Ghanima Chanzi
Water Institute, The Open University of Tanzania, Tanzania

Magreth Bushesha
Water Institute, The Open University of Tanzania, Tanzania

Subira Munishi
Water Institute, University of Dar es Salaam, Tanzania

Adam Karia
Water Institute, University of Dar es Salaam, Tanzania

Community perceptions and attitudes toward climate change impacts in the Kilombero river basin of Tanzania

Ghanima Chanzi, Magreth Bushesha, Subira Munishi and Adam Karia

Abstract
This research examines the Kilombero River Basin in Tanzania, focusing on the local communities' perceptions and attitudes towards climate change. It uncovers considerable environmental shifts, including rising temperatures, inconsistent rainfall, more frequent flooding, diminished water supplies, and the emergence of pests impacting agriculture and animal husbandry. The study underscores the extensive consequences of climate change on ecosystems, agricultural activities, and human livelihoods, highlighting the decrease in water sources, vegetation, and wildlife. These changes pose a risk to biodiversity and increase the strain on environmental resources.

Moreover, the research underscores the imperative for adopting sustainable farming methods, responsible energy consumption, and strategies for adapting to climate change, emphasizing the role of educational initiatives in raising awareness and fostering the adoption of these practices. It also references existing studies on the tangible impacts of climate change in Sub-Saharan Africa, drawing attention to the continued discussions about the scope of these impacts and the call for more in-depth investigations.

In summary, the research offers an in-depth analysis of the challenges presented by climate change in the Kilombero River Basin, stressing the necessity for cohesive strategies to tackle these issues. It points out the essential roles of education, sustainable methods, and comprehensive studies in alleviating the detrimental effects of climate change.

Keywords: Climate change, Kilombero river basin, environmental changes, water availability and adaptation strategies

1. Introduction

Climate change is a pressing global issue that poses significant challenges, particularly to vulnerable communities heavily reliant on natural resources and agriculture. The Kilombero River Basin in Tanzania is one such region profoundly susceptible to the impacts of climate change, making it an important area of study (Chatterjee *et al*., 2018; DiFalco *et al*., 2014) [6, 7]. This research aims to explore community perceptions and attitudes toward climate change within this basin, aligning with the global efforts outlined in the Sustainable Development Goals (SDGs), notably SDG 13 on climate action.

The Kilombero River Basin is a vital agricultural hub, with a substantial portion of the population engaged in farming and fishing activities. However, recent studies have highlighted the region's vulnerability to climate variability, including increased frequency and intensity of droughts, floods, and shifting rainfall patterns (Munishi *et al*., 2021; Kashaigili *et al*., 2020; Nkomoki *et al*., 2018) [13, 9, 15]. These changes pose significant risks to food security, water availability, and overall livelihood sustainability, directly impacting the targets of SDG 2 (Zero Hunger), SDG 6 (Clean Water and Sanitation), and SDG 1 (No Poverty). Despite the growing body of scientific evidence on climate change impacts in the Kilombero River Basin, there is a gap in understanding how local communities perceive and respond to these changes. Community perceptions and attitudes are crucial in shaping adaptation strategies and resilience-building efforts, which are central to achieving SDG 13 (Climate Action) and SDG 11 (Sustainable Cities and Communities). By exploring these perceptions, this research aims to provide valuable insights for policymakers, development organizations, and local authorities to design effective, inclusive, and community-driven climate change adaptation and mitigation strategies that align with local needs and priorities (Uckert *et al*., 2021; Meya *et al*., 2020) [19, 12].

Corresponding Author:
Ghanima Chanzi
Water Institute, The Open University of Tanzania, Tanzania

2. Materials and Methods
2.1 Study Area
The study focuses on the Kilombero River Basin in southeastern Tanzania, an area of approximately 40,500 square kilometers encompassing Kilombero, Ulanga, and Malinyi districts. This ecologically diverse and economically significant region lies between the Udzungwa Mountains and the Mahenge highlands, featuring a variety of geographical and ecological zones. The fertile floodplains of the Kilombero Valley, central to the basin, are pivotal for agriculture, particularly rice cultivation, a key food and cash crop for locals.

The Kilombero River, a crucial source of irrigation and domestic water, supports numerous communities and contributes to the area's rich biodiversity, including endemic and endangered species. The valley's wetlands, recognized internationally as a Ramsar site, play an essential role in bird migration and as a habitat for aquatic species.

With a tropical climate marked by distinct wet and dry seasons, the basin's rainfall is vital for rainfed agriculture and maintaining river and groundwater levels, though water availability during the dry season presents challenges. Additionally, the basin offers significant hydropower potential. However, environmental challenges such as agricultural expansion, deforestation, and climate change impacts threaten this diverse ecosystem's balance.

Fig 1: Location of Kilombero river basin

2.2 Research Design
The study utilized a mixed-methods approach to delve into community perceptions and attitudes towards the impacts of climate change within the region. By integrating both quantitative and qualitative data collection techniques, the research design was enriched, enabling a multifaceted analysis of the issue at hand.

Quantitative methods involved structured surveys and statistical analysis to gather and interpret numerical data. This aspect of the methodology provided a broad overview of the community's experiences and perceptions, allowing for the measurement of trends, patterns, and correlations among variables related to climate change impacts. The use of quantitative techniques facilitated the objective assessment of the extent to which climate change affected various aspects of the community's life and environment.

Simultaneously, qualitative methods, such as in-depth interviews, focus groups, and observations, were employed to capture the nuanced views, stories, and lived experiences of individuals and groups within the community. These techniques offered insights into the subjective dimensions of how climate change impacts were perceived, understood, and managed by the local population. Qualitative data contributed depth and context to the findings, highlighting the complexities of human-environment interactions and the personal and communal strategies devised to cope with the changes.

The combination of these methods in a mixed-methods approach allowed the study to achieve a comprehensive understanding of the issue. It bridged the gap between the measurable effects of climate change and the personal, often intangible, experiences of those living through these changes.

2.3 Sampling Technique
A multi-stage sampling approach was employed to select participants for the study. The initial phase involved purposive sampling to pinpoint villages within the Kilombero River Basin that have been notably affected by climate change. This was followed by stratified random sampling to choose households within these villages, aiming to capture a wide range of socio-economic backgrounds and livelihood practices.

Field research and a review of relevant literature helped

formulate criteria for choosing study locations, with a focus on villages engaged in agriculture. The selection also considered the variety in geographical settings, such as proximity to mountains, forests, and floodplains, to adequately assess climate change impacts across the basin. Consequently, five villages were chosen for their unique environmental characteristics: Msolwa Ujamaa, Sanje, Signali, Mngeta, and Mofu.

Sanje and Msolwa Ujamaa are situated near the Udzungwa Mountains' protected areas, vital for the region's water resources and supporting Sanje's communal irrigation system. Msolwa Ujamaa also benefits from a large community irrigation scheme, particularly useful during the dry season. Signali, in the Kilombero district, has observed land cover changes attributable to deforestation, which is believed to contribute to climate variability. Mngeta, known for its rainfed agriculture, faces anthropogenic pressures from the expansion of farming and livestock keeping within the Kilombero river basin. Lastly, Mofu was chosen because it is located around the Kilombero Ramsar site, where wetlands are impacted by agricultural activities and shifts in climate seasonality.

2.4 Data Collection Methods

This study utilized both primary and secondary information sources, incorporating qualitative and quantitative information. Subjective information assortment strategies included interviews with key sources, family surveys, and center gathering conversations. For quantitative information, organized interviews were led. To assemble subjective data, an agenda was utilized during inside and out interviews with 18 key sources. Moreover, an aide for center gathering interviews worked with the assortment of information from every one of the five villages gatherings, addressing one gathering for each town. Secondary information was gotten from different review related reports and sites. Quantitative information was gathered through interviews with an example of 208 respondents, including 82 men and 126 ladies across all towns, to approve and measure discoveries got from the subjective information. With an end goal to bring issues to light, a sum of 226 residents from every one of the five towns were locked in.

2.4.1 Primary Data Collection

Household Surveys: A structured questionnaire was administered to gather quantitative data on community perceptions, attitudes, and experiences related to climate change impacts. The questionnaire covered topics such as changes in weather patterns, agricultural productivity, water availability, and adaptive measures adopted by households.

Focus Group Discussions (FGDs): FGDs were conducted in selected villages to gain qualitative insights into community attitudes, concerns, and coping strategies regarding climate change impacts. The discussions were facilitated by trained moderators and captured through audio recordings and note-taking.

Key Informant Interviews: Semi-structured interviews were conducted with local leaders, government officials, and representatives from non-governmental organizations (NGOs) working around climate change adaptation. These interviews aimed to gather expert perspectives and understand the existing policies and initiatives related to climate change mitigation and adaptation in the region.

2.4.2 Secondary Data Collection

Secondary data sources, including reports from government agencies, NGOs, and academic institutions, were reviewed to gather information on historical climate trends, socio-economic indicators, and existing climate change adaptation strategies in the Kilombero River Basin.

2.5 Data Analysis

Quantitative data from the household surveys were analyzed using statistical software (e.g., SPSS, Stata) to generate descriptive statistics, such as frequencies, percentages, and measures of central tendency. Inferential statistical tests, such as regression analysis, were performed to examine the relationships between various factors and community perceptions and attitudes towards climate change impacts.

Qualitative data from FGDs and key informant interviews were transcribed and analyzed using thematic analysis techniques. This involved identifying recurring themes, patterns, and insights related to community perceptions, attitudes, and experiences with climate change impacts. The qualitative data provided rich contextual information and complemented the quantitative findings.

2.6 Ethical Considerations

Prior to commencing the study, ethical clearance was obtained from the relevant institutional review board(s) and local authorities. Informed consent was sought from all participants, and their privacy and confidentiality were maintained throughout the research process. Participants were informed about the purpose of the study and their right to withdraw at any time without consequences.

3. Results and Discussion

3.1 Climate change impact in the Kilombero river basin

The study on community perceptions and attitudes toward climate change impacts in the Kilombero River Basin of Tanzania revealed that forest-adjacent households perceive significant climate changes, including increased temperatures, unpredictable rainfall, and more frequent floods. These changes have led to decreased water sources and emergence of new pests. The main economic activities in the area are agriculture and livestock keeping, with most households engaging in farming of crops like rice, maize, and bananas.

The depicted effects of climate change in the table underscore the multifaceted impact on ecosystems and resources. The largest reported effect is a decrease in water availability, accounting for 42.3% of the impacts. This suggests a critical threat to the sustenance of agriculture, human livelihoods, and the health of aquatic and terrestrial ecosystems. The next significant impact, a 25.5% decrease in natural vegetation, is likely to exacerbate the loss of biodiversity, potentially leading to a cascade of ecological consequences, including the destabilization of food chains and soil erosion. Wildlife also suffers, with a 10.5% decrease, likely due to habitat loss and the diminished availability of water and food sources. While less frequent, an 8.7% increase in natural fire incidents can cause further degradation of habitats, releasing more carbon into the atmosphere and feeding into a vicious cycle of climate change. Human pressure on resources, increased by 12%, points to a growing strain on the environment as

communities struggle to adapt to changing conditions, often leading to overexploitation. As illustrated by Brown, M. & Funk, C. (2017) [5], the most significant impact of climate change variability is observed in the area of water resources availability. Lastly, at 1%, the blockage of wildlife movement may seem minor, yet it could have long-term

genetic effects on animal populations by preventing gene flow and leading to fragmented populations. Overall, this data portrays a landscape where climate change drives significant ecological and socio-economic challenges, necessitating urgent and coordinated conservation and adaptation measures (figure 2).
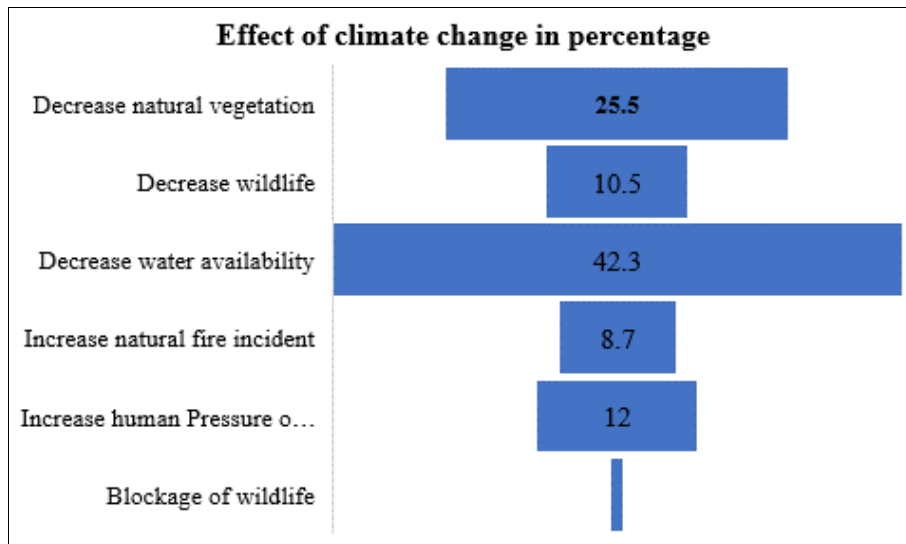
Fig 2: Villagers perception on effects of climate change in the area

Similar to the findings of Nelson *et al*., (2017) [14], Ochieng *et al*., (2015) [17], the reality of climate change is corroborated by the experiences of farmers across the surveyed villages in the Kilombero river basin. Beyond the challenges that hinder rice production in the region, certain indicators of climate change were reported more frequently than others. These prevalent signs include erratic weather patterns, a rise in temperature, the displacement of traditional rainy seasons, and a deficit in rainfall.

Similarly, as illustrated by Zommers *et al.,* (2023) [27], the impact of climate change is undeniably felt across Sub-Saharan countries; however, the extent of these effects remains a significant subject of debate. This highlights the reality that while climate change is acknowledged as a pressing issue, determining the full scope and severity of its consequences in these regions is still challenging. Zommers and colleagues point out that there is a clear recognition of climate change's presence and its impact on ecosystems, agriculture, and livelihoods. Yet, the precise magnitude of these effects is under continuous examination, indicating a critical need for more detailed research and data to understand the depth of climate change impacts in Sub-Saharan Africa fully. This ongoing quest for clarity underscores the complexity of environmental changes and the importance of targeted studies to address the unique vulnerabilities and challenges faced by Sub-Saharan countries in the context of global climate change.

3.2 Factors influencing reason of stay at Kilombero river basin
The most significant reason, with 41.3% percent, is the search for agricultural land, indicating a strong inclination towards farming activities. Employment also seems to be a major factor, with 26% of the respondents stating it as their reason for staying. Marital reasons or following relatives account for 14.4%, while a smaller percentage have moved due to unfavorable climate conditions in their previous

location.
The table illustrates the reasons why residents choose to stay in their current location. The pursuit of agricultural land is the predominant reason, reflecting the community's reliance on agriculture. Employment is another significant factor, indicating economic motivations. Marrying or following relatives is also a common reason, highlighting the social and familial factors in residency decisions. Only a small fraction moved due to unfavorable climates elsewhere, which might suggest that climate factors are less influential than economic or social reasons in this context. The category "Others" suggests a variety of less common reasons that contribute to the decision to stay.
The observation regarding the pursuit of agricultural land in the Kilombero River Basin can be supported by wider rural settlement trends, where agriculture is often a key factor in settlement patterns. Climate change, although a minor factor in Kilombero, can be a major motivator in other regions, influencing settlement patterns based on historical, geographical, and cultural factors, leading to diverse settlement designs. These trends are discussed in studies on rural settlement patterns, such as those covered by Libre Texts in their section on "Rural Settlement Patterns".
https://socialsci.libretexts.org/Bookshelves/Geography_(Human)/Introduction_to_Human_Geography_(Dorrell_and_Henderson).
The results from the figure 3 below show that firewood is the most used energy source in the given area, accounting for 52.4% of energy consumption, followed by charcoal at 23.6%. This reliance on biomass is consistent with energy use patterns in many other developing regions, where traditional biomass remains a dominant energy source due to its availability and affordability.
For example, studies on rural areas in North China also reflect a heavy reliance on solid fuels such as biomass for cooking, despite the trend towards cleaner energy sources. In these areas, biomass accounted for 44% of the energy

used for cooking, with a significant increase in the use of

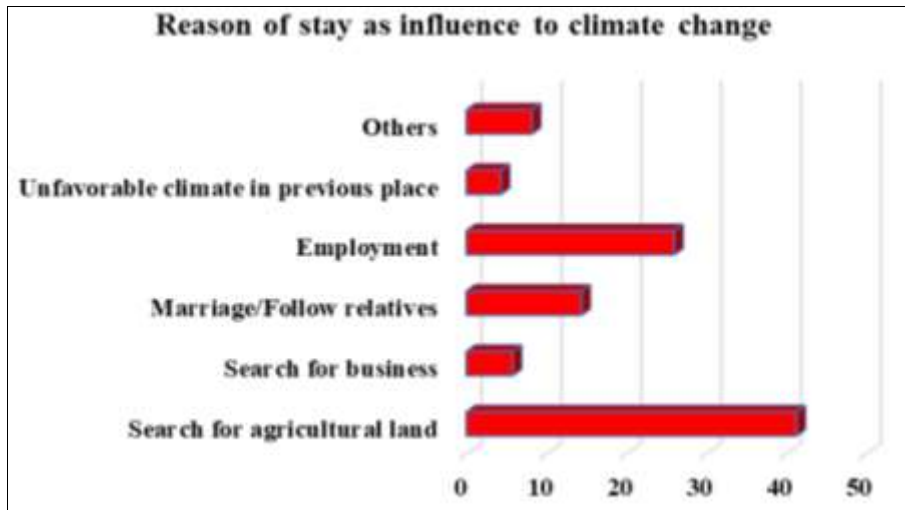clean energy for cooking, nearly reaching 50%.

Fig 3: Reason of stay as influence to climate change

Analogously, in Ethiopia, non-commercial biomass plays a significant role in energy supply, particularly in the household sector. The energy profile of the country is defined largely by the traditional use of biomass for cooking, which is both inefficient and unsustainable due to the low energy efficiency of traditional cooking technologies (Benti *et al*., 2021) [3].

On the other hand, the European Union's policy frameworks and initiatives aim to boost the production and consumption of renewable energy, targeting a 20% share of energy from renewable sources by 2020 and at least 27% by 2030. Despite these targets, renewable energy made up only 16% of the EU's energy consumption in 2014, with most of the consumption still supplied by net imports (Nordregio Policy Brief, 2017).

The comparison indicates that while some regions are making significant strides towards cleaner and more sustainable energy sources, rural areas in developing countries still heavily rely on traditional biomass for their energy needs, due to factors like affordability, accessibility, and lack of infrastructure for alternative energy sources.

3.3 Activities influence climate change
Each identified activity is part of the intricate web of causes and effects that make up the dynamics of climate change. To mitigate the impacts of these activities, it is crucial to implement measures such as embracing sustainable agricultural methods, enhancing livestock management techniques, taking preventive measures against wildfires, overseeing urban growth responsibly, and safeguarding natural habitats to support wildlife corridors and reduce migration blockages. These strategies are integral to reducing the human footprint on the environment and curbing the progression of climate change.

The interplay between human activities and the natural environment forms a multifaceted cause-and-effect relationship that underpins climate change. Each sector contributes in varying degrees to the overall picture of anthropogenic climate impact (Figure 4).
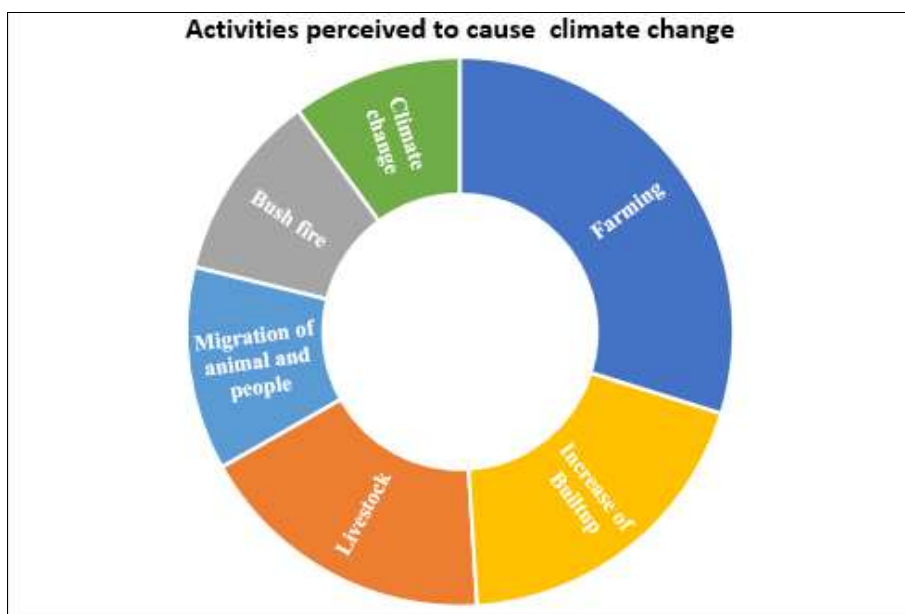
Fig 4: Activities suggested to influence climate change in the Kilombero river basin

According to respondent perception, Agriculture's role in climate change is multifaceted and substantial, contributing 29.8% to greenhouse gas emissions. Tilling, irrigation, and the application of fertilizers and pesticides are key agricultural activities that release carbon dioxide, methane, and nitrous oxide, with deforestation for farmland expansion further amplifying these emissions. Similarly, livestock farming accounts for 17.8% of emissions, predominantly from methane released through enteric fermentation in ruminants and from manure management practices.

Bushfires, constituting 11.1% of the contribution, intensify the release of carbon dioxide, worsening the greenhouse effect. The escalation in the frequency and intensity of bushfires, which climate change partly drives, forms a vicious cycle that perpetuates global warming. Urbanization is another contributing factor, responsible for 19.2% of the influence, as the growth of built-up areas results in the urban heat island effect, with man-made structures absorbing and radiating heat more than natural landscapes, thereby altering local climates and increasing energy demand.

While migration of animals and people (12%) do not directly cause climate change, it is a significant response to its consequences. Changes in habitats and the prevalence of extreme weather due to climate change force migrations, leading to additional environmental stress and potential disruption of carbon-sequestering ecosystems.

Lastly, the direct effects of climate change itself, at 10.1%, indicate a feedback loop where warming begets further warming. Processes like methane release from thawing permafrost and reduced albedo due to melting ice caps are examples where climate change accelerates its own progress by increasing the Earth's heat absorption. This intricate web of causes and responses illustrates the complex challenge that climate change presents, necessitating an integrated approach to mitigation and adaptation strategies. The same described by Singh *et al.*, (2019) [23] farming activities are the major cause of the changes in the land use, land cover hence climate change.

As detailed by Singh *et al.,* (2019) [23], agricultural practices are identified as a primary driver behind the alterations observed in land use and land cover, which in turn contribute significantly to climate change. This analysis underscores the direct link between farming activities and the transformation of natural landscapes, leading not only to changes in the physical characteristics of the land but also impacting the global climate system. The study suggests that these agricultural-induced modifications in land use and cover are pivotal factors accelerating environmental changes. These shifts, including deforestation for agriculture, altering natural habitats, and the conversion of wild areas into farmland, have profound effects on the earth's ability to regulate its climate, further emphasizing the intricate relationship between agriculture, land management, and the broader climatic impacts.

3.4 Climate Change Adaptation Practices

The level of education significantly influences the adoption of innovative management practices and the enhancement of environmental conservation. To investigate the associations between various factors, correlation studies were conducted. In the Kilombero basin, a substantial proportion of respondents, over 40%, have attained primary education (as shown in Figure 5). The findings indicated a moderate positive correlation ($r = 0.56$; $p < 0.01$) between the respondents' education level and their understanding of climate change adaptation and management strategies. Furthermore, there was a strong positive correlation ($r = 0.72^*$; $p < 0.01$) between the education level of respondents and their implementation of resource management plans in the basin. Additionally, the level of education showed a strong positive relationship ($r = 0.77^*$; $p < 0.01$) with the awareness of the benefits of conserving the environment and water resources. However, the study also uncovered that only a small percentage (5% to 12%) of respondents recognize the importance of using modern technology in agriculture across the surveyed villages.

In a manner akin to Chatterjee, S. & Jones, B. (2018) [6], it is portrayed that the awareness of adaptation strategies is closely tied to educational levels. Furthermore, the depth of understanding regarding the mechanisms of management practices also hinges on the extent of individuals' education. This implies that higher educational attainment not only enhances awareness of adaptation needs but also bolsters comprehension of the intricacies involved in effective management practices.
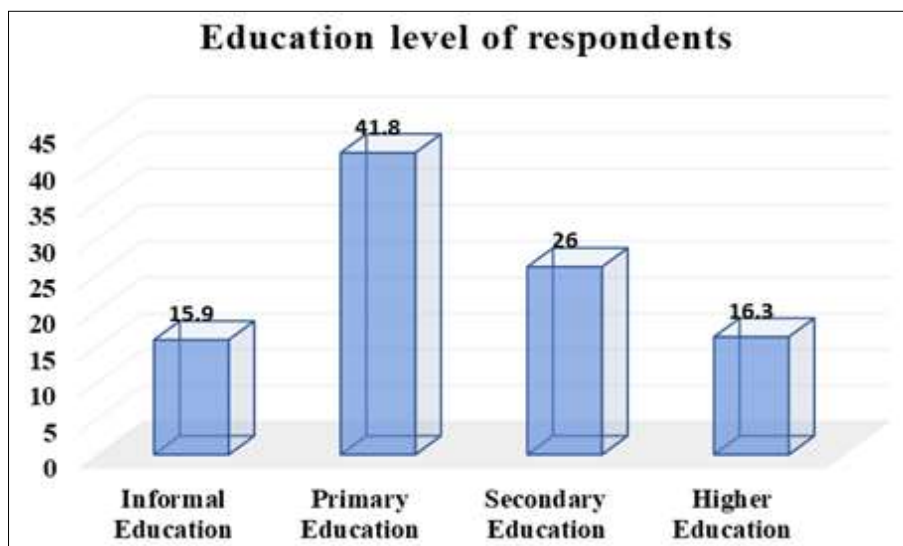

Fig 5: Education level of respondents

4. Conclusion and Recommendation
4.1 Conclusion
The study within the Kilombero River Basin reveals a stark reality where climate change manifests in increased temperatures, unpredictable rainfall patterns, and more frequent floods. These changes have substantially decreased water sources and catalyzed the emergence of new pests, adversely affecting the primary economic activities of agriculture and livestock keeping. The most pronounced effect, as reported by local communities, is the significant decrease in water availability, which presents a dire threat to agricultural sustainability, livelihoods, and the health of both aquatic and terrestrial ecosystems the same to Adebayo, A. & Mutanga, O. (2016) [1] findings. The degradation of natural vegetation and wildlife, compounded by the increase in natural fire incidents, underscores the urgency for integrated conservation and adaptation measures to mitigate these multifaceted impacts (Kijazi *et al*., 2020) [11].

4.2 Recommendation
Given the clear link between human activities and climate impacts, it is imperative to adopt a suite of measures across different sectors. Sustainable farming practices, such as conservation agriculture and efficient water use, should be promoted to reduce the agricultural sector's carbon footprint. Livestock management needs to evolve to minimize methane emissions, including adopting better feeding practices and manure management. Effective wildfire management and urban planning are essential to prevent further exacerbation of the climate crisis.

Education emerges as a pivotal element for driving change. The positive correlation between education levels and the understanding of climate change adaptation, as well as the implementation of resource management plans, indicates that educational initiatives could substantially contribute to climate change mitigation efforts. It is crucial to increase awareness and usage of modern agricultural technologies, which can offer both adaptation and mitigation benefits.

To address the pressing climate challenges in the Kilombero River Basin and beyond, policy measures and educational programs must be implemented. These should be designed to empower local communities with the knowledge and tools necessary to adapt to and mitigate the impacts of climate change, ensuring the preservation of their environment and the sustainability of their livelihoods for future generations.

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