An Assessment of the Impact of Floods and Drought on Fresh Water Resources in the Lower Catchment Region of River Tana, Kenya

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ABSTRACT

This study was carried out in the coastal lowlands of Kenya. The specifc area is administratively referred to as Tana River County or the lower catchment area of River Tana which is the main river in the region. The area suffers from both annual floods and drought. During the wet seasons there is excess water, floods are common and water flows freely, while during the dry season, there is scarcity of water. The quality of water is compromised both during the wet and dry seasons when there is plenty of water during the flood episodes and during the dry season as water scarcity bites. The general objective of this study was to assess water supply amidst the excess water and floods on one hand and prolonged drought in the lower coastal region of Kenya. Specific objectives include to: i) establish factors influencing occurrence of floods and drought in the study area; ii) establish spatio temporal dynamics of floods and drought; iii) assess the impacts of alternating episodes of drought and floods on water security in the study area; and; iv) establish existing and potential technologies and stakeholder initiatives in addressing the problems of excess water during floods and water scarcity during the dry season. The study used survey design and judgmental sampling to acquire data. A total of one hundred respondents were enlisted for the study. This consisted of Interviewees (n=60); FGDs (n=30) and Key Informants (KIs) (n=10). Tools for data collection included Questionnaire, Observation Guide, FGDs and Key Informant Guides. Both primary and secondary data and sources were used. Data was analyzed using descriptive statistics. The results indicate that the region's water security is compromised both during the dry and wet seasons. The study recommends concerted efforts to address the challenges encountered in management of these extreme events.

Keywords: Water Security, Sustainable Livelihoods, Floods, Drought; Sustainable Development Goals, (SDGs).

GLOSSARY OF ABBREVIATIONS

FEWSNET	Famine Early Warning Network
FGDs	Focus Group Discussions
GoK	Government of Kenya
IDRM	Integrated Disaster Risk Management
KIs	Key Informants
KMD	Kenya Meteorological Department

LTRB	Lower Tana River Basin
MAM	March, April, May
MoALF	Ministry of Agriculture and Livestock
NDMA	National Drought Management Authority
NDOC	The Kenya National Disaster Operation Center
OND	October, November, December
RCPs	Representative Concentration Pathways
SDGs	Sustainable Development Goals
UNDP	United Nations Development Program

INTRODUCTION

This paper investigates the impacts of drought and floods on water resources in Garsen Tana Delta, Kenya. Floods and drought have become frequent in the recent past in the study area. These extreme climatic events impact negatively on quality of water for domestic use. This means the paradox between extreme weather events, specifically floods and drought in the coastal region of Kenya compromises the quality of water for household use in the region. Specifically, the paper narrows down to the Garsen, Tana Delta region in the coastal lowlands of Kenya. Extreme weather patterns have been recorded in various parts of the region, some of which have been devastating (Makenzie et al, 2013; ISS, 2011; Langat, et al, 2017; the Star Newspaper, 2018; the Standard Digital, 2018). Projections have also been made on the future trends of rainfall and temperature conditions in the region, (FEWSNET, 2010; Funk, 2010; Herring 2012; KMD, Various Years). Climate change has been associated with extreme climatic events over the years. The causes of climate change are both natural and anthropogenic (Stern & Kaufmann, 2014).

Scarcity of clean during the dry and wet seasons impact negatively on community livelihoods. Local communities have suffered and become vulnerable to the extreme weather conditions and/or events to the extent that they often migrate temporarily or permanently to other regions. This in real sense exposes the communities and individuals to other social and economic threats that are hitherto alien to their original cultural setups. The wellbeing of local communities and individuals is a key component of the Sustainable Development Goals, (SDGs) and especially Sustainable Development Goal Number Six (6), (Le Blanc, 2015; UNDP, 2015). Sustainable development is the development that meets the needs of the present generation without compromising that of future generations. Interventions to address the impacts and effects of extreme weather conditions have faced challenges that have resulted in vicious cycles of water scarcity, poverty, malnutrition, migration and other social evils (NDMA, 2014; NDMA, 2022). Other strategies have been initiated by different government parastatal and line ministries (GoK, 2009; GoK, 2014; GoK, 2023; Leauthaud, et al 2012; UNDP, 2023).

It is therefore important to assess the impact of floods and drought in order to establish mechanisms for sustainable utilization of water resources in the study area. The findings have implications on interventions that involve government and other stakeholder initiatives in addressing management of excess water during floods and water scarcity during the dry season for the wellbeing of the society.

The study objectives include to; establish the geophysical, environmental and anthropogenic factors influencing the occurrence of floods and drought in the study area; establish the spatio temporal dynamics of floods and drought especially in terms of frequency and magnitude in the study area; assess the impacts of extreme weather events on water resources in the study area; and establish existing and potential technological interventions in management of floods and drought in the study area

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MATERIALS AND METHODS

Study Design

The study used survey and longitudinal research designs to establish existing trends in extreme weather events associated with floods, drought and water security. Floods and drought are associated with elements of weather such as rainfall and temperature. The trends in extreme weather events can therefore be deduced from the existing patterns of rainfall and temperature in a region. The weather and climatic patterns in the catchment areas also play an important role, generating excess waters that flow to the study area even without locally generated flood waters. Flooding in the region has also been associated with intrusion of ocean water to low lying areas which also compromise the quality of water for domestic use.

Study Location

The study area is Tana River County, Kenya. Specifically, the area under investigation falls under the administrative area referred to as Tana River County. Kenya is divided into forty-Seven (47) administrative boundaries referred to as Counties. Tana River County is therefore one of the Counties in Kenya located specifically in the lower coastal region of Kenya. Tana River County occupies an area of about 35,375km^2 and the *geographical locational coordinates are as follows: Latitude: -1.53333 and Longitudes: 39.41667,* Figure 1.

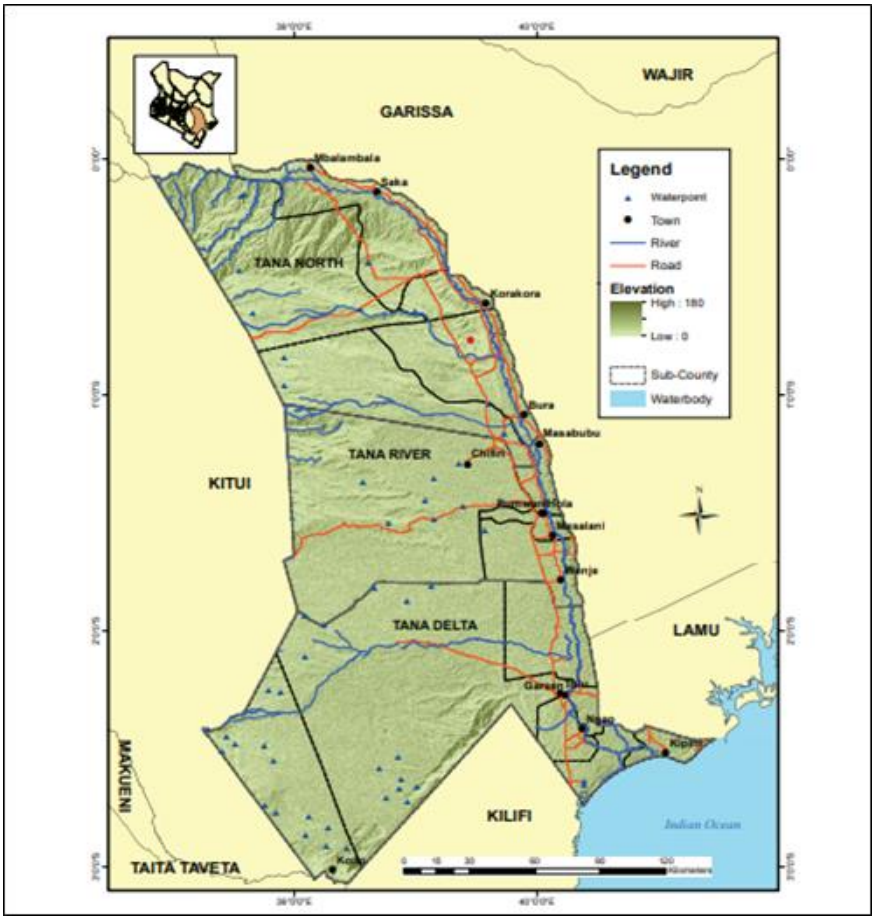

Figure 1: Location of the Study Area in Kenya

Source: Adopted from RCMRD, 2017

The Tana River County is divided into three sub-counties namely, Tana North, Tana River and Tana Delta. The study sites for Key Informant interviews and FGDs were mainly in Garsen in the Tana Delta Subcounty. However, issues on drought, floods and water resources cut across and are captured across the entire Tana

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River County. The study area is generally classified as semi-arid and most of the local populations are pastoralists while others practice mixed farming and engage in other livelihood activities.

Study Duration

The study was carried out over a period of one year, even though the secondary data on rainfall, temperature and water resources cover a wider span of over forty years.

Research Variables

Study variables included extreme weather events (drought and floods) and water resources.

Data Collection, Sampling Methods and Sample Size

Methods and Tools for Data Collection

Both primary and secondary data and sources were used. Tools for data collection included Questionnaires, Observation Guide and Key Informant Guide. Primary data was obtained through Key Informant Interviews and Observation. Secondary data was obtained though Desktop Search and application of Space and Geospatial Technologies in the form of Satellite Remote Sensing Images, Aerial Photographs and Google Earth.

Sampling Methods and Sample Size

The study used judgmental/purposive sampling method that generated a total of one hundred respondents. The respondents were mainly local community members enlisted for interviews, FGDs and Key Informants (KIs). A total of one hundred respondents including interviewed local community members (n=60); FGDs (n=30) and Key Informants (KIs) (n=10) were sampled purposively and enlisted for the study.

Statistical Analysis

Data was analyzed using descriptive statistics. Microsoft Excel was employed in data manipulation and management. Results are presented in the form of statistical and non-statistical narratives.

RESULTS

GEOPHYSICAL AND ENVIRONMENTAL FACTORS ASSOCIATED WITH FLOODS, DROUGHT AND WATER RESOURCES IN THE STUDY AREA

Geophysical Factors

The study area lies in the lower Tana River Basin catchment area which is generally a low-lying area. It is an undulating plain with isolated low hills. Low hilly areas are at Madogo and Bura. The altitude ranges between 20m to 200m above seas level. The highest area is at Bilbil hill. The area slopes south eastwards. The low lying, southeast sloping plain influences the direction of water flow and floods. The geophysical characteristics of the area is associated with frequent floods in the study area which compromises the quality of water for local household consumption.

The upper and middle Tana River basin catchment areas receive high rainfall totals that tends to result in river basin hydrological process that eventually affect the lower part of the basin. In most cases, flooding happens because of heavy rainfall in the catchment areas of Aberdare Ranges and Mr. Kenya. Major floods are associated with heavy rainfall peaks in the catchment areas, that is, during the March, April/ May (MAM) or the long rains and also during the short rainy seasons, received in the October, November, December (OND) period. The changes in weather and climate makes it difficult to project the exact onset of floods in the lower

Tana River Basin and especially the Tana River Delta. This means, the timing, extent and duration of floods vary greatly annually.

In terms of geological characteristics, the area lies over quaternary sediments consisting of marine sands, mud and coral breccia. The floodplain is also covered by alluvial sediments. The alluvial material is transported and deposited during the annual flooding of the river. In terms of soil characteristics, the Tana Delta, especially is covered by heavy clay soils and grasslands. One of the physical characteristics of clay soil is that it absorbs water, swells and this results in the pore spaces being blocked. This blockage results in slow drainage that could eventually result in flush floods from the little rainfall received in the area. Drought in the Tana Delta has been alternating with floods. However, flooding frequency has decreased in the recent past while drought episodes has increased in the same period. The failure of rains in consecutive periods and high temperatures result in drought.

Environmental Factors Associated with Floods

In order to understand the genesis of floods in the region, data on rainfall in the region was obtained from secondary sources over a period of forty-seven years. The annual rainfall in Tana River County as derived from Kipini Meteorological Station and World Weather Online (WWO, 2023). The rainfall data shows strong seasonality over the period from 1975 to 2022. Extreme events associated very low and very high rainfall episodes are registered. The average rainfall for Tana River County was 1000 mm/year and a minimum of 600mm. There is greater variability in rainfall in different locations in the region. Flooding in the region is mainly caused by intense precipitation in the upstream catchment areas to the river. The latest reports indicate that floods are also caused by ocean water overflowing into the adjacent shoreline and also into the nearby settlements. Rainfall regime is influenced by the location of the area in terms of distance from the Indian Ocean shoreline.

Environmental Factors Associated with Drought

Drought has been associated with aridity and ever-increasing temperatures in the region. Existing literature indicate that maximum temperatures go as high as 36°C or higher to a minimum of 33°C. High temperature is observed during the dry periods hence drought exacerbates the extremely high temperatures that result in forest fires, death and migration of animals and heightened human and wildlife conflicts. Due to extreme temperatures associated with drought, moisture stress and dry spells vary between the long and short rainy seasons. The first wet season experiences approximately seventy-three (73) consecutive days with moisture stress, and on the other hand, the second wet season experiences approximately ninety (79) consecutive days with moisture stress, (MoALF, (2016). It has been observed that since 1981, the region has experienced an increase in temperature conditions of between 0.5°C to 2.0°C and a tendency towards decreasing precipitation and warmer nights.

Human Factors Associated with Drought and floods in Tana Delta Region

The existing literature and FGDs revealed a number of human activities associated with floods and drought in the Tana Delta Region. These include anthropogenic climate change, deforestation, high water demand, poor farming practices; and changes in ocean temperatures. Changes in ocean temperatures and general rise in ocean levels in the Tana Delta region have resulted in floods in the recent past.

SPATIO - TEMPORAL VARIATION OF FLOODS AND DROUGHT IN TH STUDY AREA

Frequency, Magnitude and Intensity of Floods and Drought in the Area

Drought has been experienced in the study area in varying intensities in different years and/or periods. Extreme drought was experienced in 1975, 1976, 1980; 1981; 1983; 2001; 2004; 2009. Successive years have experienced a mixture of floods and drought in different seasons. The region experienced marked floods in 2002; 2003; 2010; 2014; 2015; 2016, 2020 as well as the current alternating periods of floods and drought.

Historical Records on Frequency and Intensity

Analysis of historical records from the NDMA from 1883 to 2023 indicate that the frequency and intensity of both drought and floods in the study area has increased over the years. That in some years the region experiences alternating episodes of drought and floods that compromise household water security and general health of the people. Drought is associated with hunger and outbreak of diseases. Similarly, floods are also associated with hunger, displacement of people, outbreak of diseases and insecurity, (NDMA, 2023).

It has been observed that Kenya used to have a ten year climatic cycle where drought occurred after every ten years (ISS, 2011). However, this has progressively changed. For example, in the 1970s, drought occurred after seven years; in the 1980s, draught occurred after five years; in the 1990s drought and dry spells occurred every 2-3 years, and in 2000s there were three major droughts and several dry spells. In total, drought and dry spells occur every year. Through the FGDs, it was established that some areas in the study region experiences heat waves which resulted in the death of cattle, old people, social disruption, yellow fever and malaria.

IMPACTS OF EXTREME WEATHER EVENTS ON WATER QUALITY IN THE STUDY AREA

Water Resources in the Study Area

Water resources in the study area include rivers, ponds, water pans, shallow wells and streams as well as the ocean, Figure 1.

River Tana is the main river supplying fresh water to the local communities in the study area. River Tana is the longest river in Kenya, (1000 Kilometer) in length with the upper catchment area being in the Aberdare ranges and Mr. Kenya, in the central region of Kenya and the river mouth at the Tana Delta, along the Indian Ocean Shoreline. River Tana provides water for household use, for livestock and agriculture.

The tributaries of river Tana that also supply fresh water include Galole, Hiramman and Tula. A number of seasonal streams known as *Laghas* exist and also supply fresh water. Underground aquifers also form a water supply base for fresh water through boreholes and ponds. Oxbow lakes also provide water to the local communities especially during the wet season. Specific details about water resources in Tana River County are discussed in between the lines.

The study area has a number of water pans, boreholes, water canals; wells; water tanks, water kiosks and water taps. Water Pans are important water reservoirs that store surface water. The storage capacity ranges between 10,000 – 100,000 cubic meters. The pans store water for an average of 3-6months serving an average of 500 local households (UNDP, 2024). The key stakeholders involved include the County Government, the National Government and Development Partners.

Boreholes are narrow deep wells used to access ground water where the water table lies deep ungrounds. Most boreholes provide fresh water, however, where there is intrusion of saline water from the ocean, water becomes salty thereby limiting the use. Boreholes in Tana River County are classified as permanent or dry holding water for a whole year or lasting for six months on average, respectively.

The region also has water canals used in supplying water to the irrigation schemes in the County. The County has a number of water wells that provide water through installed handpumps using the draw off method. The County also has water tanks, water kiosks and water taps. For pastoralist groups, water corridors, also known locally as Malka, are demarcated to provide access to the water points by livestock.

Shallow wells and water pans vary in size, salinity and availability of water. The availability of water in the shallow wells and water pans depends on rain cycles which has become unpredictable hence most of these wells dry up during the dry seasons.

Quality of Water during Wet and Dry Seasons (Floods and Drought)

Community members have specific ways of determining water quality for themselves using smell, color and sediment load, among others (UNDP, 2024). The physical appearance of water changes during the wet season, especially at the beginning of the wet season. The general color turns from slightly opaque to opaque at the beginning of the rainy season. This is perhaps mainly due to the dissolved particles that had accumulated during the dry period and were now washed down by floods. Water volume in the rivers and streams increased and availability to the locals increases during the wt season. There was plenty of water for general use and for livestock. The problem during the wet season is the quality of water. When the color changes to opaque and brown, the quality of water is compromised and the locals must look for ways of getting clean water which then translates into high costs per 20liter jerrican of water.

The local communities stated that water is accessible and affordable during the rainy season. However, during drought, the price goes up and water vendors 'make a kill'. This is because some of the water pans or wells dry up and boreholes become salty. The locals have to crisscross the region in search of not only clean drinking water, but also water for livestock and pasture. During such periods therefore the price of a five-liter water container goes for between Kshs 20-40 (almost half a dollar). Many people cannot afford clean water during the dry period hence resort to the use of any water available which then exposes them to diseases such as cholera and diarrhea

Accessibility of Water

Water is accessible during the wet season. During dry spells water is scarce and men and women plus children spend long hours looking for water. The average distance for some households is five kilometers. In some areas the distance increases. Apart from the long distance to water sources, the waiting time to get the water ranges between 15-45 minutes depending on the seasons. In Tana River basin, the average distance to water sources is 2-3 hours walk. Pastoral communities cover additional distance compared to other groups. This means that scarcity of water interferes with other programmes such as attending to livelihood activities.

Access to safe water is estimated for 30-39 % of the population in the study area, while for Kenya it is 42.03 %, (NDMA, 2014). Household population with access to at least basic drinking water service is 49% compared to the country percentage of 49.68% (KDHS, 2022). This means percentage of population in the study area who have access to safe water is lower compared to the national average.

Stakeholder Intervention

Water Harvesting by Local Communities Using Shallow Wells and Water Pans

Water harvesting is an ongoing practice in the study area. Since the region goes through alternating periods of floods and drought, different strategies have been put in place. Examples include drilling of boreholes (25-30m) and open pits or Zei pits or dams and furrows at different places to supplement river water by tapping surface water.

The local people use indigenous knowledge to identify the areas that are likely to yield water hence leading to the establishment of water pans and shallow wells in specific locations. A common practice is to use specific indigenous knowledge on vegetation that are common in areas with underground water resources. The specific vegetation that guided in establishments of these water points is known as *"Mukuyu"* which is scientifically known as "*Ficus Sycamorus".*

Borehole Drilling by NGOs and UNDP, CISP Agro German, etc.

Boreholes are an important source of water especially during drought though the quality changes according to weather variations. World Vision has constructed boreholes in many areas in Tana River County and examples

include sub counties of Garsen and Hola. The draw back here is the high salt content in most boreholes which make their utilization limited.

EXISTING AND POTENTIAL TECHNOLOGICAL INTERVENTIONS IN MANAGEMENT OF FLOODS AND DROUGHT IN THE STUDY AREA

Technologies exist for management of floods and drought. Geospatial and satellite technologies give spatial information on the physical and human environment that are used in management of extreme climatic events such as floods and drought. This is possible through community mapping of water resources using local and modern tools.

Through internet operations such Google earth, areas can be delineated and studied at close range to provide relevant spatial information for analysis and decision making. Local communities are able to locate water points for ease of use during both wet and dry seasons

UNDP Accelerator Lab projects in Tana River County uses collective intelligence to advance climate action. The project aims at involving various stakeholders in climate action. A summary of the project's scope is given below:

"By generating more real-time, more localized climate data, and by mobilizing more people, the Lab unleashes the untapped potential of collective intelligence for climate action. Insights generated from the water resource mapping can support communities and vulnerable populations to build resilience and adapt to climate impacts. Through these collected insights, the Accelerator Lab intends to meet the real needs of the communities with the ways that governments, civil society and development organizations seek to support", UNDP, 2024)

PREDICTIONS AND FORECASTING OF FLOODS

Predictions have been made for historical and expected extreme flood events in the study area. Historic floods from 1981 to 2015 indicate that there was more of wettest 1-day event (mm/day) in rainfall between July-December (n-14) than wettest 1-day event between January – June (n=11), (MoALF, 2016). On the other hand, in the period between 2021 – 2065, predictions using RCP2.6 predict 10 wettest 1-day events between January and June and 18 days for July – December period. RCP8.5 predict 12 episodes of wet days for January – June and 19 for July – December period. Most extreme weather conditions tend to occur during the July – December season associated with the short rains in Kenya.

Observations and predictions indicate that historical and expected extreme drought events as deduced from number of days with moisture stress (consecutive days) for January-June is 76; while for July to December it is about 77 for RCP2.6 and RCP8.5. From the Models of future climate projections, it has been established that Tana River County will remain susceptible to drought and flood events according to projections from 2021-2065. The frequency of drought events is expected between January and June, while intense rains resulting into floods are expected between July and December for decades.

DISCUSSION

Factors exacerbating the occurrence of extreme weather events associated with floods and drought

From the key informant interviews, floods and drought occurrence have been exacerbated by both anthropogenic and natural or environmental factors. Anthropogenic factors identified include deforestation, poor agricultural practices including cultivation along river basins or banks that weaken the ability of drainage systems to hold water for a long time to allow for seepage of flood water. Other factors include location of settlements adjacent to flood plains, lack of awareness on flood related hazards. Others include inadequate preparation in the management of floods and low adaptive capacity. The findings from this study mirrors that

of Stern & Kaufmann, (2014) that established the role of natural and anthropogenic factors associated with rainfall and floods as well as increasing temperatures and drought on the other hand.

From the Focus Group Discussions, it was established that the socio-economic set up of the populations in the study area make them vulnerable to floods and drought. This is mainly due to a weak and compromised socio-economic base, lack of empowerment with adequate knowledge on environmental issues and inability to prepare early or put in place Disaster Risk Reduction (DRR) mechanisms to minimize the effects of extreme weather events. Existing literature indicate that floods and drought are recurrent in Kenya and have become more frequent with greater intensity in the recent past (ISS, 2011; Marigi, 2017; Wooldridge, 2011).

Impacts of the Drought and Floods on Water Resources and its Implications

The local people confirmed that floods and drought cause famine and result in prevalence of diseases, displacement of local communities and even death. Aridity and drought results in wildfires that destroy vegetation and soils and on the overall natural environment. Floods specifically results in soil erosion, destruction of vegetation and death of animals. Soil erosion in turn compromises the quality of water, reduces fertility of soil thereby lowering agricultural productivity. This in turn results in compromised livelihoods. The major impacts of floods and drought identified through FGDs and Key Informant interviews include damage to roads, floods washing away near harvest crops, floods washing away household poultry and goats as well as compromising the benefits arising from sale of cattle as their quality go down. This results in the farmers incurring losses resulting in food insecurity and compromised livelihoods.

Tana River County therefore is 79% food insecure, while the incidence of head count poverty stands at 67.8% against the Country's 38.6%; hard core poverty at 11.6 against the country's 5.8%; and food poverty rate of 49.5% against the country's 30.5%, (G0K, 2023; Tana River Data and Statistics, 2021). The results confirm that the study area has a higher level of vulnerability compared to the other regions as the FGDs results also indicate that most of the community members are vulnerable to floods.

Stakeholder initiatives in addressing the Paradox between floods and excess water and drought and water scarcity during the dry season for sustainable development

A number of stakeholders have initiated mechanisms to address the challenges associated with management of floods and drought. The strategies range from early warning systems, awareness creation, afforestation and reforestation, management of river basin hydrologic process to minimize effects of floods, among others. Other initiatives include establishment of institutional and regulatory frameworks to address aspects of climate change and safe water. For example, development of Disaster Risk Management Policy and Disaster Risk Management Bill aimed at managing disasters and cushioning communities from adverse effects of floods and drought. The move was spearheaded by the NDMA. A National Disaster Risk Management Policy came into effect in 2017 (GoK, 2017). The overall objective of the policy is to substantially reduce natural and human-induced disaster risk and associated losses in social, economic and environmental assets at National and County levels through the establishment of an integrated multi-hazard Disaster Risk Management (IDRM) approach. The Kenya National Disaster Operation Center (NDOC) deals with the management of and co-ordination of disaster response at a national level in Kenya.

Legal frameworks include the 2010 Constitution of Kenya, Water Act 2016, No. 43; WASREB, 2008; National Water Services Strategy 2020-2025; National Water Policy 2021; National Climate Change Action Plan (2018-2022). Other institutions include Water Users Associations.

CONCLUSION AND RECOMMENDATIONS

Conclusion

Extreme weather and climatic conditions are experienced in the Lower Tana River Basin or region. The extreme weather and climate events are in the form of floods and extended periods of drought. These extreme

events have and continue to affect the natural environment and even the socio-economic setups that are dependent on the environment. Local communities, the regional government, the national government and other stakeholders have designed mechanisms to address the paradox between floods and drought. Challenges exist hence the need for continuous research, policy designs and implementation and awareness creation.

Recommendations

The study recommends concerted efforts and application of both indigenous and modern technologies to address the challenges encountered in management of these extreme events and especially in relation to water resources.

ETHICAL APPROVAL

The research did not involve experiments with live animals or human beings

CONFLICT OF INTEREST

There is no conflict of interest reported

FUNDING STATEMENT

The study was funded by the researcher with support from host institution in terms of physical and supporting non-physical infrastructure.

DATA AVAILABILITY

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