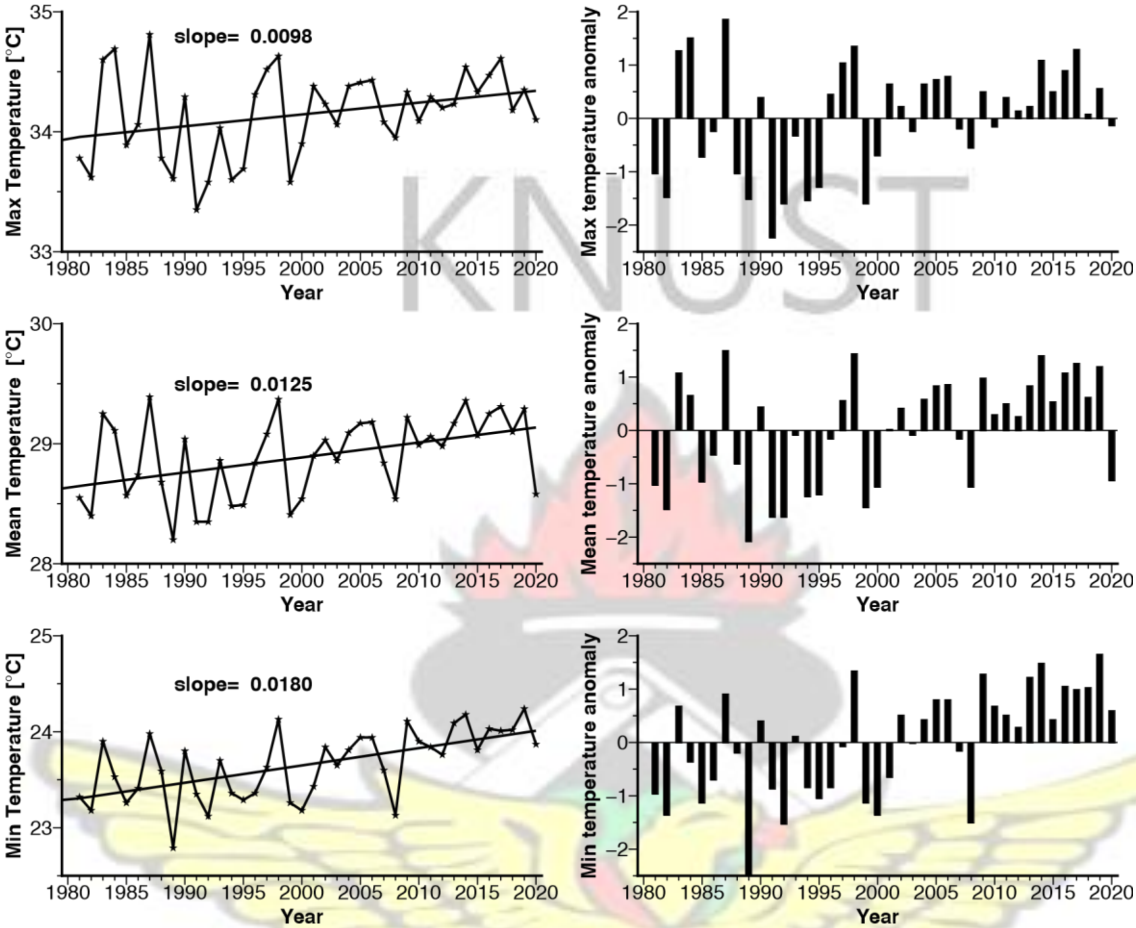


**Figure 4.2: Annual Trends and Anomaly in Temperature from 1981-2020 in the Nasia Catchment**

Source: Ghana Meteorological Agency

The trend of the minimum temperature was extremely significant relative to the increasing trends of both the maximum and mean temperature in the study setting (see Table 4.2). This finding is likely to have a considerable impact on the hydrological cycle of the basin, reducing water availability. This is because warming temperatures can directly influence the rate of evaporation in the catchment (Zhou et al., 2021) and consequently reduce availability of water used for domestic and other water applications in the study setting, an observation also made by Awotwi et al. (2015) in the Sekyere Kumawu District in Ghana. The finding of the study is similar to the previous studies conducted globally. For instance, Olujumoke et al. (2016) found an increasing trend of temperature in Nigeria (Akure) throughout the year. The predicted warming with temperature increases would however have adverse effects on water availability, human well-being and food security.

**Table 4.2: Mann-Kendall Trend Statistics for Temperature (Max., Min. And Mean) in the Nasia Catchment**

| Description | Temperature Statistics |
|---|---|
| **Maximum temperature (Tx)** | |
| P-value | 0.0475 |
| Alpha | 0.05 |
| Sen's slope | 0.0098 |
| **Minimum Temperature (Tn)** | |
| P-value | 0.0001 |
| Alpha | 0.05 |
| Sen's slope | 0.0018 |
| **Mean Temperature (Tm)** | |
| P-value | 0.0034 |
| Alpha | 0.05 |
| Sen's slope | 0.0125 |

Source: Ghana Meteorological Agency

The variability of temperature was also studied. Results indicate that maximum temperatures varied from 1981 to 2020, with a baseline of 34.15°C (Figure 4.2). Maximum temperature was observed to be very high in 1987, 1998 and 2017. The lowest maximum temperature occurred in the year 1991 while the highest maximum temperature was in 1987. During the 40-year, majority of annual maximum temperature values were above 34.15°C. These years include 1983, 1984, 1987, 1990, 1996, 1997, 1998, 2001, 2002, 2004, 2005, 2006, 2009, 2011, 2012, 2013, 2014, 2015, 2016, 2017,

2018 and 2019 while 1981, 1982, 1985, 1986, 1988, 1989, 1991, 1992, 1993, 1994, 1995, 1999, 2000, 2003, 2007, 2008, 2010, and 2020 had temperature values lower than the baseline value (Figure 4.2).

The minimum temperature, as shown in Figure 4.2, shows variability as well, but with faster increasing temperature than the maximum temperature. Between 1981 and 2020, the average minimum temperature was 23.66°C. Twenty years had minimum temperature values that were higher than the baseline value, with the exception of 2003, which had the same value as the baseline. These years include 1983, 1987, 1990, 1993, 1998, 2002, 2004, 2005, 2006, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019 and 2020 while 1981, 1982, 1984, 1985, 1986, 1988, 1989, 1991, 1992, 1994, 1995, 1996, 1997, 1999, 2000, 2001, 2007, and 2008 had values lower than the baseline (see figure 4.2).

Further, the basin had an average annual mean temperature of 28.89°C. The year 2001 had the same value; however, the years 1983, 1984, 1987, 1990, 1996, 1997, 1998, 2002, 2004, 2005, 2006, 2009, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018 and 2019 had values that were higher than the mean (see figure 4.2). The remaining years had values that were lower than the baseline value. The findings show an upward trend in yearly maximum and minimum temperature. However, with a slope of 0.018 and 0.010, Figure 4.2 clearly shows that the minimum temperature is increasing faster than the maximum temperature. The highest and lowest maximum temperature was respectively recorded in 1987 and 1991. However, same records did not apply to minimum temperature over the same period of investigation. The year 2019 had the highest minimum temperature, while 1989 had the lowest minimum temperature. This means that the warmest year was 1987, and the coolest year was 1989. With the exception of 2007 and 2008, minimum temperature began to increase consistently from 2002 to 2020, as seen in Figure 4.2. In comparison, the first two decades (1981-2000), annual maximum, minimum and mean temperature exhibited greater inter annual variability than the last two decades (2001-2020), indicating a continued temperature trend, which suggest an increasing temperature being experienced in the basin. In addition, while the maximum temperature decreased in 2020, the minimum temperature increased. The analysis demonstrates that maximum and minimum temperatures are rising, and this could influence evapotranspiration processes in the basin, and consequently have significant implications for streamflow and water availability. Simwela et al. (2018) reported that water supplies in many regions in Asia are expected to reduce due to increased evaporation and this is as a result of increased temperatures coupled with erratic rainfall.

The variability of the temperature was further analysed based on the anomaly index (see Figure 4.2). This was to see how far an observed value (temperature value) deviates from the dataset's average as well as determining how much warmer (positive anomaly) or colder (negative anomaly) it is at the Nasia river catchment at a specific period.

As indicated in Figure 4.2, the highest positive deviation of maximum temperature was in 1987 (34.81°C) with the highest negative being in 1991(33.35°C), implying that 1987 was the warmest year while 1991 was the coldest year for the 40-year period under study. From 1981 to 2000, maximum temperature recorded fourteen coldest years with the exception of 1983, 1984, 1987, 1990, 1997 and 1998 suggesting warm years. On the other hand, fifteen warmest years occurred from 2011 – 2020 with 2003, 2007, 2008, 2010 and 2020 indicating cold years.

From Figure 4.2, minimum temperature indicates that the warmest year within the study period was 2019 with 1989 being the coldest. Fifteen out of twenty years from 1981 – 2000 suggested colder years while 1983, 1987, 1990,1993 and 1998 recorded values above the reference value showing warming years while sixteen out twenty years indicate warming from 2001 – 2020 with 2001, 2003, 2007 and 2008 showing colder years.

With regard to the mean annual temperature, 1987 was warmest while1989 was the coldest in the data set. Fourteen years in the first two decades (1981 - 2000) showed annual mean temperature below the reference value indicating colder years while 1983, 1984, 1987, 1990, 1997 and 1998 were above the reference value suggesting warmer years. From 2000 to 2020, annual mean temperature recorded fourteen warmest years with the exception of 2000, 2003, 2007, 2008 and 2020 suggesting colder years. The year 2001 had value very close to the reference value (figure 4.2).

An important observation made from Figure 4.2, showing annual maximum, minimum and mean temperature for the 40-year period under investigation with few respites suggests that generally, colder years were recorded between 1981 to 2000, whereas warmer years have been observed after 2001 to 2020. This is clearly evidence of change in temperature over the study period. An increase in temperature is among the indications of global climate change. Similarly, Mabe et al. (2014) found out that the climate in the Northern Region of Ghana has gotten warmer during the previous 40 years. Besides, computing temperature anomalies over time is prudent, as the results may have an impact on the basin's water supply. Increasing temperature and rainfall variability in the basin could lead to water bodies drying up in the various communities. When this happens, it would result in water shortage and have great impact on communities that solely depend on the river for domestic and other purpose.

**4.4 Seasonal Rainfall and Temperature Distribution in the Nasia River Catchment**

The study further analysed the seasonal distribution of the climate patterns (temperature and rainfall) in the study milieu. Results are captured in Figure 4.3. The top panel shows the monthly distribution of rainfall and temperature and the down panel shows the rainfall anomaly. The basin has a unimodal rainfall regime. The rainy season spans from May to September. The months of July to September are often the wettest, with August being the peak. The peak month receives rainfall amount of 240mm on average. The down panel, which indicates the rainfall anomaly, is showing the wet and dry months. As shown in the down panel, the basin has five wet months starting from May to September with the rest of the months (October - April) being dry. This indicate that, the area has a longer drier season.

Temperature in the basin are usually high during the dry months and low during the rainy (wet) season (Figure 4.3). Maximum temperature varies from 33°C to 38°C during the dry months and from 29°C to 31°C in the wet months. Mean temperature varies from 28°C to 32°C in the dry month and from 26°C and 27°C in the wet season. Minimum temperature ranges between 22°C to 26°C in the dry month and between 22°C and 24°C in the wet season.

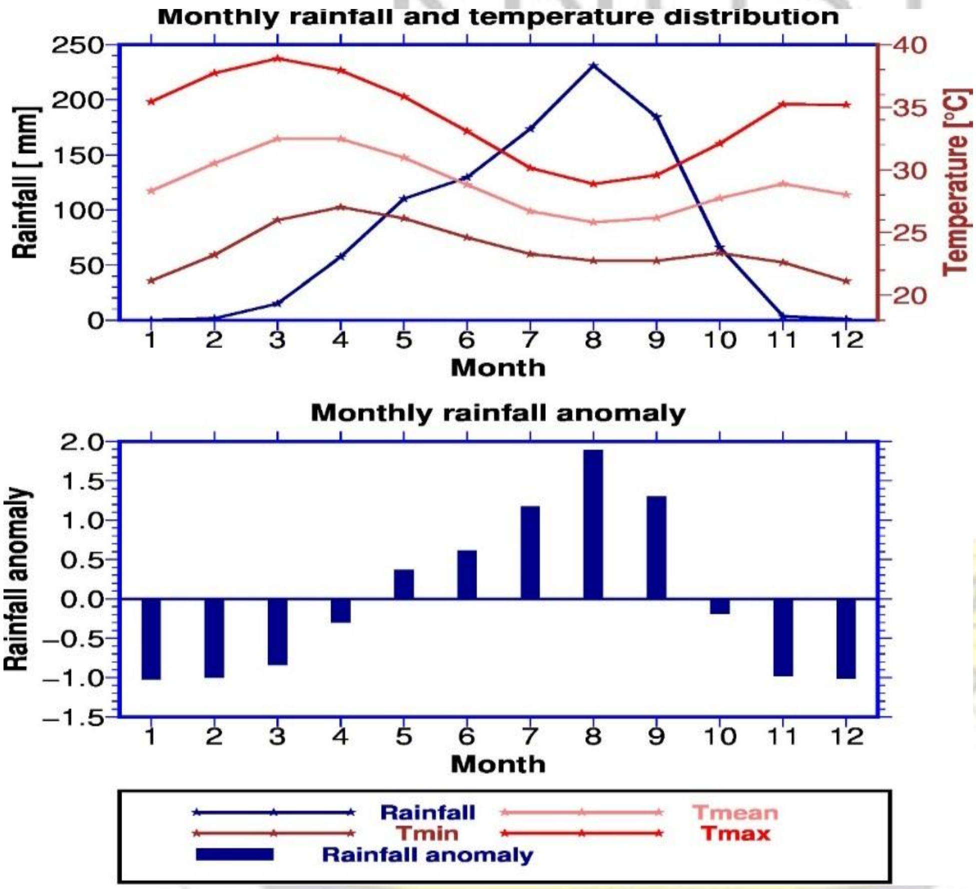


**Figure 4.3: Monthly Rainfall, Temperature Distribution and Monthly Rainfall Anomaly.**

Source: Ghana Meteorological Agency

### 4.5 Analysis of River Discharge Trend and the Impact of Temperature and Rainfall on Discharge from the Period of 1988-2010

#### *4.5.1 Discharge Trends*

The time series of annual average discharge during the period 1988–2010 at Nasia catchment is displayed in Figure 4.4. Results revealed inter annual variability and a generally decreasing trend in discharge in the Nasia catchment. Annual discharge was higher during 1989-1995 than the rest of years under study. The highest and lowest discharge was recorded in 1991 and 2015 respectively. The rate of decline in discharge is 11.0891.

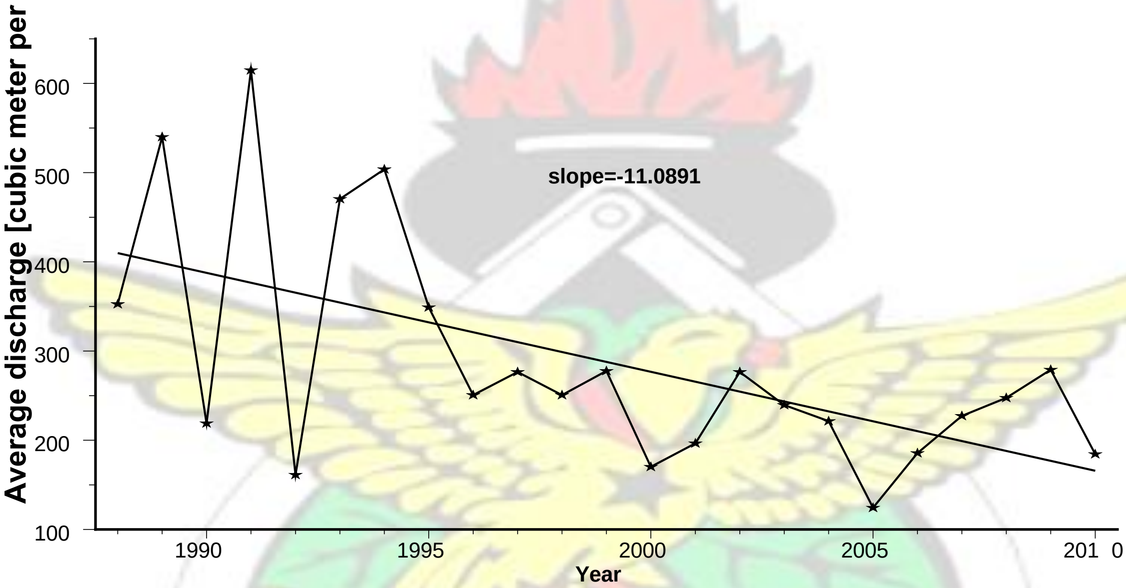


**Figure 4.4: Annual trends in discharge during the period of 1988-2010 at the Nasia catchment.**

#### *4.5.2 Temperature*

The coefficient of temperature quantifies the amount of discharge that is temperaturerelated. As per Table 4.3, a one percent increase in temperature causes a 168.627 $m^3/s$ reduction in discharge while holding all other factors constant in the Nasia catchment. This association is statistically significant, as shown by the probability value

(P- value) of 0.040. Discharge responds to changes in temperature implying that an increase in temperature is concomitant with river discharge in the catchment. Therefore, the null hypothesis ($H_0$) of no statistically significant effect of temperature on discharge is rejected. That is, there is a statistically significant relationship between temperature and discharge in the Nasia catchment, hence we reject $H_0$. This can be further explained by the fact that temperature in the last two decades (2009-2019) have increased by about $1.5^0$C and this is very significant to cause evapotranspiration in the catchment and consequently affect the discharge of the river. Similar findings were reported by Cherinet et al. (2019) in the Abbay River Basin of Ethiopia, where high temperatures during the study period (1980 to 2016) led to significant levels of evaporation, which in turn resulted in a decline in discharge. The fact that the discharge of the Nasia river is decreasing is detrimental for the residents of the basin who depend on it for domestic use and other livelihood activities. Temperature increases, are a warning indication for water shortages and possible droughts in the basin which is exacerbated by a long period of dry season.

#### *4.5.3 Rainfall*

Accordingly, when all other factors are held equal, a 1% increase in rainfall causes a 0.578 $m^3/s$ increase in discharge in the catchment. The probability value (P- value) of 0.023 reveals that this relationship is statistically significant (Table 4.3). Discharge responds to changes in rainfall implying that a proportionate increase in rainfall increases discharge and vice versa. The amount of discharge that is ascribed to rainfall is also measured by the coefficient of rainfall (mm). Therefore, the null hypothesis ($H_0$) of no statistically significant effect of rainfall pattern on discharge is rejected. That is, there is a statistically significant relationship between rainfall amount and discharge in the Nasia Basin, hence we reject $H_0$. This means that rainfall contributes or influences discharge in the Nasia Basin. Awotwi et al. (2017) noticed that rainfall directly affect discharge at Surma River in Bangladesh.

The F-statistic provides information about the overall significance and effectiveness of the regression model. The joint significance of each explanatory variable in the regression model is examined using the F-statistic. For this model, the F-statistic is 0.002. The adjusted R-squared shows the goodness of fit of the model and how proportionately the variations in the dependent variable is jointly explained by the independent variables. The adjusted R- squared value of 0.477 (Table 4.3) means that

47.7% of the total variability in river discharge can be explained jointly by rainfall and temperature. This further suggests that there are other important variables which could explain the variability observed in river discharge including LULC, soil composition, among others in the Nasia catchment. Therefore, drawing conclusions and making generalisations about the impact of climate change on river discharge in the Nasia catchment should be carefully done.

**Table 4.3: Linear Regression Results for River Discharge**

| **Explanatory variable** | **Coefficient** | **Std. Error** | **t-statistics** | **Sig. (**P- value**)** |
|---|---|---|---|---|
| Mean Temp | -168.627 | 76.665 | -2.200 | 0.040 |
| Rainfall | 0.578 | 0.234 | 2.471 | 0.023 |
| **Sig. F change (jointly)** | 0.477 | 113.51180 | | 0.002 |

Dependent Variable: River discharge

**Source (GMA, 2020 and HSD, 2020)**

### 4.6 Analysis of Land Use and Land Cover Change Between 1980 and 2020 and Its Implications on the Nasia River

The study conducted a land use and cover change to ascertain the implications of change on the Nasia river and the availability of water in the Nasia catchment. The results are analysed quantitatively in hectares on comparative basis to assess the pattern of change. The Nasia catchment has a total land area of 533,409.72 hectares. Table 4.4 indicates the land use/cover classes, area in hectares and their variations in percentages during the last forty years. The study classified the images into built up/bare land, farmland, vegetation and water bodies over a 41-year period from 1980 to 2020. In terms of area coverage, the LULC classes of 1980 imagery are used as base year of analysis (see figure 4.5). In 1980, the dominant land cover was vegetation with 50.27% of the Nasia catchment area, followed by farmland (37.10%), water (8.25%) and builtup/bare land (4.37%). Vegetation and farmlands in total covered 87.37% of the total land area of the catchment (table 4.4).

In 1990, vegetation decreased from 50.27% to 43.77%. Farmland decreased from 37.10% to 34.64%. Built up/Bare land increased from 4.37% to 21.08%. Water reduced reaching 0.51% of the land area (table 4.4). In 2000 land use classes showed significant increase in farmland to 50.97% in the area. Vegetation continues to decrease to 12.77% of the area. Built up/bare land on the other hand increased to 35.97% of the land area. Water reduced to 0.29% as shown in table 4.4. LULC in 2010 shows significant change with some overwhelming increase in water. The area of water in that year was 16.27%. This increase in coverage could be attributable to the flood incidence in the Volta Basin at that time (National Disaster Management Organization, 2010). Built up/ bare land increase to 39.26% of the area coverage. Vegetation and farmland in that year was 20.04% and 24.43% of the total area respectively (see table 4.4). The catchment has seen noticeable cover changes, as indicated by the catchment's increasing percentage of built-up and bare areas, which reached 62.81% in the 2020 image. Farmland reduced drastically to 3%. Vegetation covered 27.42%. Water reduced to 6.77% as indicated in table 4.4.

**Table 4.4: Land Use/Cover Classification Based On Landsat Images from 1980, 1990, 2000, 2010 and 2020.**

| YEAR (1980) | Land cover | Area (ha) | Area (%) | 1990-1980 | Area (%) | Annual change rate(Ha) | Area (%) |
|---|---|---|---|---|---|---|---|
| 1980-1990 LULC DYNAMIC | Built-up/Bareland | 23329.58 | 4.37 | 89121.97 | 382.01 | 8912.20 | 38.20 |
| | Farmland | 197914.23 | 37.10 | -13117.83 | -6.63 | -1311.78 | -0.66 |
| | Vegetation | 268165.56 | 50.27 | -34707.53 | -12.94 | -3470.75 | -1.29 |
| | Water | 43995.90 | 8.25 | -41295.17 | -93.86 | -4129.52 | -9.39 |
| **1990** | **Land cover** | **Area 1990 (ha)** | **Area (%)** | **2000-1990** | **Area (%)** | **Annual change rate(Ha)** | **Area (%)** |
| 1990-2000 LULC DYNAMIC | Built-up/Bareland | 112451.55 | 21.08 | 79404.48 | 70.61 | 7940.45 | 7.06 |
| | Farmland | 184796.40 | 34.64 | 87091.86 | 47.13 | 8709.19 | 4.71 |
| | Vegetation | 233458.03 | 43.77 | -165333.93 | -70.82 | -16533.39 | -7.08 |
| | Water | 2700.73 | 0.51 | -1165.93 | -43.17 | -116.59 | -4.32 |
| **2000** | **Land cover** | **Area 1990 (ha)** | **Area (%)** | **2010-2000** | **Area (%)** | **Annual change rate(Ha)** | **Area (%)** |
| 2000-2010 LULC DYNAMIC | Builtup/Bareland | 191856.03 | 35.97 | 17542.38 | 9.14 | 1754.24 | 0.91 |
| | Farmland | 271888.26 | 50.97 | -141582.60 | -52.07 | -14158.26 | -5.21 |
| | Vegetation | 68124.10 | 12.77 | 38797.18 | 56.95 | 3879.72 | 5.70 |
| | Water | 1534.80 | 0.29 | 85248.54 | 5554.39 | 8524.85 | 555.44 |
| **2010** | **Land cover** | **Area 1990 (ha)** | **Area (%)** | **2020-2010** | **Area (%)** | **Annual change rate(Ha)** | **Area (%)** |
| 2010-2020 LULC DYNAMIC | Built-up/Bare land | 209398.41 | 39.26 | 125659.62 | 60.01 | 12565.96 | 6.00 |
| | Farmland | 130305.67 | 24.43 | -114319.50 | -87.73 | -11431.95 | -8.77 |
| | Vegetation | 106921.28 | 20.04 | 39351.23 | 36.80 | 3935.12 | 3.68 |
| | Water | 86783.33 | 16.27 | -50690.34 | -58.41 | -5069.03 | -5.84 |
| **2020** | **Land cover** | **Area (ha)** | **Area (%)** | **2020-1980** | **Area (%)** | **Annual change rate(Ha)** | **Area (%)** |
| 1980-2020 LULC DYNAMIC | Built-up/Bare land | 335058.04 | 62.81 | 311728.46 | 93.04 | 31172.85 | 9.30 |
| | Farmland | 15986.17 | 3.00 | -181928.06 | 1138.03 | -18192.81 | -113.80 |
| | Vegetation | 146272.51 | 27.42 | -121893.05 | -83.33 | -12189.30 | -8.33 |
| | Water | 36093.00 | 6.77 | -7902.90 | -21.90 | -790.29 | -2.19 |

Analysed Satellite Imagery, United States Geological Survey (USGS) Earth Explorer

Source:

Between 1980 and 2020 there was remarkable increase in the extent of built-up/bare land from 4.37% to 62.81%, whilst farmland and vegetation cover drastically reduced from 87.37% to 44.47% over the same period. Vegetation has consistently reduced over the period whiles Built-up/ bare land has drastically increased and this could contribute to the increasing minimum and mean temperatures experienced in the Nasia catchment. Hence, if this persist, it will further exacerbate the reduction of the Nasia river as there would not be enough trees to prevent excessive evaporation. This result emphasises the importance of effective land use planning policies. These policies must encourage responsible land management practices, which play a crucial role in curbing greenhouse gas emissions and safeguarding biodiversity. Focusing on conserving vegetation, particularly in ecologically vulnerable areas, will facilitate carbon sequestration, thereby helping to mitigate climate change, enhance resilience to extreme weather events, and sustain water resources. This finding is consistent with that of Yaung et al. (2021) which found that reduction of areas under vegetation and expansion of settlements area contributed to the warming trends in Myanmar and Thailand.

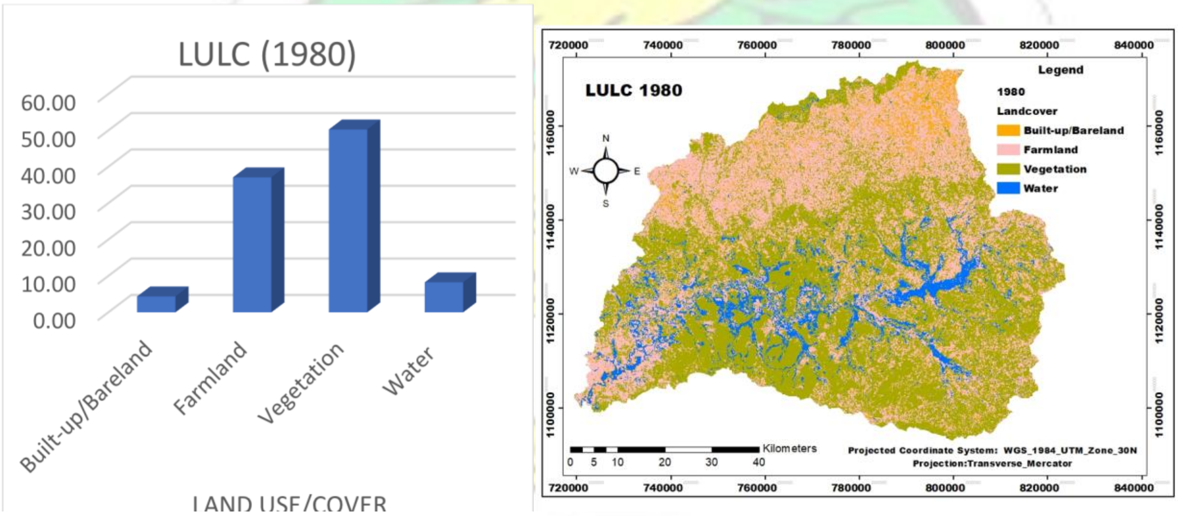


**Figure 4.5: LULC Categories for Nasia Catchment (1980)**

*Source:* Satellite Imagery, United States Geological Survey (USGS) Earth Explorer

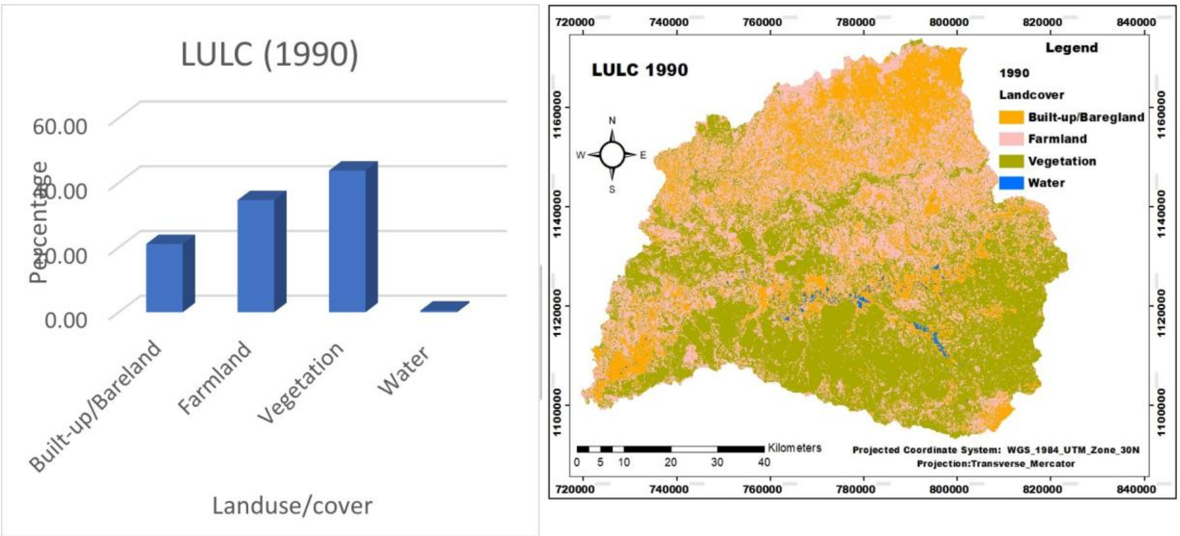


**Figure 4.6: LULC Categories for Nasia Catchment (1900)**

*Source:* Satellite Imagery, United States Geological Survey (USGS) Earth Explorer

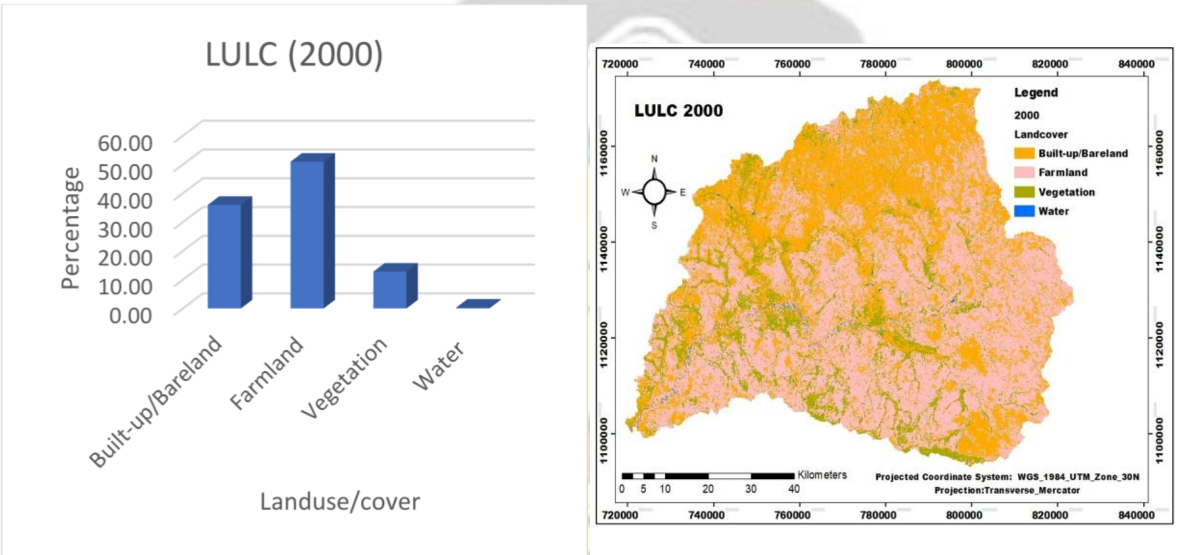


**Figure 4.7: LULC categories for Nasia Catchment (2000)**

*Source:* Satellite Imagery, United States Geological Survey (USGS) Earth Explorer

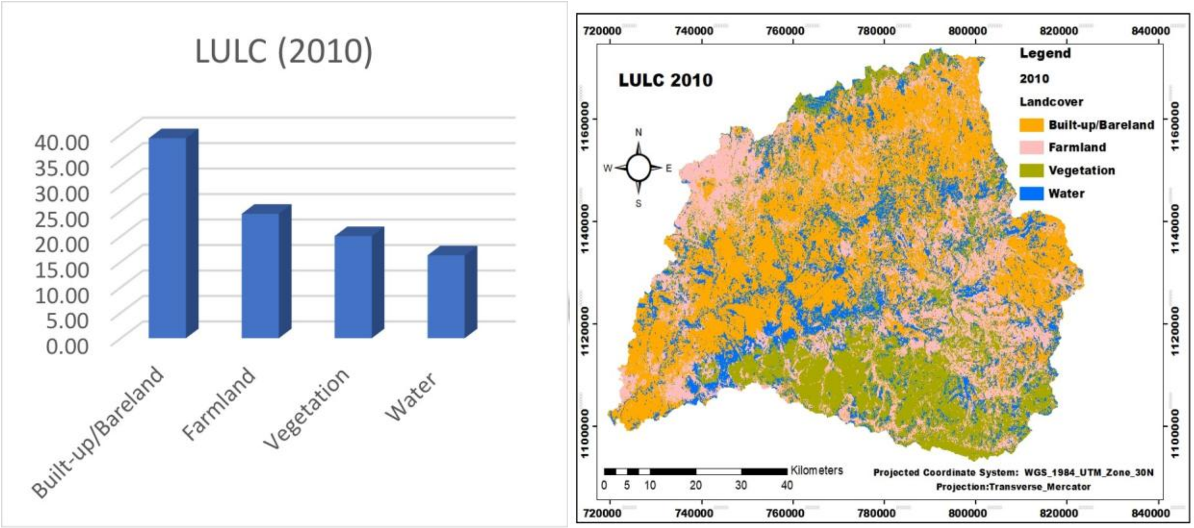


**Figure 4.8: LULC categories for Nasia Catchment (2010)**

*Source:* Satellite Imagery, United States Geological Survey (USGS) Earth Explorer

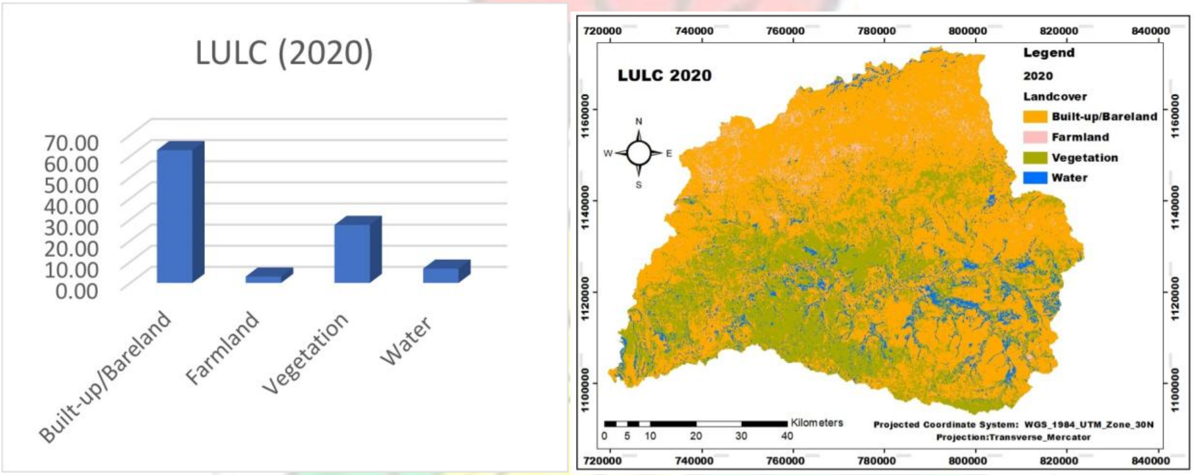


**Figure 4.9: LULC categories for Nasia Catchment (2020)**

*Source:* Satellite Imagery, United States Geological Survey (USGS) Earth Explorer

With the exception of 2010, when the Volta Basin experienced floods as a result of heavy rainfall in the savannah regions, compounded by spill water from the Bagre Dam in Burkina Faso (National Disaster Management Organization 2010(Accra, Ghana), the Nasia river has reduced in terms of size in hectares over the last five decades. A considerable percentage of the shrinkage is as a result of the exposure of the water body due to removal of vegetation and the farming activities around the Nasia river. One cannot help but agree with Aboagye et al. (2013) that while rainfall intensity appears to be linked to large floods in the savannah, the effect of human activities in increasing the frequency and intensity of flooding cannot be discounted.

### 4.7 Summary

The chapter discussed the impact of temperature and rainfall on river discharge and changes in land use/ land cover in the Nasia catchment. Annual maximum, minimum, and mean temperatures indicate increasing trends over the pasts four decades, with minimum temperature increasing relatively faster than the rest. Mean and minimum temperatures in the last two decades have increased by about $1.5^0$C and this is very likely to cause evapotranspiration in the catchment and consequently affect the discharge of the river.

The decline in discharge in the Nasia catchment corresponds to increasing trends in temperature and variability in rainfall. There exists an obvious relationship between temperature, rainfall and discharge in the Nasia catchment and this relationship is statistically significant. Therefore, the null hypothesis ($H_0$) of no statistically significant relationship between temperature and discharge as well as rainfall and discharge is rejected. That is, there is a statistically significant relationship between temperature and discharge and rainfall and discharge in the Nasia catchment, hence we reject $H_0$. The Nasia catchment is experiencing changing LULC. Between 1980 and 2020, there was remarkable increase in the extent of built-up/bare land, while farmland, vegetation and water bodies drastically reduced in the same period. Vegetation has consistently reduced over the period while built-up/ bare land has drastically increased and this could contribute to the increasing minimum temperature experienced in the Nasia catchment.

## CHAPTER FIVE

## PERCEIVED EFFECTS OF CLIMATE CHANGE ON WATER AVAILABILITY AND COPING STRATEGIES

### 5.1 Introduction

This chapter analyses the availability of water from the Nasia river for domestic use in relation to the effects of climate change in the catchment. The chapter presents the analyses and discussion of the primary data obtained from the field. It captures the demographic and socio economic characteristics of the respondents. Cross tabulation and frequencies have been used to present the responses of respondents concerning the effect of climate change on the availability of water for domestic use and their coping strategies amidst the changing climate.

### 5.2 Household Background Characteristics

As shown in table 5.1, a total of 48 representing 32.7% respondents were males while 99 respondents representing 67.3% were females. The study further reports 69.4%, 55.3% and 82.1% female household head and 30.6%, 44.7% and 17.9% male household head in West Mamprusi, Savelugu and Karaga respectively. The study's higher female representation can be attributed to the fact that females were at home at the time the data was collected.

In terms of age, an overwhelming percentage of respondents, 70.8%, 55.3% and 67.9% belonged to the age category of 41 to 50 years while 23.6%,27.7% and 17.9% of respondents were within the ages of 51 to 60 years and 5.6%, 17.0% and 14.3% is reported for respondents who were 61 and above in West Mamprusi, Savelugu and Karaga respectively (see table 5.1).

The analysis reveals that majority of respondents 76.2% had no formal education while 17.0% had basic education, 4.8% had secondary education and 2.0%, had tertiary education in West Mamprusi, Savelugu and Karaga respectively. Majority of respondents had no formal education, which reflects the low level of education in the study area. Communities with low-education are more likely to be unaware of the consequences of their behavior. When people are educated, they become aware of the need to preserve and sustainably use their rivers and other sources of water. Moreover, most of the household heads lack the requisite qualification to pursue positions in professional fields.

Hence, the study found that farming was the dominant occupation. Respondents in Karaga were all farmers (100%). Majority of the respondents in West Mamprusi 88.9% and Savelugu 85.1% were also farmers. Other forms of occupation that respondents were engaged in were fishing, artisanal work, petty trading, driving and teaching. The monthly income from these occupations was found to be above the minimum wage of GH¢319.14 in West Mamprusi (51.4%) while majority of respondents in Savelugu (68.1%) and Karaga (78.6%) earned below the minimum wage (see table 5.1).

The study revealed that most respondents (53.1%) had been farming for 41 years and above, 32.7% had been farming between 31-40 years, 8.8% between 21 -30 years, 2.0% between 10 -20 years, 3.4% for less than 10 years in West Mamprusi, Savelugu and Karaga respectively as shown in table 5.1.

According to the survey, a higher percentage (55.8%) of respondents had household sizes of 7 to 9 people, 34.7% had household sizes of over 10 people, while only 9.6% of respondents had 1 to 6 people making up the household (see table 5.1). The higher household size in the Nasia basin could be attributed to the traditional extended family and compound housing systems that urge families to live together in the same household in the study area (GSS, 2014). Therefore, with large households, the use and demand of water would be high and these would consequently put a lot of pressure on the available source of water.

**Table 5.1: Socio-Demographic and Economic Characteristics of Respondent**

| Variables | Categories | District/ Municipality | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | West Mamprusi | | Savelugu | | Karaga | | Total | |
| | | **Freq.** | **%** | **Freq.** | **%** | **Freq.** | **%** | **Freq.** | **%** |
| Sex | Male | 22 | 30.6 | 21 | 44.7 | 5 | 17.9 | 48 | 32.7 |
| | Female | 50 | 69.4 | 26 | 55.3 | 23 | 82.1 | 99 | 67.3 |
| | **Total** | **72** | **100.0** | **47** | **100.0** | **28** | **100.0** | **147** | **100.0** |
| Age | 41-50years | 51 | 70.8 | 26 | 55.3 | 19 | 67.9 | 96 | 65.3 |
| | 51–60years | 17 | 23.6 | 13 | 27.7 | 5 | 17.9 | 35 | 23.8 |
| | 61 and above | 4 | 5.6 | 8 | 17.0 | 4 | 14.3 | 16 | 10.9 |
| | **Total** | **72** | **100.0** | **47** | **100.0** | **28** | **100.0** | **147** | **100.0** |
| Educational level | No formal education | 55 | 76.4 | 37 | 78.7 | 20 | 71.4 | 112 | 76.2 |
| | Basic | 13 | 18.1 | 5 | 10.6 | 7 | 25.0 | 25 | 17.0 |
| | Secondary | 3 | 4.2 | 3 | 6.4 | 1 | 3.6 | 7 | 4.8 |
| | Tertiary | 1 | 1.4 | 2 | 4.3 | 0 | 0.0 | 3 | 2.0 |
| | **Total** | **72** | **100.0** | **47** | **100.0** | **28** | **100.0** | **147** | **100.0** |
| Size of household | 1-3 | 2 | 2.8 | 0 | 0.0 | 0 | 0.0 | 2 | 1.4 |
| | 4-6 | 9 | 12.5 | 2 | 4.3 | 1 | 3.6 | 12 | 8.2 |
| | 7-9 | 46 | 63.9 | 17 | 36.2 | 19 | 67.9 | 82 | 55.8 |
| | ≥10 | 15 | 20.8 | 28 | 59.6 | 8 | 28.6 | 51 | 34.7 |
| | **Total** | **72** | **100.0** | **47** | **100.0** | **28** | **100.0** | **147** | **100.0** |
| Occupation | Farming | 64 | 88.9 | 40 | 85.1 | 28 | 100.0 | 132 | 89.8 |
| | Fishing | 3 | 4.2 | 2 | 4.3 | 0 | 0.0 | 5 | 3.4 |
| | Trading/business/ driving | 3 | 4.2 | 2 | 4.3 | 0 | 0.0 | 5 | 3.4 |
| | Civil/Public Service | 1 | 1.4 | 2 | 4.3 | 0 | 0.0 | 3 | 2.0 |
| | Artisanal work | 1 | 1.4 | 1 | 2.1 | 0 | 0.0 | 2 | 1.4 |
| | **Total** | **72** | **100.0** | **47** | **100.0** | **28** | **100.0** | **147** | **100.0** |
| Average monthly income | Below GH¢319.14 | 35 | 48.6 | 32 | 68.1 | 22 | 78.6 | 89 | 60.5 |
| | GH¢319.14 and above | 37 | 51.4 | 15 | 31.9 | 6 | 21.4 | 58 | 39.5 |
| | **Total** | **72** | **100.0** | **47** | **100.0** | **28** | **100.0** | **147** | **100.0** |

Source: Fieldwork (2021)

### 5.3 Source of Domestic Water in the Nasia River Catchment

The source of water for domestic use in the study setting was investigated. Although it was not one of the study's objectives, it was suitable to explore whether residents sourced their household water from the Nasia river because the study planned to examine water availability in that river. Results of this investigation are captured in Table 5.2. The results show that Nasia river, standpipes, boreholes and wells are the major sources of domestic water in the Nasia river catchment. The Ghana Statistical Service (GSS, 2014) similarly reports these findings. Accordingly, the study reported that streams, rivers, lakes, wells, ponds, boreholes, and standpipes are the sources of water for residents in Ghana. This finding is also in agreement with Yeleliere et al. (2018), who cited that the common/dominant sources of water in Ghana are springs, streams, rivers, wells, dams and boreholes.

The study discovered that the dominant source of water for domestic applications, both the main and secondary sources, was from the Nasia river, 49.7% and 64% respectively (Table 5.2). The heavy reliance on the Nasia River is as a result of insufficient and unreliability of other alternative sources like standpipes and boreholes. More specifically, 55.6% respondents in West Mamprusi get their water from the standpipes, whiles in Savelugu 72.3% of respondent use both the standpipes and boreholes for domestic applications. However, in Karaga the source of water was solely the Nasia river. Aside domestic use, the river is used for farming, fishing, and as a means of transportation.

**Table 5.2: Source of Domestic Water in the Nasia River Catchment**

| **Source of water** | **Category** | **District/ Municipality** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **West Mamprusi** | | **Savelugu** | | **Karaga** | | **Total** | |
| | | **Freq.** | **%** | **Freq.** | **%** | **Freq.** | **%** | **Freq.** | **%** |
| Main | Nasia river | 32 | 44.4 | 13 | 27.7 | 28 | 100.0 | 73 | 49.7 |
| | Borehole | 0 | 0.0 | 9 | 19.1 | 0 | 0.0 | 9 | 6.1 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Public standpipe | 40 | 55.6 | 25 | 53.2 | 0 | 0.0 | 65 | 44.2 |
| | **Total** | **72** | **100.0** | **47** | **100.0** | **28** | **100.0** | **147** | **100.0** |
| Secondary | Nasia river | 40 | 59.7 | 33 | 70.2 | 0 | 0.0 | 73 | 64.0 |
| | Borehole | 0 | 0.0 | 2 | 4.3 | 0 | 0.0 | 2 | 1.8 |
| | Well | 0 | 0.0 | 8 | 17.0 | 0 | 0.0 | 8 | 7.0 |
| | Public standpipe | 27 | 40.3 | 3 | 6.4 | 0 | 0.0 | 30 | 26.3 |
| | Pond | 0 | 0.0 | 1 | 2.1 | 0 | 0.0 | 1 | 0.9 |
| | **Total** | **67** | **100.0** | **47** | **100.0** | **0** | **0.0** | **114** | **100.0** |

Source: Fieldwork (2021)

### 5.4 Source of Domestic Water by the Study Communities

The study further analysed the sources of water by the study communities (see Table 5.3). The results revealed that the main source of water for communities in peri-urban areas (Nasia and Kukobila) were standpipes and boreholes while that of rural communities (Sooba, Namburugu, Tamalgu and Kpubo) was solely rivers. Again, it was observed from the analysis that most respondents in peri-urban areas that is, Nasia and Kukobila had alternative source of water while their counterparts in the rural areas obtained their water solely from the Nasia river. It is worth noting that until the year 2012, the peri-urban areas also relied solely on the Nasia river. On this, the assemblyman at Kukobila recounted:

> Currently, we depend on the standpipes and boreholes for drinking and other domestic applications. However, the number of standpipes and boreholes are inadequate. We drink from the river when we are at the farm, and when the standpipes and boreholes are not functioning. Besides, we were drinking and using the water from the Nasia river before the provision of standpipes and boreholes. (Male, 42 years, FGD)

Sooba, Namburugu and Kpubo communities depend solely on the Nasia river for domestic and other applications whereas at Nasia, 40.3% of respondents use the Nasia river as the main source of water and 59.7% use the river as secondary source. In Kokubila, only 12.8% use the river as their main source and 84.6% as their secondary source (see table 5.3). All the respondents in Tamulgu depend on the Nasia river as their main source of water and well as their secondary source. The higher number of people at Nasia and Kokubila community who still depend on the Nasia river as a secondary source is linked to high population, and poor maintenance of standpipes and boreholes, making the water from these sources insufficient and unreliable for the increasing population. The sources of water for the Nasia community and other periurban areas are limited. A sub chief at Nasia during a FGD had this to say:

> The standpipes and boreholes are insufficient and unreliable to meet the water needs of the Nasia community; hence we continue to rely on the river. Most at times, the standpipes and boreholes do not function, thus we still rely on the river. (Male, 56 years, FGD)

Interestingly, an opinion leader at Nasia linked the preferred use of the Nasia river to its taste and the health benefits they derive from the root of trees in the river. This is what the respondent had to say:

> Most of us in this community do not like the taste of the water from the standpipes, hence we completely depend on the river for drinking and other domestic applications. When we use the standpipes to prepare Tuo zaafi, is like we have added saltpetre to it, but the water from the Nasia river is not like that. This is why we don't like to use water from the standpipes for domestic purpose. The river is also very healthy in comparison with the water from the standpipes because of the tree roots in the river. (Female, 59 years, FGD)

The finding reveals that the Nasia river was widely preferred for domestic applications even for communities with alternative source of water. This was exhibited in their dependence on the Nasia river for both primary and secondary use. However, in a FGD with community heads in Namburugu, they complained that Nasia River is the only water source available in the community. They further added that the aforementioned source of water is mostly dirty for domestic applications but they have no option but to use it. This is what one of the community heads had to say:

> Our greatest hurdle is water. We have the Nasia river as our only source of water for domestic and other applications and we also have to compete with cattle's for it. The river is really in a bad state especially in the dry season however; we cannot stop using it because without it we will perish. (Male, 51 years, FGD)

The inhabitants of Namburugu community further complained that during certain months, notably in March, their only source of water which is the Nasia river dries up. Due to this acute shortage, they compete not just with humans but also with animals for this scarce resource. Communities without alternative water supply thus become vulnerable to those who manage the limited water supplies. The PEA therefore argues that where water resource ownership belongs to certain communities, individuals outside these areas are considered free riders and are denied access to the resource.

**Table 5.3: Source of Domestic Water by the Study Communities**

| Source of Water | Category | Name of Community | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Nasia (peri urban) | | Sooba (rural) | | Kokubila(peri urban) | | Tamalgu (rural) | | Namburugu (rural) | | Kpubo (rural) | | Total |
| | | Freq. | % | Freq. | % | Freq. | % | Freq. | % | Freq. | % | Freq. | % | Freq. |
| **Main** | Nasia river | 27 | 40.3 | 5 | 100.0 | 5 | 12.8 | 8 | 100.0 | 15 | 100.0 | 13 | 100.0 | 73 |
| | Borehole | 0 | 0.0 | 0 | 0.0 | 9 | 23.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 9 |
| | Public standpipe | 40 | 59.7 | 0 | 0.0 | 25 | 64.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 65 |
| | **Total** | **67** | **100.0** | **5** | **100.0** | **39** | **100.0** | **8** | **100.0** | **15** | **100.0** | **13** | **100.0** | **147** |
| **Secondary** | Nasia river | 40 | 59.7 | 0 | 0.0 | 33 | 84.6 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 73 |
| | Borehole | 0 | 0.0 | 0 | 0.0 | 2 | 5.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 2 |
| | Well | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 8 | 100.0 | 0 | 0.0 | 0 | 0.0 | 8 |
| | Public standpipe | 27 | 40.3 | 0 | 0.0 | 3 | 7.7 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 30 |
| | Pond | 0 | 0.0 | 0 | 0.0 | 1 | 2.6 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 |
| | **Total** | **67** | **100.0** | **0** | **0.0** | **39** | **100.0** | **8** | **100.0** | **0** | **0.0** | **0** | **0.0** | **114** |

Source: Fieldwork (2021)

### 5.5 Water Availability for Domestic Use in the Nasia River in the Midst of Changing Climatic Conditions

The study investigated the availability of water for domestic water application from the users. This was to see whether the prevailing climatic conditions in the catchment has negative ramifications on the availability of water or not. To arrive at the conclusion, the researcher asked respondents several questions including quantity of water received from the river in relation to the past four decades, change in the color, smell of the river and shrinking nature of the river.

On the question regarding the quantity of water received from the river, respondents from Namburugu and Kpubo communities in the Karaga District indicated that the quantity of water they receive from the Nasia river is not adequate and it is more severe in the dry season when mostly the river completely dries up (see figure 5.1). This can be attributed to the fact that those areas are located at the inlet of the river hence the volume and size dwindle faster in the dry season. This can also be due to the change in climatic pattern over the past four decades.

However, Nasia, Kukobila and Tamalgu communities in the West Mamprusi Municipality and Savelugu District receive enough water from the river. This is attributed to their location at the outlet of the river where there is plenty of water. The low water quantities were blatant evidence of a water shortage in Nasia river at Namburugu and Kpubo, which was the only source of water for the people. In the FGD, a community head at Kpubo had this to say:

> Growing up, we were not facing this challenge, because the water was not drying up but we don't know what we have done to God. That rain does not come like the way it used to, which make the river normally dry up…. Thus, our challenge.
> (Female, 50 years, FGD)

A sub chief at Namburugu also reported that:

Hmm, we do not get enough water as we need and even with that, we compete with animals for water from the Nasia river because we have no option. (Male, 45 years, FGD)

This result supports Opare's (2018) claim that the main source of water for the residents of Dupong, the River Nsaakye, showed signs of a water deficit due to its low volume.

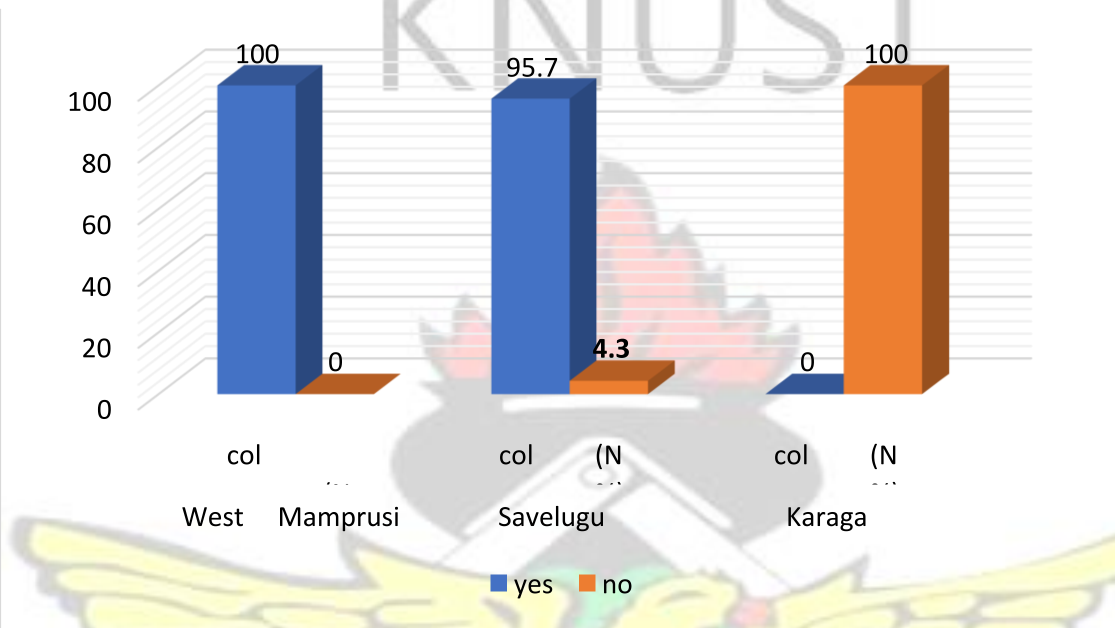


**Figure 5.1: Is the Quantity of Water that you Receive from the Nasia River Adequate?**

Source: Fieldwork (2021)

On the issue regarding the nature of the color of the Nasia river, most respondents (83.3%, 91.5%, 100%) in the West Mamprusi Municipality, Savelugu and Karaga Districts respectively cited that the color of the Nasia river has changed when compared with the past three decades (see figure 5.2). The changes of the color of the river could be attributed to erratic rainfall, which consequently causes flooding, and sediment and soil runoff, implying that climate change has effects on the Nasia river. Moreover, with all the runoff that flows into river after heavy rains, the river turns brown. Although, the color change is temporary, it becomes permanent after storms, if the river always carries a lot of sediment. It was also revealed that the struggle for water contributes to the change in the color sometimes as people move together to fetch water with some people riding donkeys and tricycle (motor king) into the river to fetch water at the same time. Moreover, some respondents indicated that uncontrolled use of the river also resulted in the change in the color of the water.

An opinion leader at Nasia in a FGD stated that:

> Most people do whatever they want when they go to the riverside to fetch water or to wash their cloths. They wash and pour the dirty water into the river. Those who fetch and sell water using motor king and horse also ride them into the river before fetching. Also, in the wet season, the river normally turns brown when it rains heavily. (Male, 51 years, FGD)

This can affect the availability of water for domestic application because the water is bad for usage. Flood occurrences are projected to increase (Kankam-Yeboah et al., 2010), which will consequently lead to pollution of water bodies that will restrict their use and availability.

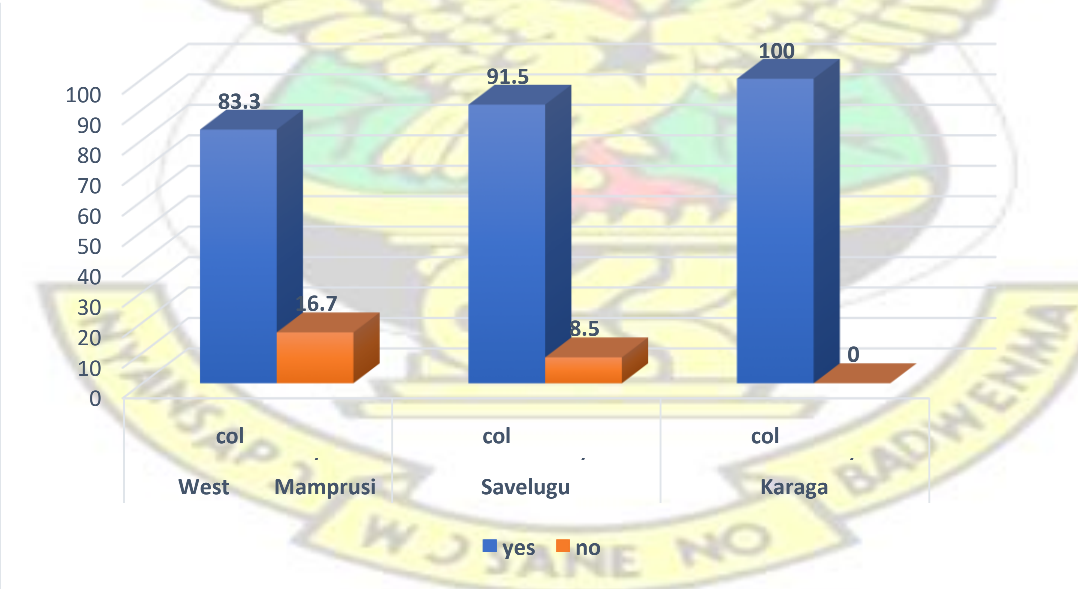


**Figure 5.2: Have You Noticed Change in the Color of the Water from the Nasia River?**

Source: Fieldwork (2021)

Respondents from the FGDs indicated that when the color of the Nasia changes, the river has a distinct odor. A higher percentage of respondents 88.9%, 80.9% and 100% in the West Mamprusi, Savelugu and Karaga Districts respectively stated that the water in the river smells sometimes, especially when the river color changes, partly due to floods (Figure 5.3). With regards to the nature (color and smell) of the river, a sub chief at Namburugu remarked:

> Due to irregular and heavy rains that causes flood during the wet season, the river becomes polluted with particles, elastomers, and chemicals from farmlands making the water unsafe for drinking and domestic use. However, we have no choice but to use it because we cannot survive without water.
> (Male, 64 years, FGD)

An opinion leader at Nasia in a FGD also reported that:

> The water sometimes smells, particularly in the dry season due to the leaves of the trees that fall in the river. (Female, 56 years, FGD)

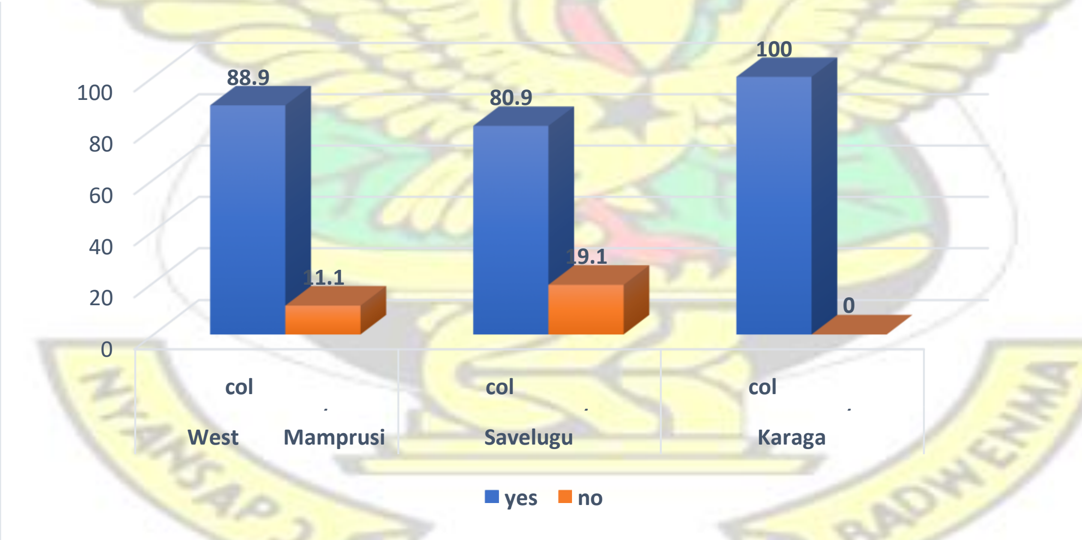


**Figure 5.3: Does The Water Smell?**

Source: Fieldwork (2021)

Whether the water at the Nasia river contains particles or not was also interrogated. Responses indicate that the water contain particles; however, no sample of water was sent to the lab to either affirm or reject the claim made by the respondents. This is reflected by the overwhelming majority (90.3%, 97.9% 100%) in the West Mamprusi, Savelugu and Karaga Districts respectively of household heads who indicated that the Nasia river contains a lot of particles (Figure 5.4).

This could possibly be attributed to climatic conditions in the basin. For instance, runoffs due to heavy rainstorm may remove nutrients from the soil and pick up pollutants, dirt, and other contaminants, discharging them into neighboring bodies of water. Moreover, people also leave rubbers among others behind as they go to fetch water and wash and this will eventually be deposited into the river. Since the Nasia river is unprotected, it is susceptible to a variety of contaminants, which has health implications for those who rely on it for domestic purposes, such as drinking. The presence of particles in the Nasia river, perhaps due to climatic conditions could affect its availability for domestic applications in the catchment. This confirmed the proposition that water for domestic use has been affected by climate change in the catchment.

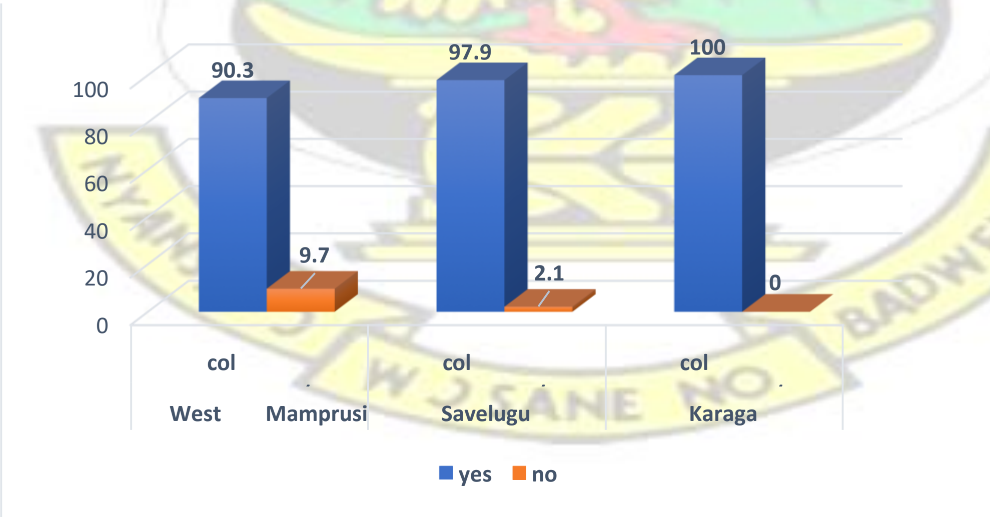


**Figure 5.4: Does The Water Contain Particles?**
Source: Fieldwork (2021)

All the study participants revealed that the Nasia river has shrank over the years (Figure 5.5). This was reinforced in the correspondence between the researcher and the FGD respondents, where comparable points of view were expressed. They expounded to the researcher that the size of the Nasia river had decreased dramatically, and it was even worse in the year 2000. The land use and land cover analyses for the year 2000 in comparison to the base year (1980) aided this response (see figure 4.8). In connection with this, one of the community heads recounted:

> We have been experiencing reduction in the size of the Nasia river however in the year 2000; the change in the size of the river was unprecedented. This was the worst in the history of the river. We experienced severe water shortage as a result.
> (Female, 58 years, FGD, Sooba)

These can be ascribed to human endeavors like farming along the river's bank. Farming along the Nasia river has led to the removal of the vegetation at the course of the river. Hence, the river is exposed to direct sunshine. The reduction in the size of the Nasia river has implications on the quantity of water in the river. The consequences of a deterioration in the quality and quantity of water resources may have an impact on water supply and the attainment of goal 6 of the SDG in Ghana. Freshwater resources are continually decreasing in quality and quantity (Yeleliere et al., 2018). This is at variance with the proposition that water for domestic use has not been affected by land use/land cover change of the catchment.

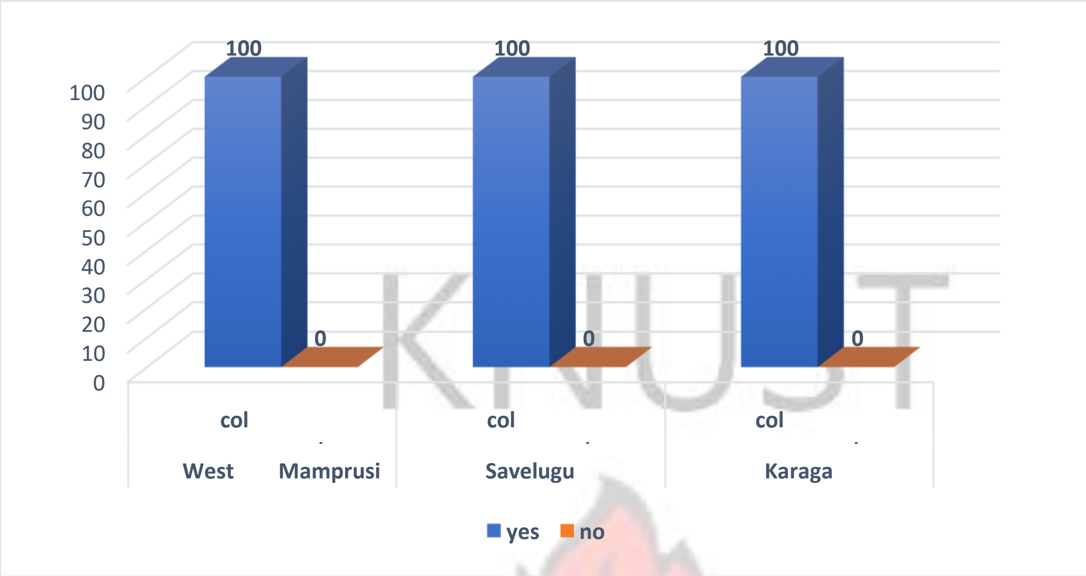


**Figure 5.5: Has The Nasia River Shrank in Size?**

**Source:** Fieldwork (2021)

The Nasia river shrinking in size has the consequence of lowering the amount of water available for domestic use. All respondents in the Karaga District (100%) cited that the change in the size of the Nasia river has negatively affected water availability for their domestic water application over the past years; however, that was not the situation in the West Mamprusi Municipality and Savelugu District (1.4%, 10.6%) respectively (Figure 5.5). Though the dwindling of the river in terms of size and volume had negative implications for all the Districts, the impact was much felt in the Karaga District where the respondent had no option than to rely solely on the river. This according to them have triggered water scarcity in their communities (Namburugu and Kpubo in the Karaga Districts).

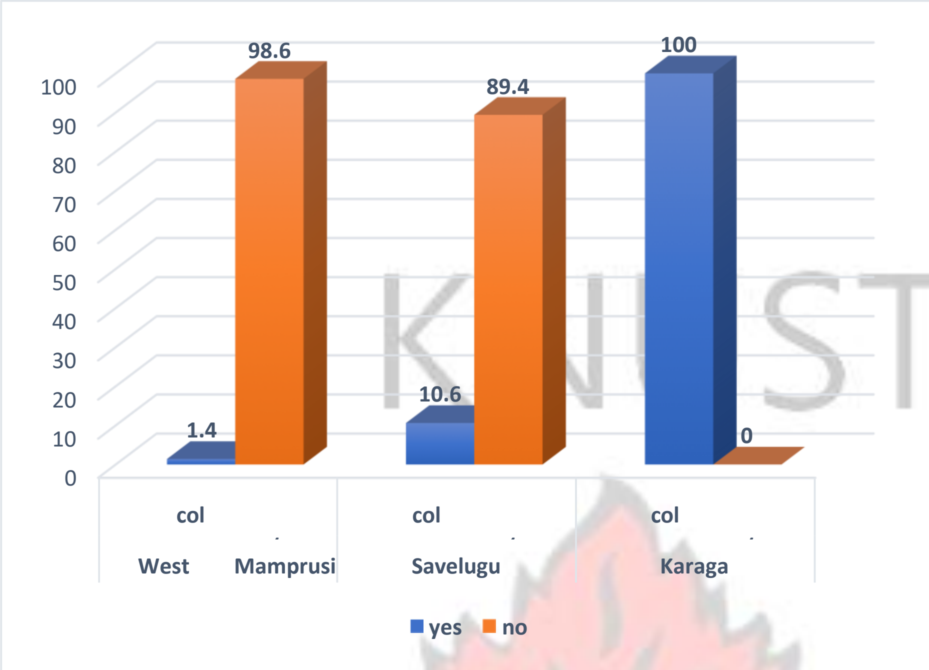


**Figure 5.6: The Effects of River Shrinkage On Water Availability** Source: Fieldwork (2021).

The fact that people in Karaga District face water scarcity is not surprising (see table 5.6), given that the study community do not have alternate water sources, as shown in table 5.3. Water scarcity in Karaga District is tied to the physical concept of scarcity as evidenced by insufficient water availability, lack of alternate water sources, poor water quality, and the length of time spent getting water. According to the study, the demand for water for household purposes has outpaced the available water supplies. At Kpubo, a sub chief expounded the issue of water scarcity in a focus group discussion:

> The issue of water scarcity in our community has been a headache since… especially in March. However, for the past three years the shrinkage in the size of the river, which has consequently reduced the volume of the water has exacerbated the situation, we struggle to get water as early as mid-January. During those periods, we will have to go the river at dawn when we are able to scoop something that looks like water. We hardly bath and mostly reuse the water we have at hand. (Male, 70 years, FGD)

This finding validates the assertion of Adjei-Mensah and Kusimi (2020) that water resources are diminishing and that this has exacerbated water demand in Sekyere Kumawu District in Ashanti Region.

An opinion leader had this to say at Namburugu:

> We use water for almost everything in this community. Hence, we have no option but to use the unclean water. Sadly, water used for these domestic purposes are kept and reused again for other purposes as well because of the scarcity of water in the community (Female, 57 years, FGD).

These responses from respondents show the difficulties people face every day in getting access to water for domestic and other applications. This illustrates severe shortage of water in the Karaga District. At Kokubila in the Savelugu District, however, respondents have different experiences with regards to water shortage as a result of the reduced size of the river. A 45-year-old female participant at Kokubila said this in a focus group discussion:

> The Nasia river has reduced in size relative to the past years, but has not dry-up totally. We have abundant of water therefore we don't experience any water scarcity. However, I strongly believe that, in years to come, if nothing is done to combat the current situation the river would completely dry up. (Female participant)

The study found that water shortage was mostly experience at the inlet of the river.

**Table 5.4: Experience of Water Scarcity**

| | **District/ Municipality** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **West Mamprusi** | | **Savelugu** | | **Karaga** | | **Total** | |
| | | **Freq.** | **%** | **Freq.** | **%** | **Freq.** | **%** | **Freq.** | **%** |
| Are you experiencing water shortage for domestic use | Yes | 0 | 0.0 | 0 | 0.0 | 26 | 100.0 | 26 | 83.9 |
| | No | 0 | 0.0 | 5 | 100.0 | 0 | 0.0 | 5 | 16.1 |
| | Total | 0 | 0.0 | 5 | 100.0 | 26 | 100.0 | 31 | 100.0 |

Source: Fieldwork (2021)

**5.6 Perceived Causes of Water Shortage in the Nasia River Catchment**

Changing climatic conditions among others in the Nasia basin has led to prolonged dry season which has also resulted in periodic drying-up of the Nasia river especially at the inlet and consequently causing scarcity of water for domestic and other applications. In a FGD, community heads attributed the water shortage especially in Karaga District to climate variability and change. Participants explained that although they have limited water points, the changing climatic patterns is worsening the water shortage in their communities, because the availability of water from the Nasia river (their main water source) have been reduced in recent times due to climate variability. In connection with this, one respondent in Namburugu in the Karaga District recounted:

> The rainfall pattern this time is like "family planning" it does not give birth to children… The duration of rainfall is very short in comparison with years back. This has reduced water availability in the Nasia river, causing water scarcity in this community. (Male, 49 years, FGD)

Another respondent in Kpubo had this to say:

> Changes in climate particularly rainfall variability has negatively affected the availability of water from the Nasia river. In years of copious rainfall, the water does not dry up but in years of less rainfall, the river dries up around March. In some years too, the water dries up preceding the cessation of rainfall (that is around October-November). This situation has trigger water scarcity in the community. We barely get water from the basin in such years for our domestic and other applications. We spend almost all our time at the river collecting water due to the unavailability of water ensuing from the rainfall variability and high temperature. Sometimes, there is competition for the water from the river between and among human and animals. (Female, 65 years, FGD)

The hydrological Service Department also made mention of recording low flow (discharge) in the Nasia river and linked it to rainfall variability. A key informant from the Hydrological Service Department reported that:

> Even though discharge recorded in previous years varied in the dry and wet season across years, the current situation is unpredictable. Now even within wet season the discharge record varies across years with varying trend. For instance, in a certain year discharge recorded can be high and low in the following year. (Male respondent, IDI)

This finding corroborates the findings of Andah et al. (2014) that lower rainfall amounts over the years as a result of lengthier dry seasons have led to main rivers and their tributaries drying up quickly, leading to reduced amounts of surface water available to meet the demands of the increasing population. Niang, et al. (2017) reported that Africa would experience future decrease in water availability stemming from series of drivers including climate change. In Ghana, climate change predictions imply that extreme weather events will negatively affect rivers and other water bodies in the near future (Oti et al., 2020). The study revealed that extreme temperatures and rainfall variability has negatively affected the Nasia river for domestic applications. This was manifested in the shrinking, breaks and dry up of the river in some parts of the basin, which has greatly impacted on volume of water in the river. Asamoah and Ansah-Mensah (2020), noted that changes in temperature and precipitation have dire consequences on water security. This finding validates that of Adjei-Mensah and Kusimi (2020), who reported a reduction in the water resource base for domestic water provision in the Sekyere-Kumawu District of Ghana and this reduction is perceived to be as a result of rising temperature and declining rainfall amounts.

Apart from the meteorological variables that contributed to the study's water scarcity, respondents also mentioned non-climatic factors that contributed to their water shortage.

These factors as mentioned by the respondents during the FGD and the indepth interview were; geological formation (poor aquifers) of some of the study communities and human activities. Concerning the poor aquifers, a board member of the Nasia basin explained it this way:

> Countless efforts have been made by the various Municipal Assemblies and NGOs to drill borehole to provide safe drinking water for the Sooba community in West Mamprusi and Namburugu and Kpubo in Karaga District but to no avail due the geological formation of the area (poor aquifers). (Board member, IDI)

Some of the respondents also made mention of certain activities including cutting down of the trees and farming close to the river basin. These factors were mentioned based on their knowledge through diverse experiences and observations. In this regard, an opinion leader in the Namburugu community narrated:

> We used to have lots of trees close to the river basin, but as it stands now, most of the trees have vanished due to cutting down of trees that protected the river from direct sunshine. This has greatly not only reduced the river size but also the quantity of water. (Male, 69 years, FGD)

This finding corroborates the Land use/land cover analysis (see table 4.4) which revealed that vegetation is decreasing as well as water over the past four decades.

### 5.7 Coping Strategies in the Nasia River Catchment

Given the importance of water in our daily lives, coping strategies are needed to avert significant societal impacts amidst the changing climate. The implementation of these coping strategies by respondents varied across the six communities in the three districts. The study revealed that in West Mamprusi and Savelugu, majority (52.4%, 78.7%) of the respondents respectively engage in rain harvesting, adding alum and filtering of water before use (Table 5.7). However, all respondents in Karaga cited rainharvesting, reuse, reduced use of water, adding alum, filtering and boiling of water before use as coping strategies amidst the changing climate. The major reason accounting for the variation among the districts may be due to the location of Karaga District at the inlet of the river and lack of alternative water source. For instance, communities such as Sooba in West Mamprusi and Tamalgu in Savelugu District which do not have any alternative source of water but the Nasia river however by virtue of their location at the outlet of the river had the advantage of having water available for domestic applications during dry seasons than Namburugu and Kpubo in the Karaga District. It is therefore not surprising that all respondents in Karaga resorted to reuse and reduced use of water in addition to what respondents in the other districts cited.

In addition, (see table 5.7), 7.5%, 5.4% and 9.5% respondents employ rain harvesting only, rain harvesting and filtering only and rain harvesting, adding alum and filtering water only respectively. Community heads in a FGD shared similar views with respondent on the coping strategies. Among all, water harvesting, adding alum and filtering of water particularly appeared to be the most used strategy for domestic applications. Rainwater harvesting from the rooftops during rainy season is very helpful. This is what a discussant had to say:

> We jubilate during the rainy season and forget our problem of water scarcity. The water we collect during this time is comparatively better than what we fetch from the river. We don't have to worry about distance to the river or the state of the river. (Male, 47 years, FGD)

This finding corresponds with Yannopoulos et al. (2019) and Owusu and Teye (2015), who observed that rainwater is free, and gathering it requires only a few simple supplies. Moreover, rainwater is predominantly a good choice for rural populations to obtain clean water for domestic application and this helps to minimise issues of water supply.

Likewise, rainwater can be used to minimise water loss and at the same time augment water supplies in any watershed systems. These findings confirm some of the coping strategies on the conceptual framework.

**Table 5.5: Coping Strategies**

| Coping strategies | District/ Municipality | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | West Mamprusi | | Savelugu | | Karaga | | Total | |
| | Freq. | % | Freq. | % | Freq. | % | Freq. | % |
| Rainwater harvesting(RH) | 10 | 13.9 | 1 | 2.1 | 0 | 0.0 | 11 | 7.5 |
| Rainwater harvesting and adding alum to water before use | 8 | 11.1 | 0 | 0.0 | 0 | 0.0 | 8 | 5.4 |
| Rainwater harvesting and filtering water before use | 14 | 19.4 | 0 | 0.0 | 0 | 0.0 | 14 | 9.5 |
| Rainwater harvesting, adding alum to water before use and filtering water before use | 40 | 55.6 | 37 | 78.7 | 0 | 0.0 | 77 | 52.4 |
| RH, reuse of wastewater, reduced use of water, adding alum, boiling water and filtering water | 0 | 0.0 | 9 | 19.1 | 28 | 100.0 | 37 | 25.2 |
| **Total** | **72** | **100.0** | **47** | **100.0** | **28** | **100.0** | **147** | **100.0** |

Source: Fieldwork (2021)

The Municipal assemblies also made mention of some programs ongoing to help provide safe water for the people and to restore the river catchment. A key informant from the Water and Sanitation Department in West Mamprusi reported:

> In June, 2021, Saha developed a water business model in collaboration with CRS and WAN as an alternative to providing safe drinking water to communities with low groundwater potential, such as Sooba in the West Mamprusi Municipality. Some women are responsible for collecting raw water from the Nasia river, treat it in poly tanks and barrels with chlorine (alum) and other purifying tablets before selling it to households at low prices. The NGOs also provided Saha Clean Storage Containers (CSC) to the households, which they use to transport treated and safe water to their homes for domestic use. (Water and Sanitation Department, IDI)

**Plate 5.1: Water Business at Sooba**

A sub chief at Sooba who was pleased with the intervention remarked:

> With the introduction of the Water Treatment site in Sooba, we now have access to treated and safe water for drinking hitherto we drank dirt not water from our river. (Male, 78 years, FGD)

The board member of the river basin reported that the board is working with the Municipal/District Assemblies to restore the basin back to its original state. He further stated that this could go a long way to solve the problem of water scarcity for the unborn generation, resulting in a reliable supply of water from the Nasia river. The trees along the river, which serve as shade and buffer to protect the river from direct sunshine and further prevent extreme evaporation, have been cut down. Currently, we are encouraging the chiefs to plant trees along the river where they have authority and also ensure that their people do not encroach the Nasia river for whatever reason. The board member in an in-depth interview recounted that:

> Restoration of the Nasia river basin as well as its sustained use is of priority to us now. Encroachments near water bodies must be avoided. Afforestation will prevent streams from drying up and rivers from receiving less runoff. We are putting in place specific legislation which will be enforced to discourage

> widespread deforestation and ensure that afforestation projects are carried out responsibly. (Nasia board member, IDI)

This study agrees with Adjei-Mensah and Kusimi (2020) that municipal assemblies must enforce buffer zone laws around water bodies to stop the encroachment of surface water resources. Afforestation is one of such acceptable environmental management method that should be promoted through education and sensitization.

**5.8 Summary**

The chapter dealt with the perceived effects of climatic condition on water availability and coping strategies. The study found that the river contains particles, has odor and has changed in color and this was mostly experienced during the wet season. However, no sample of water was sent to the lab to either affirm or reject the claim made by the respondents. Communities in West Mamprusi and Savelugu had sufficient water for their domestic applications due to high volumes of water in the Nasia river at that location and also had access to standpipes and boreholes. Water dearth was obvious in the low volumes of the water in the Nasia river at Namburugu and Kpubo, which was the only water source for the people.

Communities were found to have adopted different coping strategies. In West Mamprusi Municipality and Savelugu District, rainwater harvesting, adding alum to water before use and filtering water before use were the dominant coping mechanisms. However, reuse of wastewater and reduced use of water were adopted in Namburugu and Kpubo communities in Karaga District in addition to the ones adopted in the other study areas. Aside the short-term reactive responses employed mainly during the longer drier season experienced in the catchment, the households and communities did not have adaptation mechanisms to enable them diminish the ills of water scarcity.

# CHAPTER SIX

# SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Introduction

This chapter summarises the key findings of the trend analysis, LULCC and field survey in relation to the research questions and objectives. Conclusions were drawn and appropriate recommendations provided in relation to the empirical findings of this research and supported literature.

## 6.2 Summary of the Study

Water remains the basic necessity for human and ecosystem survival all over the world. Water resources such as rivers, streams and lakes are major economic and natural resources and their availability and distribution are largely determined by the climate elements particularly temperature and rainfall. The study examined the effects of the changing climate and land use/land cover change on the availability of water at the Nasia river catchment. Specifically, five objectives were set out to be achieved by the researcher. These objectives were to: analyse temperature and rainfall data from the 1981-2020 for local climatic trends in the Nasia river catchment, analyse the impact of climate change (rainfall and temperature) on discharge from 1988-2010, analyse LULC changes in the Nasia river catchment from 1980-2020 and its implications on the river, assess the effects of the changing climate extremes on water availability for domestic use in the study setting and examine the coping strategies that are being used in the midst of changing climate in the Nasia river catchment.

The study used a mixed-method approach, involving the concurrent embedded mixed method design of qualitative and quantitative techniques, using both primary and secondary data sources. One-hundred and forty-seven (147) household heads, three (3) key informants and thirty-six (36) community heads, six (6) from each study community were sampled from the study communities in the West Mamprusi, Karaga and Savelugu Districts **(**Nasia river catchment) using simple random and purposive sampling techniques respectively. Questionnaires, interview guide and FGD guide were used to obtain the primary quantitative and qualitative data from the sampled household heads, key informants and community heads. These data were analysed based on descriptive statistics using IBM SPSS (Version 23) and Microsoft Excel 16 and thematic analytical framework. The secondary data (temperature and rainfall time series data) were analysed using MAKESENS Solver from Python software and Microsoft Excel 16, while Landsat satellite images were processed and analysed using QGIS. Frequency distribution tables, bar charts, graphs as well as verbatim quotations were used to present the analyses. The findings from the study are summarized below.

***6.2.1 Temperature and Rainfall Analyses for Climate Variability and Change*** As one of the objectives, the study analysed the trend in rainfall and temperatures over a 40- year period. The annual rainfall has witnessed an increase albeit insignificant trend in the Nasia catchment. There is evidence of rainfall variability than change. The annual mean, minimum and maximum temperatures has witnessed an increasing significant trend with minimum temperatures increasing faster than maximum temperatures. The analysis shows that temperature have been changing and moving upwards per the time series and Mann-Kendall test. The identification of the climatic trend in the Nasia catchment validates this objective.

#### *6.2.2 Impact of Climate Variability and Change on Discharge*

The study examined the impact of climate variability and change on discharge. The rate of change in discharge is a cause for worry. Discharge is declining in the catchment leading to water deficit in some areas over the years. The decline in discharge in the Nasia basin corresponds to increasing trends in temperature and variability in rainfall of which all were statistically significant. The fact that the discharge of the Nasia river is declining, suggests a detrimental effect on the residents of the basin who depend on it for domestic use and other livelihood activity.

***6.2.3 Land Use/Land Cover Change (LULCC) and Its Implication on Water*** The study examined the LULCC in the Nasia catchment over a 41-year period. The study found that vegetation cover in the catchment has continuously reduced whiles built-up areas drastically increased in 2020 as compared to the base year value in 1980. The Nasia river likewise shrank over this time, with the exception of 2010, when the catchment experienced significant floods. Since the vegetation along the river that protect the river from excessive evaporation have been cleared, the Nasia river is now directly exposed to sunshine and the warming temperatures. Consequently, the size of the river in hectares have generally decreased over the study period and this could be as a result of evapotranspiration. Moreover, shrinkage of the Nasia river can lead to low volumes of water in the river. The identification of changes in LULC and its implication on the Nasia catchment validates this objective.

#### *6.2.4 Water Availability for Domestic Water Applications in the Midst of Changing Climate*

The study analysed the impact of climate variability and change on the availability of water for domestic applications. Since the Nasia catchment is greatly rainfed, when the area experiences rainfall variability coupled with high temperatures, availability of water especially at the inlet becomes a great challenge. Namburugu and Kpubo communities which are located at the inlet of the catchment are faced with the physical notion of water scarcity. These communities did not have alternative source of water compared to the other study communities located at the outlet of the catchment. The study found that the demand of water for domestic and other applications in some study communities (Namburugu and Kpubo) has outpaced the available water supplies in the catchment. Erratic rainfall in the catchment area consequently causes flood which makes water unavailable for use. The identification of climate change impact on water availability validates the fourth objective.

#### *6.2.5 Water Coping Strategies to Climate Variability and Change*

The study also examined the coping mechanisms used by the study communities for domestic use. Households in the study communities made use of various coping strategies to deal with the effects of the changing climate and LULCC on the Nasia river catchment and its availability for domestic use and other applications. The study found that the spatial location of the study communities determined the coping strategies employed. Communities located at the outlet of the Nasia catchment including Nasia, Sooba, Kokubila and Tamalgu employed coping strategies such as rainwater harvesting, adding alum and filtering of water. In Namburugu and Kpubo communities located at the inlet of the Nasia catchment, households employed coping strategies encompassing those employed by the communities located at the outlet to include reduced use of water and reuse of waste water. According to the households, these strategies proved beneficial in coping with the water shortage in the area especially in the dry season. The identification of coping strategies used by these communities validates the fifth study objective and invalidates the hypothesis that rainfall harvesting is the only coping strategy at the Nasia catchment. The study also found that Sooba, Namburugu and kpubo had low water table (poor aquifer). Unlike Namburugu and Kpubo who face water shortage, Sooba by the virtue of its location at the outlet does not experience water shortage. Also, in Sooba, Saha in collaboration with CRS and WAN developed a water business model as an alternative to providing safe drinking water due to the low groundwater potential of the community in the West Mamprusi Municipality.

## 6.3 Conclusion

The Nasia river catchment is gradually dwindling with time, with some tributaries drying up. Warming temperatures and erratic rainfall are some of the contributing factors. The decline in discharge in the Nasia catchment corresponds to increasing trends in temperature and variability in rainfall and this is statistically significant. Increased temperature and rainfall variability which decreases the quality of the river and dries up the river has made the water in the river unavailable for use. In such events, households without alternative source for domestic application will experience severe water shortage. The study concludes that to sustain the river in the Nasia catchment, awareness of the potential effects of rising temperatures and probable evaporation is necessary.

With diminished role of climate, physical factors and other anthropogenic factors have also contributed to the reduction of the water in the Nasia river. Built-up and bare lands are drastically increasing at the expense of vegetation cover and the vegetation along the river have been cleared for farming purposes in the catchment. This exposes the river to direct sunshine and evaporation.

Different coping strategies are employed by households located at the inlet and outlet to cope with water issues in the catchment. Aside the short-term reactive responses employed mainly during the longer drier season experienced in the catchment, the households did not have adaptation strategies to enable them reduce the ills of water scarcity.

### 6.4 Recommendations and Future Studies

In the light of the identified problems, the study puts forward the following recommendations.

The Department of Water and Sanitation in Karaga District should provide the communities (Namburugu and Kpubo) with adequate storage facilities such as several poly tanks to store excess rainwater in rainy seasons. This will be somewhat adequate to make up for the short fall in the dry months. This must be regulated very well by the community to ensure that the stored water is judiciously used during the long dry season.

The local assembly in the study communities which have high water table (good aquifer) should encourage and aid households to construct wells in their homes to ease the burden on the limited public mechanised boreholes. This is meant to avoid challenges that arise when these limited public mechanised boreholes are in bad conditions as well as augment the water provision by the Nasia river.

The Department of Water and Sanitation in the Karaga District should employ adaptation strategies such as building a reservoir near the river to harvest water in times of excess flow, to enable the indigenes have water all year round since the problem of water scarcity has come to stay with them.

The local assemblies within the Nasia catchment led by stakeholders in collaboration with the environmental protection agency should educate and sensitize the residents to protect the Nasia river and other water supplies by reducing the cutting of trees especially along river banks.

The Nasia catchment board in collaboration with the forestry commission should promote and engage the locals in the reforestation and revegetation of some of the most degraded areas of the catchment to prevent rapid evapotranspiration.

The Department of Water and Sanitation in the study area should encourage the use of water treatment to prevent the occurrence of water borne diseases such as cholera and diarrhea, since some communities have no option but to always depend on the Nasia river for domestic purposes.

Further research is required to unearth other critical variables responsible for the variability observed in river discharge in the Nasia catchment. The Soil Water Assessment Tool (SWAT), could be an important hydrological modeling tool to quantify other climate and environmental variables in addition to rainfall and temperature. This discovery may help policymakers and other interested parties in
Ghana to better understand the causes of fluctuations in river discharge in the Nasia catchment and devise strategies for managing water resources sustainably, particularly in the rural areas of northern Ghana.

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# APPENDICES

## APPENDIX 1

## KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

## SCHOOL OF GRADUATE STUDIES

## DEPARTMENT OF GEOGRAPHY AND RURAL DEVELOPMENT

**Questionnaire for Household Survey**

This questionnaire is purely designed to solicit information from Household Heads concerning the effect of climate change for domestic water use as well as to identify sustainable water coping strategies under climate change. The information obtained will be used exclusively for academic purposes and your identity will be kept confidential.

The questions are categorized under the following themes:

1. Socio-demographic characteristics of household heads
2. Effect of climate changes on water availability for domestic use in the catchment 3. Coping strategies by household

**IDENTIFICATION**

| No. | Questions | Response |
|---|---|---|
| a. | Name of Enumerator | |
| b. | Name of community | |
| c. | District/ Municipality | |
| d. | Respondent's house number | |

**SECTION A: SOCIO-DEMOGRAPHIC CHARACTERISTICS OF HOUSEHOLD HEADS**

| No | Questions | Response (Please check the box next to the correct answer.) | |
|---|---|---|---|
| 1 | Sex | 1. Male | |
| | | 2. Female | |
| 2 | Age | 1. 41-50years | |
| | | 2. 51 – 60years | |
| | | 3. 61 and above | |
| 3 | Highest level of education attained | 1. No formal education | |
| | | 2. Basic education | |
| | | 3. Secondary education | |
| | | 4. Tertiary education | |
| 4 | Religious affiliation | 1. Christianity | |

| | | | |
|---|---|---|---|
| | | 2. Islam | |
| | | 3. Traditional | |
| | | 4. No religion | |
| | | Other (specify)………………… | ………… |
| 5 | Current marital status | 1. Never married | |
| | | 2. Cohabiting | |
| | | 3. Married | |
| | | 4. Widow/Widower | |
| | | 5. Divorced/separated | |
| 6 | Ethnicity | 1.Gonja | |
| | | 2. Dagomba | |
| | | 3. Mamprusi | |
| | | 4. Dagarbas | |
| | | 5. Konkomba | |
| | | 6. Akan | |
| | | Other (specify)………………… | ………… |
| 7 | Size of household | 1. 1-3 | |
| | | 2. 4-6 | |
| | | 3. 7-9 | |
| | | 4. ≥10 | |
| 8 | Current occupation | 1. Farming | |
| | | 2. Fishing | |
| | | 3. Trading/business/driving | |
| | | 4. Civil/Public Service | |
| | | 5. Artisanal work | |
| | | Other (specify) ……………………………… | |
| 9 | Number of years into your current occupation | 1. < 10 years | |
| | | 2. 10-20 years | |
| | | 3. 21-30years | |
| | | 4. 31-40years | |
| | | 5. 41years and above | |
| 10 | Average monthly income | Below GH¢319.14 | |
| | | GH¢319.14 and above | |

**SECTION B: EFFECT OF CLIMATE CHANGE ON WATER AVAILABILITY FOR DOMESTIC USE IN THE CATCHMENT**

| | | | |
|---|---|---|---|
| 11 | Which of the following main sources of water does your | **Water source** | **Tick** |
| | | 1. Nasia river | |
| | | 2. Borehole | |

| | | |
|---|---|---|
| | household use for domestic purposes? (**specific response**) | 3. Well<br>4. Public standpipe<br><br>Others(specify)……………………………….. |
| 12 | Which of the following secondary sources of water does your household use for domestic purposes? (**specific response**) | **Water source** / **Tick**<br>1. Nasia river<br>2. Borehole<br>3. Well<br>4. Public standpipe<br><br>Others(specify)……………………………….. |
| 13 | Number of years using the above mentioned source for domestic use? | 1. < 10 years<br>2. 10-20 years<br>3. 21-30years<br>4. 31-40years<br>5. 41years and above |
| 14 | Is the quantity of water that you receive from the Nasia river adequate? | 1. Yes<br>2. No |
| 15 | Is water available in the Nasia river throughout the year? | 1. Yes (skip to q. 17)<br>2. No |
| 16 | Which months do you experience water shortage in the Nasia river? **Tick as many as apply** | January, May, September<br>February, June, October<br>March, July, November<br>April, August, December |
| 17 | Have you noticed changes in the color of water from the Nasia river? | 1. Yes<br>2. No |
| 18 | Does the water contain particles? | 1. Yes<br>2. No |
| 19 | Does the water smell? | 1. Yes<br>2. No |
| 20 | Has the Nasia river shranked in size? | 1. Yes<br>2. No |
| 21 | Have change in the size of the river affected water availability for domestic use over the past | 1. Yes<br>2. No (skip to q. 23) |
| | years? | |
| 22 | | 1. Yes |

| | | |
|---|---|---|
| | Are you experiencing water shortage for domestic use as a result? | 2. No |
| 23 | Are you aware of any significant factors causing water shortage? | 1. Yes<br>2. No<br><br>If 'Yes' specify…………………………….. |

**SECTION C: HOUSEHOLD COPING STRATEGIES IN THE CATCHMENT**

| | | |
|---|---|---|
| 24 | Do you engage in any coping strategies to optimize water for domestic use? | 1. Yes<br>2. No (skip to q. 30) |
| 25 | Which water management/ coping strategies do you engage in to optimize water for domestic use?<br><br>**Tick all that apply and rank them according to priority** | See coping strategies table below<br><br>Others(specify)………………………………… |
| 26 | Are the various copying practices you employ effective? | 1.Yes (skip to q. 30)<br>2. No |
| 27 | If not, what are some of the challenges? | ……………………………… …………<br>……………………………… ………… |
| 28 | Has there been any institutional/ organization support to improve your coping practices? | 1.Yes<br>2. No (skip to q. 30) |
| 29 | Briefly explain how? | ………………………………………..<br>……………………………………….. |

| **Coping strategies** | **Tick** | **Rank** |
|---|---|---|
| 1. Rainwater harvesting | | |
| 2. Recycling of wastewater | | |
| 3. Reuse of wastewater | | |
| 4. Reduced use of water | | |
| 5. Adding alum to water before use | | |
| 6. Boiling water before use | | |
| 7. Filtering water before use | | |
| 8. Identifying alternative water source | | |
| 9. Increased number of storage vessel | | |

| | | |
|---|---|---|
| 30 | Is there a committee for managing the Nasia river in this community? | 1. Yes [ ]<br>2. No (skip) [ ]<br><br>If ‘Yes’ specify ……………………………… |
| 31 | What are some of their activities? | ………………………………………………..<br>……………………………………………….. |

**Thank you very much for sparing your time.**

**APPENDIX 2**

**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY**

**SCHOOL OF GRADUATE STUDIES**

**DEPARTMENT OF GEOGRAPHY AND RURAL DEVELOPMENT**

**Community Heads FGD Guide THESIS**

**TOPIC:**

**Impact of Climate Change and Land Use/Land Cover Change on Water Availability in The Nasia Catchment**

This FGD guide is purely designed to solicit information from Community Head through FGDs concerning the effect of climate change for water availability for domestic use, as well as to identify water coping/adaptation strategies for sustainable management under climate change.

This research is being conducted by a postgraduate student from the Kwame Nkrumah University of Science and Technology. This research is intended to add to existing knowledge and also to help promote sustainable water coping/adaptation strategies under climate change in the catchment. I am relished of your participation in this discussion and want to assure you of my absolute commitment to secure your privacy and confidentiality as far as your responses or information you provided are concerned.
The information collected will be for academic purpose only.

***Warm up questions*** ……………………………………

**A. Length of stay**

- How long have you been living in this community?
- What is/are the main source(s) of water for your household?

**B. BACKGROUND INFORMATION**

| | |
|---|---|
| **District:** | **Region:** |
| **Suburb:** | |
| **Interviewer:** | **Date of interview:** |
| **Time started:** | **Time end:** |

**C. Community climate history/experience**

- Have you noticed any changes in climate during your lifetime? (*probe for indicators of changes*)
- Have you observed any changes in rainfall and temperature over the past 40 years? (*probe for the extent of this change*)
- What has been the rainfall pattern in this community for the past 40 years *(probe for intensity, quantity, duration and timing?)*
- Over the past years, how often have you suffered water shortage due to rainfall variability?
- How does the changes in climate affect water availability for domestic use over the past years? *(probe for the extent of this changes i.e. experiences and examples)*

**D. Coping and Adaptation strategies in the basin**

- What strategies have you adopted so far to withstand these waves of effects? *(probe for the success of these strategies)*
- What are some obstacles to climate change adaptation? *(Probe for what resources, information, and interventions are needed to overcome these obstacles)*
- Is there any committee for water resource management in this community? (*probe for their activities)*
- Are there any programs ongoing to help the community adapt to climate change?
- What can be done to adapt to these changes? (*probe for how these strategies could be implemented and by who*)
- At what level (Household, community, district, national, international)

**This marks the end of our conversation. Do you have any comments on what we have discussed? Thank you very much for sparing your time.**

**END**

## APPENDIX 3

## KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

## SCHOOL OF GRADUATE STUDIES

## DEPARTMENT OF GEOGRAPHY AND RURAL DEVELOPMENT

**Interview Guide for Key informants**

**THESIS TOPIC:**

**Impact of Climate Change and Land Use/Land Cover Change on Water Availability in The Nasia Catchment**

This interview guide is purely designed to solicit information from relevant institutions through in-depth interviews, concerning the effect of climate change on water availability for domestic use, as well as to identify water coping/adaptation strategies for sustainable management under climate change.

This research is being conducted by a postgraduate student from the Kwame Nkrumah University of Science and Technology. This research is intended to add to existing knowledge and also to help promote sustainable water coping/adaptation strategies under climate change in the catchment. I am relished of your participation in this discussion and want to assure you of my absolute commitment to secure your privacy and confidentiality as far as your responses or information you provided are concerned.
The information collected will be for academic purpose only.

***Warm up questions*** ……………………………………

**A. Length of stay**

- How long have you being working in this institution?
- What is/are the main source of water for households in the catchment?

**B. BACKGROUND INFORMATION**

| | |
|---|---|
| **Sex:** | **Institution:** |
| **District:** | **Suburb:** |

| | |
|---|---|
| **Position of the Personnel Responding:** | **Interviewer:** |
| **Level of education:** | **Date of interview:** |
| **Time started:** | **Time end:** |

**C. Institutional climate history/experience**

- Have you noticed any changes in climate during your stay in the catchment? (*probe for indicators of changes*)
- Have you observed any changes in rainfall and temperature over the past 40 years? (*probe for the extent of this change*)
- What has been the rainfall pattern in this community for the past 40 years *(probe for intensity, quantity, duration and timing?)*
- How does the changes in climate affect water availability for domestic use over the past years? *(probe for the extent of this changes i.e. experiences and examples)*

**D. Institutional water management strategies in the catchment**

- What strategies have you put in place to withstand these waves of effects in the catchment? *(probe for the success of these strategies)*
- What are some obstacles to climate change adaptation? *(Probe for what resources, information, and interventions are needed so overcome these obstacles)*
- Do the communities ask for institutional help for water coping/adaptation strategies?
- Are there any programs ongoing to help the community adapt to climate change?
- What can be done to adapt to these changes? (*probe for how these strategies could be implemented and by who*)
- At what level (household, community, district, national)

**This marks the end of our conversation. Do you have any comments on what we have discussed? Thank you very much for sparing your time.**

**END**