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Linking Local and Scientific Knowledge in Climate Change Adaptation in Semi-Arid Area: A Case Study of Igunga District, Tanzania

Josephat Malero Mung'onya[1] and Nangware Kajia Msofe[2]*
[1]School of Environment, Northeast Normal University, China
[2]The Open University of Tanzania,
*Corresponding author:nangware.msofe@out.ac.tz

Abstract
Climate change poses threats to semi-arid biomes worldwide that calls for global efforts to combat its effects through adaptation and mitigation practices. Recent studies recognized the importance of including Indigenous and Local Knowledge (ILK) and Scientific Knowledge (SN) in research on climate change impacts and adaptation. This paper explored indigenous knowledge on climate change impacts and adaptation and its relation to scientific knowledge in semi-arid areas, Igunga District, Tanzania. The study adopted a mixed methodology combining qualitative and quantitative approaches including household questionnaires survey, key informant interviews and field observations. The study found out evidence of pronounced climate change impacts in Igunga District from the scientific literature and local reports. The findings highlighted that, there is extensive overlap between information derived from local and scientific knowledge systems. And that about 96% of respondents in the study area uses their ILK in predicting weather and adaptation to climate change impacts. Majority of the respodents reported the associated climate change impacts with erratic rainfall, increase of temperature and frequent prolonged droughts. Overall, our results suggest that cross information of indigenous and scientific should be used to develop local community coping and adaptation strategies to climate change. The study concludes by suggesting inclusion of ILK in policy formulation for climate change adaptation and risk management.

Keywords: *Indigenous and Local Knowledge, Scientific Knowledge, Climate change, Climate Change impacts, Adapation, Semi-arid area*

1.0 INTRODUCTION

Climate change exacerbating violent storms, heat waves, prolonged drought and flood have brought severe risks to local communities in sub-Saharan Africa (Nyadzi et al., 2021). Predictions indicate that climate change is expected to increase the frequency and severity of its effects globally (IPCC, 2019). Semi-arid areas are expected to experience much severe consequences of drought. Persistency of droughts in the semi-arid areas are anticipated phenomenon under current and future climate change that caused greatest serious threats to water availability, food security, and indigenous local livelihoods (Liwenga, 2008; Mkonda, 2018; Mdemu, 2021). Water scarcity is pointed as one of the drought-induced impacts which causes several environmental challenges in rural areas

(Pamla et al., 2021). Thus, adaptation is seen as a feasible choice in reducing the vulnerability related with anticipated negative impacts of climate change (Nyong et al., 2007). For a long period of time, local communities have developed indigenous knowledge that helps them to cope with environmental changes. The local communities and indigenous people hold knowledge on practices such as agriculture, fishing, hunting, foraging and the use of medicinal plants (Ajibade and Eche, 2017). These communities developed long-term ecological knowledge base on managing the impacts of climate change, predicting, anticipating or responding to weather and seasonal climatic changes (Abu et al., 2019). This knowledge enables communities to make decision regarding climate variability, other related changes and problems (Zvobgo et al., 2022; Walter et al., 2022). For instance, livestock management is widely used as indigenous and local knowledge (ILK) in farming systems across communities in Africa. Likewise, an early-warning system is also used as an indicator of the quality of the rainy season (Mapfumo et al., 2016).

Adaptation on an individual or household scale includes activities done by individuals such as the use of local indicators, risk assessment, and planting season. On the contrary, adaptation at community scale includes communal activities such as ritual practices, traditionally managed method, and community-wide rules for resource management and tradeoff (Kangalawe et al., 2011). They take such measures after recognizing indicators in nature. For example, the Peach tree flowering and the first rains in August indicate the proximity of summer (Basdew et al., 2017). Thus, farmers can identify these indicators much in advance due to generations of using the same indigenous knowledge. They then plan the well-being of their crops or livestock based on the weather they are expecting. The locals feel that this is especially important as indigenous knowledge is not vulnerable to external forces. Indigenous knowledge communication and applications are largely unaffected by the challenges faced by scientific forms of knowledge (Basdew et al., 2017).

Knowledge systems including Indigenous and local knowledge are accepted as a 'major resource' for climate change adaptation but ILK has not been applied regularly in adaptation efforts and have often been ignored in policy, research, academic and public discourses (Petzold et al., 2020). Despite this negligence, Indigenous peoples themselves have long acknowledged the significance of their knowledge systems for handling changes in their natural environments (Ford et al., 2020). Thus, the Intergovernmental Panel on Climate Change (IPCC) and part of the scientific community have called for greater inclusion of indigenous and local knowledge in adaptation interventions and environmental management. Indigenous and local knowledge constitute complex knowledge systems embracing biological and ecological dynamics, practice shaping environmental use and management and their socio-cultural dimensions. While attempts have been made to integrate Indigenous knowledge into science

knowledge in environmental assessment and resource management, still science knowledge remains to be valued over indigenous knowledge (Abu et al., 2019).

However, recent discussion about the collaboration and exchange between ILK and scientific knowledge systems can occur suggest that knowledge pluralism has the potential for enabling transformative change through partnership between knowledge holders (Orlove et al., 2010). Previous adaptation studies in Tanzania and East Africa, focus most on indigenous knowledge, rather than investigating how indigenous knowledge can be integrated with scientific knowledge in adaptation approaches to climate change impacts in semi-arid areas (Elia et al., 2014). Consequently, the environmental knowledge of indigenous people living in semi-arid settings including Igunga District is scarcely recognized in the adaptation literatures (Elia, 2014; Basdew, 2017). This study thus aims to examine the relationships between indigenous-science knowledge in adaptation in semi-arid area, Igunga district. This will offer valuable insights that can inform policy and decision makers on adaptation strategies to climate change impacts that links indigenous and scientific knowledge.

2.0 MATERIALS AND METHODS

2.1 Study Area

This study was conducted in semi-arid area of Igunga District, Tabora Region, Tanzania. The district is located between latitude 10°00 – 08°40' South and longitude 35°10' – 37°10' East (Figure 1).

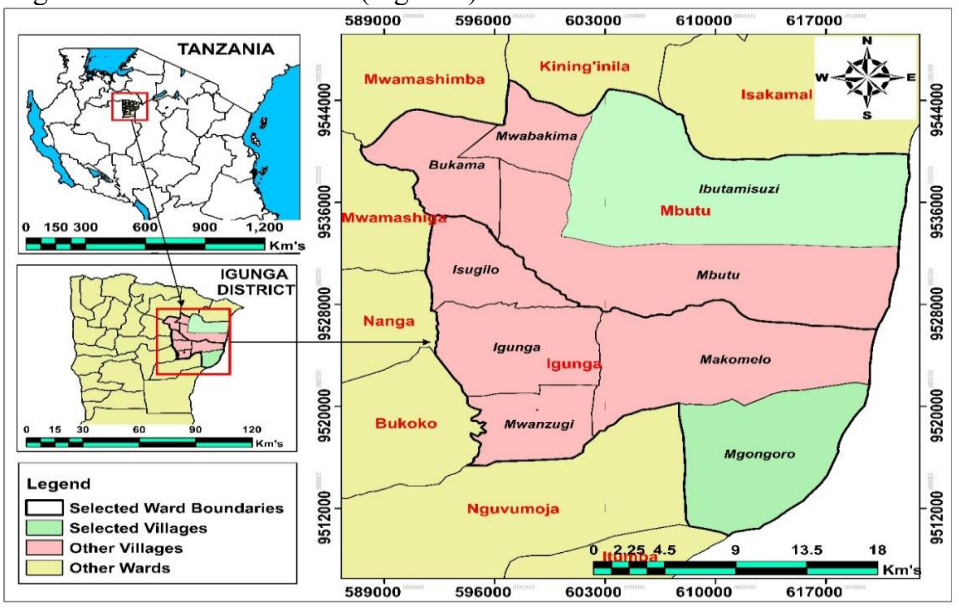

Figure 1: Geographical location of the studied villages in Igunga District, Tanzania
Source: Authors, 2024

Igunga District is largely dominated by plain land, characterized by semi-arid conditions with a long dry season and receives relatively low rainfall. Due to this, the district is one of the driest districts in the Region. The main livelihood of the indigenous is largely agro-pastoralism which is sensitive to climatic shocks. This kind of livelihood is a rain-fed dependant. This implies that the livelihoods of the communities have been under strain because all indigenous people in the study area are reliant on the provision of natural resources and that agricultural remain the predominant sources of indigenous sustenance. Given such facts, it was then thought selecting this district could yield informative results than elsewhere in Tabora Region. Within this study area, researchers purposively selected two villages that are most vulnerable to climate risks and semi-arid agro-pastoral livelihood activities variation. In this concern, Ganyawa and Mgongoro villages were selected aiming at obtaining the extent on how ILK is being used in adaptation.

2.2 Data Collection

Researchers used a mixed research method to address the study's objectives. A mixture of qualitative and quantitative research methods was adopted to collect primary data in order to identify cases with a lot of information and capture different points of view. Researchers collected (i) secondary data from the scientific literature (ii) and meteorological data. To ensure comparability between scientific data and local information, researchers asked for individual reports of change over the last 30 years. In this paper data were collected using questionnaires, interviews, observations and documentary literature review.

Questionnaire survey employed structured and semi-structured questions to obtain household responses. The questionnaires were administered face to face to the head of the household as the sample unit. The sample size was derived from the Krejcie and Morgan, (1970) where the sample size was determined from the table depending on the population available in selected villages. Sampling involved purposive and random methods to gain a wide range of local indigenous people awareness. In this way, 35 households from Ganyawa village representing 8.8 % out of 398 total households in the village, and 35 households from Mgongoro village representing 8.10% out of 432 total households in the village were selected.

Key informant interviews are meant to interview a selected group of people who are likely to bear specific information, ideas and insights on the issue at hand (Nyeme, 2010). Key informants included in this study are indigenous elders at least 50 years old and above, village leaders, agricultural and environmental officers. Two key informant interviews were conducted one in each study village, with the aim of sympathizing with climatic changes observed in the area over 30 years in regard to indigenous knowledge, and comprised both male and female elders. Field observations involved walking in the study area with GPS

taking some coordinated of some features and take photo of various place and climatic events.

Secondary data refers to information collected from published or unpublished sources (Kothari, 2004). Major sources of secondary data in this study involved reviewed scientific literature and the data from the Tanzania Meteorological Agency (TMA), http//: climexp.knmi.nl/ for rainfall and temperature data. Other secondary data sources were documentary reports on trend of precipitation, drought and temperature from Igunga District Council, various stakeholders, and non-governmental organizations.

2.3 Data Analysis

Different methods were employed in this section to analyses data. Descriptive statistical analysis was used for household survey data. The interviews were auto taped, transcribed, coded and finally edited and analyzed. Qualitative data collected edited and classified based on specific objectives. Also, quantitative data were edited, coded and entered in Statistical Package for Social Science (SPSS) computer software SPSS version 20. Data obtained through interviews were analyzed according to report objectives. Analysis through SPSS included descriptive summaries, percentages, frequencies and cross tabulation which were presented in tables, charts, figures and graphs. Moreover, TMA meteorological data taken from 1970-2022 were analysed using descriptive statistics of annual rainfall and temperature using MS Excel and plotted using R software. The results were presented in figures and graphs.

3.0 RESULTS AND DISCUSSION

3.1 Indigenous and Local Knowledge on the Climate Change

Local communities in Ganyawa and Mgongoro villages have observed numerous climate driven changes indicators in their environment over the last 30 years. The seven indicators most frequently reported by the respondents from the questionnaire survey data are; (1) disappearance of some flora and fauna is among of the sensitivity observed by 18%, (2) a shortage of water reported by 28%, (3) an increased in the frequency of extreme droughts (45%), (4) increase in temperatures (14%), (5) unpredictable rainfall reported by 12%, (6) increase in animal mortality reported by 6% and, (7) increased pests and diseases by (25%). These indicators have resulted to death of livestock; poor crop yields due to shortage of water and pasture for livestock affecting local communities' livelihoods. In depth discussion with elders, it was found that, in 1960's rains used to be heavy, frequent and throughout the year, and agro-pastoralism was consistent. April used to be the maximum peak of rainfall where one could not get out of household for several periods a day. Additionally, every household engaged full in agro-pastoral activities and food was abundant. But current April is one of the driest months in the area and rains can no longer be predictable ever. Elders further clarified that, several of the observed changes started in around 1970's, and started to get little worse in 1980's and intensified in the

1990's. Furthermore, there is predominant drying of water sources, and decline of flow volumes in rivers such as river Mbutu that discharges its water into Ganyawa plains where the Taturu ethnic agro-pastoralists reside (Figure 2). The following extract from one of the interviews with a respondent in Ganyawa on 05th May 2024 provides as sense of practice:

> *"We are primarily pastoralists. But recently we have adopted agro-pastoralists in order to cope with changes in our natural environments. During prolonged droughts, livestock are dying of shortage of water, pasture and disease. In the past, River Mbutu stayed with water throughout the season. Pastures were available and little diseases. In recent times, the situation has changed and became worse than before"*

Figure 2: Part of dried Mbutu River shared by Mgongoro and Ganyawa villages,
Source: Photo by Author on May, 2024

However, key informants had further to say that, the study area is harshly affected by uneven rainfall where previously rainfall was well-known to commence on October to December and march to early June, nevertheless now days it is undefined. They further reported that, there are now changes especially increase in frequency of dry spells during rainy season, high temperature, late onset and earlier cessation of rainfall hence worsens pasture availability for animals, water shortage. Through field observations, drying up of rivers, streams, ponds, wells, wetlands that formerly used to flow in high volumes was observed; and this was associated with prolonged droughts. Forest resource which was much dependable during harshly weather conditions has been affected at great extent. Furthermore, the indigenous agrees to have contributed to climate change and variability as they carry various socio-economic activities, whereby 89% of local communities agreed that climate change is the outcome of environmental degradation in common and poor agricultural practices were informed and non-socio-economic activities by 11%. Cutting trees down for charcoal and preparation of new land for crop production were reported to the causative for their environmental changes.

3.2 Local Perceptions and Meteorological Measurements on the Climate Change Trends

Perception is the course of realizing awareness of understanding of sensory information. What one perceives is a result of interplays between past experiences one's culture (Mdemu, 2021). Though there is diverse perception on climate change and variability, through their local knowledge, majority of informants agreed 100% that changes in climate is real. Findings from household survey reveal that, 98.4% of respondents perceive that temperature amounts have been increasing extremely in their environment, 1.6% considers no changes in temperature patterns. Key informants reported that, temperature patterns have changed at both spatial and temporal scales. In addition, the general view of many respondents was that temperatures have been increasing steadily over since 1990's. According to the analysis of the meteorological data analysed from 1970-2022 it indicates there was a consistent upward trend of temperature in the study area indicating increased temperature (Figure 3).

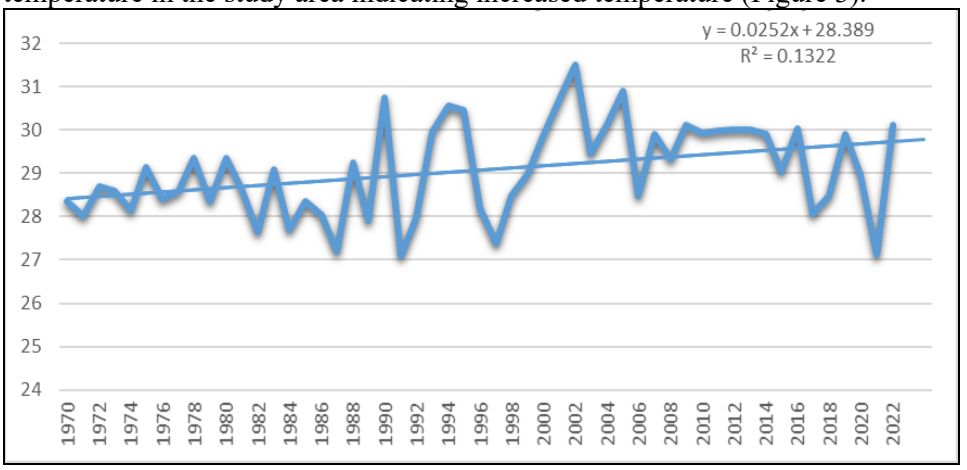

Figure 3: Mean Annual Temperature from 1970-2022 of the Igunga District
Source: Authors, 2024

3.2.1 Perceived Rainfall Trends

To grasp the extent of climate change in terms of rainfall in relation to the most observed climate events in the study area was important, in establishing the impacts of climate change on households' economic activities. Analytical results indicate that, 88% of respondents have observed at great extent a drop in the number of rainy seasons linked with late start and early cessation. On the other hand, 12% confirmed that, the seasonal rainfall distribution was unpredictable accompanied with dry spells. Key informants agreed that, the start, duration, distribution and amount of rainfall in the study area had changed tremendously since 1970s to current and had become unpredictable. This state has made cropping and pastoral activities more challenging to make decision. Rainfall erratic is increasing year to year causing negative effects on agricultural production, thus food insecurity. In a situation, according to informants one cannot predict it with confidence. Also, rainfall amount has been decreasing

progressively since 1990's and its impacts have been felt to have constant unsuccessful agricultural production and water scarcity in the study area. According to the analysis of the meteorological data analyzed from 1970-2022, it indicates there was rainfall variability from year to year and decreasing trend of rainfall amounts that correlates with respondents' views (Figure 4).

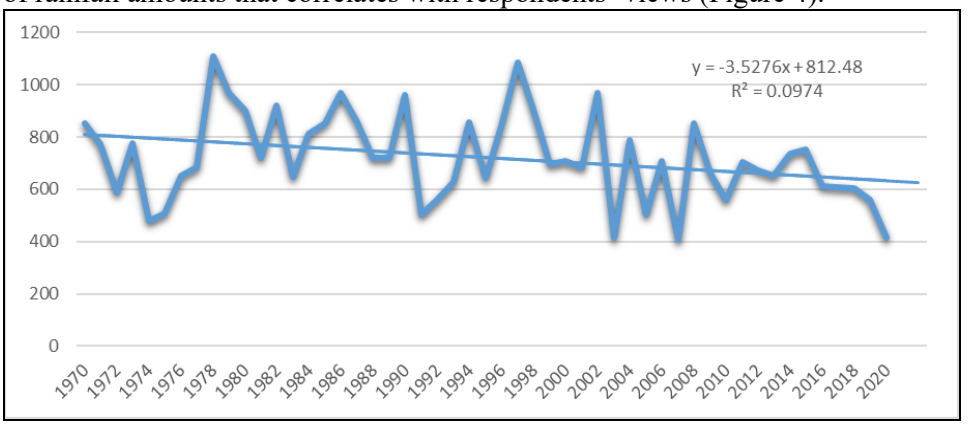

Figure 4: Mean Annual Rainfall from 1970-2022 of the Igunga district
Source: Author, 2024

3.2.2 3.2.2 Perceived Trends on Drought Incidences

Drought is a recurrent phenomenon in semi-arid areas of Tanzania including Igunga District. Majority of respondents from both villages agreed that, drought events have become more frequent than before by 12.2% and has occurred at least every 1 to 2 years, 63.7% of household's respondents argued that, droughts has occurred every 2 to 3 years. Yet, 11.5% of respondents claimed that, drought incidences have occurred from 3 to 4 years and 4 to 5 years agreed by 8.6% (Figure 5).

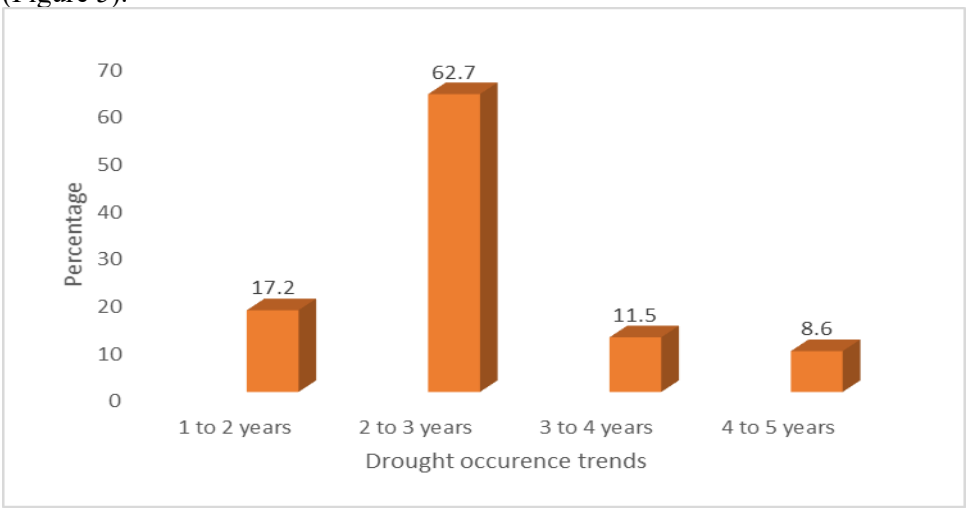

Figure 5: Percentage of Respondents on the Drought Incidence in Igunga District
Source: Authors, 2024

According to key informants' information, droughts and prolonged dry spells have affected the study area at various times throughout the history and it is now more repeated than previously and it is not a new event to them. Key informants explained in detail that, the area is getting drier because of increased drought frequency where slight normal, moderately dry and severe droughts were experienced in the study area in the year between 1977and 2023 in the study area. It was reported further that, drought seems to be the major cause of the drying up of rivers, streams, ponds, swamps, shallow wells, food insecurity, animal mortality, extinction of some indicators and inability for ILK to perform effectively.

3.3 Indigenous and Local Knowledge on Climate Adaptation

Households were probed of their coping and adaptation experience on climate change in the study area. The results show that, local communities have invented and developed certain long-term immediate traditional techniques and approaches using knowledge transmitted orally and in practice of coping and adaptation strategies without any sophisticated equipment such as traditional animals and plant varieties by 46%, planting timely 23%, water conservation 15%, soil improvement practices 8%, migration 4%, controlling pest and disease 2% and food preservation 2%.

3.3.1 Traditional Animals and Plant Varieties

In order to be resilient to climate vulnerabilities, it was found that, indigenous have relied most on the traditional animals and plant varieties which are to somewhat resistant to local changing conditions, pests and diseases and maintain food security at households. These information merge with respondents' perception during deep discussion with key informants explained that, animals are the commonly extensively used as indicators for coping and adapting to climate such as ants' appearance at various places, different birds. They added that, behaviors of domesticated animals are good signs to them for understanding. For example, cattle, goats and sheep jumping when entering and coming out in the herd kraal from and to grazing respectively. During night hours, they seem to be violent, at the same time donkeys shouting out. This habitually often occurs in mid-September to October, indicating good rains and pasture for coming season. But when these animals' behavior does not happen in line with outing running speedy for grazing indicate that there will be dry season taking long time. In case of wild animals like insects, appearance and gathering of various ants, grasshoppers in large groups, termite starting molding soil on top of the tunnel, birds flying high above the sky, songs played by and rebuilding nests few weeks or days before the beginning of rainfall indicates good season is going to prevail, in contrast with such behavioral features, indicate little rainfall along with dry seasons. Frogs are too used to indicate good season or bad. This is when the croaking of frogs is heard in September to December and during rainy season, but when this kind of behavior not experienced or little, indicate poor season. During rainy seasons, disappearance

of these animals' behaviors marks the end of rainy, new season of prolonged drought, dry spells or winter develops.

On the other hand, numerous native tree species offer environmental benefits as well as multiple economic uses. Some of them are soil properties, and contribute to the environmental sustainability. Native trees play a well-recognized role in maintaining and improving agricultural production by protecting water sources, stabilizing soil, improving soil fertility and water retention. The value of trees in general, as stabilizers, enhancers and indicators of the environment is well-known by indigenous people. Key informant went further by insisting that, in the study area there are dominant native trees locally known as Migunga (Nilotica, Malifera, Albida and Tortilis- thorns and non-thorns acacia) and miduguyu (Balanites Aegyptiaca-simple thorned torchwood) and other plants are used in weather prediction, coping and adapting to harshly changing environments. These native plants are mostly distributed in the study area tolerant to range of conditions including droughts and dry spells (Figure 6).

Figure 6: Different natural acacia (Indicators) used in weather prediction in the study area
Source: Authors, 2024

The back, root, the gum bark and fruits of Acacia and balanites Aegyptiaca(miduguyu) trees are used for curing coughing, fever, diarrhea, haemorrhage, abdominal pain and colds to human. Elders added that, gum from the balanites aegyptiaca is mixed with maize or millet porridge to cure chest complications. This kind of tree produces fruits even in dry seasons which is one of the food sources in the study area. Similarly, regular slash around farms and cleaning cattle kraal is implemented in order to prevent invasive pests and diseases.

3.3.2 3.3.2 Conservation of Water Sources

Water sources conservation was among of the initiatives that has been undertaken many years ago to conserve catchment areas for coping and adapting to climate variability and change. Observation was used to systematically to

walk across the study area with key informants to observe specific areas like water sources. From such observation, it was recognized that, water resources are conserved and remain the first priority for household as domestic use, livestock and brick making in the study area. Key informants were probed of their experience on water resources availability in the study area. According to IK possessed by elders stated that, in certain previous years (especially in 1970s) the duration of rain water in rivers, wetlands, ponds and swamps and the distance covered by green grasses at the banks determined the surface and groundwater availability throughout the dry season. Unfortunately, this does not take place. Rainwater in mentioned sources dry fast few weeks after the rain season ends. They explained further that, when unlike species like butterflies normally used to gather around drying water, indicate groundwater is unavailable, this is then happening almost every dry season. According to Key informants in the study villages, groundwater is less cost fully and can be pure and safe for both households and livestock. They further informed that, groundwater is tolerant to climate and environmental extremes than surface water which is directly heat by the sun and dry fast within few weeks. Interviews with experts (IGUWASA) informed that, there is extreme decrease in water resources specifically surface and of groundwater due to environmental and anthropogenic factors. Consequently, indigenous had have invented and developed traditional diverse techniques and measures to cope with water resources scarcity such as household hand-dug ponds, dug ponds at dried river beds, ponds, swamps and wetlands locally knowns as "lwijee". Lwijee normally is supervised by the head of households. There was of shared village/communal pond that serves the indigenous, and protection, conservation of catchment areas and making an ox and donkey cart for searching water from distant places (Figure 7). Similarly, these findings are in line with Rutten (2005) who found that, in Kenya, during dry spells pastoralists dig shallow wells on dry water pans and dry river beds by scooping sand to access the water for their livestock and other basic uses.

(a)

(b)

(c)

Figure 7: (a) A hand-dug well at Mbutu river bed (Lwijee) (b) A hand dug pond around a household, dug during rainy season in March, 2024 (c) Catchment area conserved as a water source, now it is dry in the study area.

Source: Authors, 2024

Miscellaneous, ILK face challenges, linked with weather forecasting and climate prediction in the study area have been ineffective with poor dependability and lack of consistence due to climate variability and change. Information conveyed by elders indicate that over the recent years the indicators are becoming less dependable, and even if observed, the expected state of weather develops unlikely, for instance delayed onset of rain in the anticipated seasons or decrease in the amount of rainfall within exact season. In addition, prolonged drought has led to drying of communal ponds, shallow wells due to high rate of evaporation. However, an expert reported that, siltation, leaching and overuse of water by households during these dry seasons, are one of the reasons of water scarcity affecting human and livestock in general, the following extract from one of the interviews with an informant in Ganyawa on 08th May 2024 explained in details that:

We have and we are still depending on our forefathers ILK, but due to increase in environmental change, ILK is sometimes uncertain. This has forced us to rely largely on coping strategies rather adaptations strategies, since we have no means, facilities and knowledge on modern adaptive ways of drawing water deep from the ground. Also, we lack the capacity of collecting large amount of water during rainy season and hence we collect for daily use and not for future use.

3.3.3 Food Preservation

In the absence of rainfall and in order to adjust to harsh environmental change and its related impact on the household livelihoods, indigenous people have developed ILK measures in time of scarcity before, during and after the change in environment like selecting, storing and conserving food ways such as sun drying of meat, okra, leaves of green vegetable (locally knowns as Nkarango, Nzubho) of cowpea, pumpkins and cleome gynandra. Also, sweet potatoes are

preserved by being cooked or either, pee then being cut into small pieces and dried for future needs (locally known as mapalage/mathobholwa) (Figure 8).

Figure 8: Preparation of Sweet Potatoes (Mapalage) for Future Use in the Ganyawa Village
Source: Authors, 2024

Other crops stored are millets and maize. All these types of food are stored for 1 to 2 years in traditional food storage facility locally known as Kihenge) made of woven sticks plastered with cow dung or mud and mounted on a table-like structure. Indigenous have managed preserve cattle food to be used during pasture scarcity, such as keeping leaves and peels of sweet potatoes, groundnuts, maize stalks and the alike. They are preserved and stored on table-like structure (locally known Kichanja) (Figure 9).

Figure 9: Preserved Food for Cattle and Harvested Native Millet in the Study Area
Source: Authors, 2024

3.4 Linking ILK and Scientific Knowledge

It was imperative to grasp knowledge to what extent ILK and science have been linked in the study area and thus can be useful to other areas. In this regard, the challenges and opportunities that were noted from indigenous weather forecasting in this study, highlights link of techniques and approaches from the two knowledge as an instant and sustainable way for shared and inclusive weather forecasting in diverse local indigenous communities. The reliability and accuracy of the ILK have yet scientifically proven. But, the viability and utility value of ILK can only be enhanced when linked with scientific approached and know-how for good prediction and adaptation to changing environments. The reports from respondents indicated that 86.3% are aware of scientific weather forecasting. They further explained that, science knowledge is not applicable in predication of weather for their activities. Since, most of the weather forecasting information contains vocabularies which are misunderstandable to indigenous as many of indigenous are illiterate. And about 100% of households do not possess televisions and except few own radios, electricity poles pass through their villages and going far and there is no transformer.

Moreover, analysis of household survey indicates that, more than 92% rely on IK in prediction without scientific knowledge and 8% agreed to link the two knowledge through listening to media outlets specifically radios news on weather issues but do not understand properly due to language barriers. The IK in the study is paid little attention due to poor reliability of its indicators, promotion, no documentation, and integration with modern weather information. Some of them reported that, the main problem is the poor accessibility of modern weather information from media outlets especially radios so as to link with their IK and find a solution. Though some own radios, remoteness of their residential areas is faced with broadcasting radio waves and language used.

Indigenous perception on the linkage between knowledge system was revealed as an opportunity discuss how to best ways to deal with climate change events. Results showed that 100% of respondents are unfamiliar with existing or future initiatives to link indigenous-science knowledge. The challenges noted in the study area to why IK is not linked into science for weather forecasting seems to be constrained by poor cooperation between indigenous and science experts, every group is working on their own outcome. Informants revealed that, in order IK to work effectively, science must be closer monitoring and improving of IK and itself by taking valuable knowledge from elders and utilize it. Nevertheless, there is poor participation of elders indigenous with weather experts in weather prediction, no information sharing programmes, language barriers that impedes more clarification of the information, improving networks to assist perfect coverage of media. Inclusion elders, leaders in the whole process and establishing local weather forecast stations at village level, will aid indigenous to engage and enlightened hence science knowledge dissemination and exploitation of integrated weather forecast information.

Meanwhile, climate change still intensifies the frequency and intensity of extreme weather events, affecting indigenous livelihood activities in the study area. Due to this situation, the study focused more on how ILK and Scientific Knowledge can be together linked on food preservation and livestock protection. Hence indigenous were probed on their opinion and experiences with ILK and SK linkage. The report from the field indicates that, ILK is more suitable and applicable than SK in the study area, though scientific knowledge (SK) is head among them, but not applicable apparently, since no school farms/classroom garden preparations for smallholder farmers, seminars and workshops. However, more described on unavailability of modern food preservation facilities. Therefore, poor skills and experience for SK on food preservation.

It was asserted during key informant interviews with elder, village government representatives and other respondents that, the practice of ILK to forecast atmospheric weather conditions is significant for crop management and long-term strategies, for instance, crop planting, harvesting and preservation, avoiding costly mistakes in severe weather conditions. This reduces food and income losses due to lack of surplus to supplement households' need and ensure indigenous resilient and reliable food supply anytime. Informants added that, agro-pastoralists in the study area ILK typically lessen the death and loss of their livestock by observing biotic features such as animals' behaviors and trees characteristics. This normally indicates precipitation, climate extreme conditions and drought circumstances. Changes in their behavior and characteristics in response to change in the surrounding environment assist indigenous appropriate find water sources and grazing locations that can make livestock resistant from harsh condition. The results above suggest that, while indigenous local people can have a wide range of choices on knowledge systems to protect food and livestock depending on climate conditions and circumstances of the household, still ILK is priority number one. Despite the potential benefits of SK, it was observed that, SK is facing several challenges for its adoption as strategy for adaptation to climate impacts in the study area. These include climatic or environmental challenges and other such as social, economic and political challenges.

Basing on these enlightenments, since weather forecasting, interpretation, language barrier along with illiteracy seem a setback, in this context intervention is inevitable. It will enable them link the two knowledge systems, understand and utilize them for better weather foresting and adaptations as well. Moreover, there are deficient studies of IK particularly in Tanzania that document and validate the effectiveness of the IK and the scientific knowledge. The linkage of these systems is imbedded in the selection of compatible indicator that is indigenous prediction indicators may or not merge with scientific indicators. On the other hand, the problem is also drawn from how the two are carried out, where indigenous people use animals' behaviours, plants, wind directions and rainbow in forecasting concentrating on the onset and cessation of the season.

Scientific experts (e.g., TMA) normally cover a large geographical area for a certain period of time in forecasting weather using meteorological indicators (especially wind and sea surface temperatures). Furthermore, Officials were probed on how IK and scientific in formulating and implementation of climate change interventions can be achieved. Reports from the study area verify that, there is division in institutions. Speaking with officials proposed that, linking the two systems there should be proper policies formulation methods to establish better environment and collaboration among non-governmental organizations, community-based organizations, governmental institutions, private sectors and indigenous. By so doing, intervention of scientific and indigenous concepts could bring bottom-up entry point for TMA, indigenous and other sectors. They further explained that, there should be more studies on IK to strategies to climate variability and change through animals and plants, keeping livestock, know better about the value of this knowledge. But this does not prevent it from linking them.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Fundamental findings of this study and yet the global climate change is on large scale, linkage between IK and science is inevitable. This study revealed that in predicting weather and climate using indigenous knowledge in rural area had has helped them to observe, perceive and recognize what is going on in their environments. Indigenous people accepted that, since their livelihoods depend on climate, noticeable changes in main variables of climate such as temperature and rainfall are real and at great extent. It was found that, indigenous people used their natural environment to forecast and decision making. Astonishingly, they have discovered and developed their own coping and adapting cultivating native food and cash crops, hand dug ponds among others. Single indicator could not provide enough information to interpret the coming weather, but multiple indicators are normally observed before arriving at a conclusion. However, approaches applied have gone through challenges, because of extinction and disappearance of some indicators (flora and fauna), frequency prolonged drought and dry spells, illiteracy and lack of modern way of predicting weather, thus altering the effectiveness of indigenous natural adaptation means. Moreover, the indigenous people rely on their ILK ways of prediction and adaptation, and scientific experts on the other hand on their own, creating gap between the two systems. A call upon the link between indigenous and scientific knowledge for better weather forecasting and data gathering is of important. It will contributions to reducing risk and vulnerability, developing resilient among indigenous people, environmental improvement, increasing economic activities and enhancing governance and institutions. The cross information of indigenous and scientific should be used to develop local community coping and adaptation strategies to climate change.

4.2 Recommendations

This study recommends the reinforcement advocacy and policy dialogue on indigenous-science knowledge related matters among and beyond the district institutions and organizations. On that, adaptation policy should be reviewed and indicate the deserved priority and importance of indigenous-science per sector, as a key entry point on the face of climate variability and change now, and in the coming future. Much as climate change and variability appears not to be a strange phenomenon in the study area and that indigenous local people have adapted to its adverse impacts. However, there should be sufficient and reliable weather forecast information by complement indigenous' autonomous responses and modern responses. In order to avoid challenges, TMA need to involve local communities in trainings and orientations before embarking on observing the selected indicators, data gathering and recording information as a way of community empowerment and maximizing acceptability of the strategy. And lastly, decision and policy makers should integrate ILK in policy formulation for climate change adaptation and risk management.

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6.0 COMPETING INTERESTS

The authors declare that they have no competing interests.

REFERENCES

Abu, Razak & Reed, Maureen & Jardine, Tim. (2019) Using two-eyed seeing to bridge Western science and Indigenous knowledge systems and understand long-term change in the Saskatchewan River Delta, Canada. International Journal of Water Resources Development. 36. 1-20. 10.1080/07900627.2018.1558050.

Ajibade L, Eche J. (2017). *Indigenous knowledge for climate change adaptation in Nigeria. In: Indigenous knowledge systems and climate change management in Africa.* Wageningen, The Netherlands: CTA. p. 219.

Basdew, Myuri & Jiri, Obert & Mafongoya, Paramu (2017) Integration of indigenous and scientific knowledge in climate adaptation in KwaZulu-Natal, South Africa. *Change and Adaptation in Socio-Ecological Systems.* 3. 10.1515/cass-2017-0006.

Elia, E., Mutula, S., & Stilwell, C. (2014) Use of Indigenous Knowledge in Seasonal Weather Forecasting in Semi-Arid Central Tanzania. *South African Journal of Libraries and Information Science*, 80(1).

Ford, J. D., King, N., Galappaththi, E. K., Pearce, T., McDowell, G., & Harper, S. L. (2020) The resilience of Indigenous peoples to environmental change. *One Earth,* https://doi.org/ 10.1016/j.oneear.2020.05.014.

Intergovernmental Panel on Climate Change (IPCC) (2019). *Climate change and land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.* Cambridge University Press. https://doi.org/10.1017/9781009157988.

Liwenga, E. T. (2008) Adaptive livelihood strategies for coping with water scarcity in the drylands of central Tanzania. *Phys. Chem. Earth* 33, 775–779. Doi: 10.1016/j.pce.2008.06.031.

Kangalawe, R., Mwakalila, S., & Masolwa, P. (2011) Climate change impacts, local knowledge and copping strategies in the great Ruaha River catchment area, Tanzania. *Natural Resources,* 2, 212–223. https://doi.org/10.4236/nr.2011.24027.

Krejcie, R. V., & Morgan, D. W. (1970) Determining sample size for research activities. Educational and Psychological Measurement.

Kothari C.R (2004). *Research Methodology; Methods and Techniques* (Second Ed.), New Age International Publishers.

Mapfumo, P., Mtambanengwe, F., & Chikowo, R. (2016) Building on indigenous knowledge to strengthen the capacity of smallholder farming communities to adapt to climate change and variability in southern Africa. *Climate and Development.* https://doi.org/10.1080/17565529.2014.998604.

Mdemu, Makarius. (2021) Community's Vulnerability to Drought-Driven Water Scarcity and Food Insecurity in Central and Northern Semi-arid Areas of Tanzania. Frontiers in Climate. 3. 737655. 10.3389/fclim.2021.737655.

Mkonda, M. Y., and He, X. (2018). *Climate variability and crop yields synergies in Tanzania's semiarid agroecological zone. Ecosystem Health Sustainability*, doi: 10.1080/20964129.2018.1459868.

Nyeme L; (2010). *Effectiveness of community Participation in Forest Resource Management and Poverty Reduction in Suledo Forest, Kiteto District Tanzania.* Unpublished M.Sc. Dissertation, University of Dar es Salaam.

Nyong, A., Adesina, F. & Osman Elasha, B. (2007) The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. *Mitig Adapt Strat Glob Change*. https://doi.org/10.1007/s11027-007-9099-0.

Orlove, B., Roncoli, C., Kabugo, M. and Majugu, A. (2010) Indigenous climate knowledge in southern Uganda: the multiple components of a dynamic regional system. Climate Change.

Pamla, Avela & Thondhlana, Gladman & Ruwanza, Sheunesu. (2021) Persistent Droughts and Water Scarcity: Households' Perceptions and Practices in Makhanda, South Africa. Land. 10. 593. 10.3390/land10060593.

Petzold, Jan & Andrews, Nadine & Ford, James & Hedemann, Christopher & Postigo, Julio. (2020) Indigenous knowledge on climate change adaptation: A global evidence map of academic literature. *Environmental Research Letters.* 15. 113007. 10.1088/1748-9326/abb330.

Walter Leal Filho, Edmond Totin, James A. Franke, Samora Macrice Andrew, Ismaila Rimi Abubakar, Hossein Azadi, Patrick D. Nunn, Birgitt Ouweneel, Portia Adade Williams, Nicholas Philip Simpson, (2022) Understanding responses to climate-related water scarcity in Africa, Science of The Total Environment, Volume 806, Part 1, 2022, 150420, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2021.150420

Zvobgo, L., Johnston, P., Williams, P.A. et al. (2022). The role of indigenous knowledge and local knowledge in water sector adaptation to climate change in Africa: a structured assessment. Sustain Sci 17, 2077–2092, https://doi.org/10.1007/s11625-022-01118-x,